TOWN OF GROTON

2020 HAZARD MITIGATION PLAN (HMP) – MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PLAN

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EXECUTIVE SUMMARY

Hazard mitigation planning is a proactive process used to systematically identify policies, actions, and tools that can be used to reduce the dangers to life and property from natural hazard events. Climate adaptation planning recognizes that climate change will exacerbate the vulnerabilities and risks associated with natural hazards. The Town of Groton completed a planning process focused on both hazard mitigation planning and climate adaptation, which provides a robust assessment and implementation plan to build the Town's resilience. The Town is now also eligible for hazard mitigation funding through the Federal Emergency Management Agency (FEMA) and climate adaptation funding through the Massachusetts Executive Office of Energy and Environmental Affairs' Municipal Vulnerability Preparedness (MVP) Grant Program.

Planning Process

The Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) was developed through the following steps.

1) Convened a core team of municipal department heads who provided key input through meetings, taking online surveys, and participating in interviews.
2) Created a set of hazard mitigation and climate adaptation goals.
3) Engaged stakeholders through a Community Resilience Building (CRB) Workshop.
4) Sought public feedback on the hazards, strengths, vulnerabilities, and action items through a virtual webinar and other online public engagement techniques.
5) Established a list of critical facilities and assets.
6) Conducted a vulnerability and risk assessment of historic hazards and the potential impacts of climate change.
7) Documented the Town's capacity to mitigate and respond to hazards.
8) Updated the Town's previous HMP from 2015.
9) Developed an action and implementation strategy.

Hazard Mitigation and Climate Adaptation Goals

The Town endorsed the following set of hazard mitigation and climate adaptation goals to protect public health, property, infrastructure, the environment, and cultural resources through a hazard mitigation and climate adaptation program that involves increased coordination, planning, education, and capital improvements.

- Shelters: To provide adequate shelter, water, food, and basic first aid to displaced residents in the event of a natural disaster.
- Coordination: To increase coordination between departments, surrounding communities, regional efforts, and state agencies in pre-disaster planning and the implementation of hazard mitigation and climate adaptation projects.
- Education: To increase awareness of hazard mitigation and climate adaptation among town officials, private organizations, businesses, and the general public.
- Notification: To provide adequate information to residents in the event of a natural disaster.
- Infrastructure: To protect public infrastructure, buildings, and essential services such as electric power, drinking water, and the sewer system from climate change impacts.
- Vulnerable Populations: To building community and individual resilience, specifically focusing on vulnerable populations.
- Natural Environment: To develop hazard mitigation and climate adaptation measures that employ nature-based solutions and protect the natural environment.

- Development: To ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards under climate change projections.
- Finance: Identify potential funding sources to support the implementation of climate adaptation strategies.

Vulnerability and Risk

Hazard mitigation planning for Middlesex County communities tends to focus on flooding, which is the most likely natural hazard to impact these areas. However, the Groton HMP-MVP Plan assesses the potential impacts to the Town from a variety of natural disasters, including:

- Flooding
- Extreme temperatures
- Fire and drought
- Extreme weather (Nor'easters, wind, and snow)

The HMP-MVP Plan documents the location and exposure of over sixty critical facility and assets. Among them are emergency services, roads, utilities, social services, and natural resources.

Hazard Mitigation and Climate Adaptation Strategy

Through the planning process, several hazard mitigation and climate adaptation measures were identified as high priorities.

- Address flooding and improve drainage on Broadmeadow Road and Route 119
- Develop new regulations to ensure roadways, culverts, bridges, and stormwater infrastructure design consider climate change
- Upgrade existing culverts and stormwater infrastructure where necessary using future precipitation data. Develop a priority list of undersized culverts.
- Increase maintenance and drainage ditch cleaning. Update O&M Plan with climate change considerations.
- Evaluate water supply demand projections under drought conditions and current supply's ability to meet future needs. Evaluate options for additional storage or emergency supply.
- Increase access to water in places without hydrants that are also more vulnerable to brushfires
- Develop a water conservation program that may include regulating irrigation systems or developing a water conservation rate pay system.
- Revise stormwater management regulations and wetland regulations to require or recommend the use of climate data and to encourage stormwater infiltration
- Assess municipal properties for Low Impact Development or green infrastructure opportunities
- Update FEMA FIRM and continue Groton's participation in the NFIP
- Conduct public education and outreach on emerging threats. Leverage volunteers and work with neighbors, including Pepperell.

Next Steps

The Town of Groton is dedicated to implementing the findings of this plan and documenting the process. As a now eligible community for funding through the MVP Program and FEMA, the Town will look to secure resources, and to work with regional and local stakeholders, to complete the projects identified herein. The Town will also continue to document hazard impacts and needed improvements to the Town's capacity to mitigate and adapt. Lastly, the Town will proactively incorporate the hazard mitigation and climate adaptation goals into municipal planning, budgeting, and operations. By doing so, the Town will be ready to update this plan in five years to maintain its eligibility for grant funding.

1.0 INTRODUCTION

The Town of Groton prepared a joint Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) to create a strategy to reduce the impacts of natural hazards and climate change within the community and the region. The Groton HMP-MVP Plan was adopted by the Select Board on December 24, 2020 to update and replace the Montachusett Region Natural Hazard Mitigation Plan 2015 Update.

1.1 What is a Hazard Mitigation Plan?

Natural hazards, such as earthquakes, hurricanes, and flooding, can result in loss of life, disruptions to everyday life, and property damage. Hazard mitigation is the effort to reduce these impacts through community planning, policy changes, education programs, infrastructure projects, and other activities.[1] Hazard mitigation planning uses a stepped process with participation of a wide range of stakeholders to:

1. define local hazards
2. assess vulnerabilities and risks
3. review current mitigation measures
4. develop priority action items

The resulting plan and implementation saves lives and money. For every dollar spent on federal hazard mitigation grants, an average of six dollars are saved.[2] There are many additional benefits of mitigation planning. HMPs increase public awareness of natural hazards that may affect the community. They allow state, local, and tribal governments to work together and combine hazard risk reduction with other community goals and plans. HMPs focus resources and attention on the community's greatest vulnerabilities.

By completing an HMP, municipalities also become eligible for specific federal funding and allow potential funding sources to understand a community's priorities. Hazard mitigation funding is available through the Federal Emergency Management Agency (FEMA). To be eligible for FEMA Grants, local governments are required to prepare an HMP meeting the requirements established in the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by the Disaster Mitigation Act of 2000.[3] A summary of disaster assistance programs offered by FEMA is included in the following table.

[1] Federal Emergency Management Agency (FEMA), "Hazard Mitigation Planning."
[2] Federal Emergency Management Agency (FEMA) and Federal Insurance and Mitigation Administration, "Natural Hazard Mitigation Saves Interim Report."
[3] Federal Emergency Management Agency (FEMA), "Hazard Mitigation Grant Program."

Table 1-1. FEMA Grants

FEMA Grants	Purpose
Hazard Mitigation Grant Program (HMGP)	Funds the implementation of long-term hazard mitigation planning and projects after a Presidential major disaster declaration[4]
Pre-Disaster Mitigation (PDM) Program	Offers annual funding for hazard mitigation planning and projects[5]
Flood Mitigation Assistance (FMA) Program	Offers annual funding for planning and projects that reduce or eliminate flood damage to buildings insured under the National Flood Insurance Program (NFIP)[6]
Public Assistance (PA) Grant Program	Facilitates recovery after disasters by providing communities with funding for debris removal, life-saving emergency protective measures, and restoring public infrastructure[7]
Fire Management Assistance Grant (FMAG) Program	Funds mitigation, management, and control of fires on forests or grasslands, to prevent major disasters[8]

1.2 What is a Municipal Vulnerability Preparedness Plan?

In 2017, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) initiated the Commonwealth's Municipal Vulnerability Preparedness (MVP) grant program to help communities become more resilient to the impacts of climate change. The program provides two grant phases.

1. Planning Grant: The first grant phase is the planning grant, which funds a planning process to identify priority action items to address vulnerabilities and utilize strengths in preparation for climate change. The MVP planning process includes convening a team of municipal staff, engaging stakeholders in a Community Resilience Building (CRB) Workshop following a guidebook developed by the Nature Conservancy,[9] and engaging the public. After completing the planning process, communities are eligible for the second phase of the grant program and receive increased standing in other state grant programs.

[4] Federal Emergency Management Agency (FEMA), "Hazard Mitigation Assistance."
[5] Federal Emergency Management Agency (FEMA).
[6] Federal Emergency Management Agency (FEMA).
[7] Federal Emergency Management Agency (FEMA), "Public Assistance: Local, State, Tribal and Private Non-Profit."
[8] Federal Emergency Management Agency (FEMA), "Fire Management Assistance Grant Program."
[9] Federal Emergency Management Agency (FEMA), "Flood Insurance Rate Map: Groton, Middlesex County, Massachusetts."

2. Action Grant: MVP action grants fund the implementation of priority climate adaptation actions identified in the planning grant process and described in the MVP Plan.[10] There are three types of projects eligible under the MVP action grant; resilient redesigns, vulnerability and risk assessments, and nature-based solutions.

1.3 Hazard Mitigation and Municipal Vulnerability Preparedness Planning in Groton

Many of the required steps of the MVP process also satisfy requirements for updating an HMP. Following the lead established by the Commonwealth when it adopted the first-ever Massachusetts State Hazard Mitigation and Climate Adaptation Plan in 2018, the Town of Groton prepared this joint HMP-MVP Plan in accordance with FEMA guidelines for hazard mitigation planning (*Title 44 Code of Regulations (CFR) 201.6*) and with the Massachusetts Executive Office of Energy & Environmental Affairs' (EEA) MVP requirements. This enabled Groton to consider the impacts of climate change in its hazard mitigation planning simultaneously.

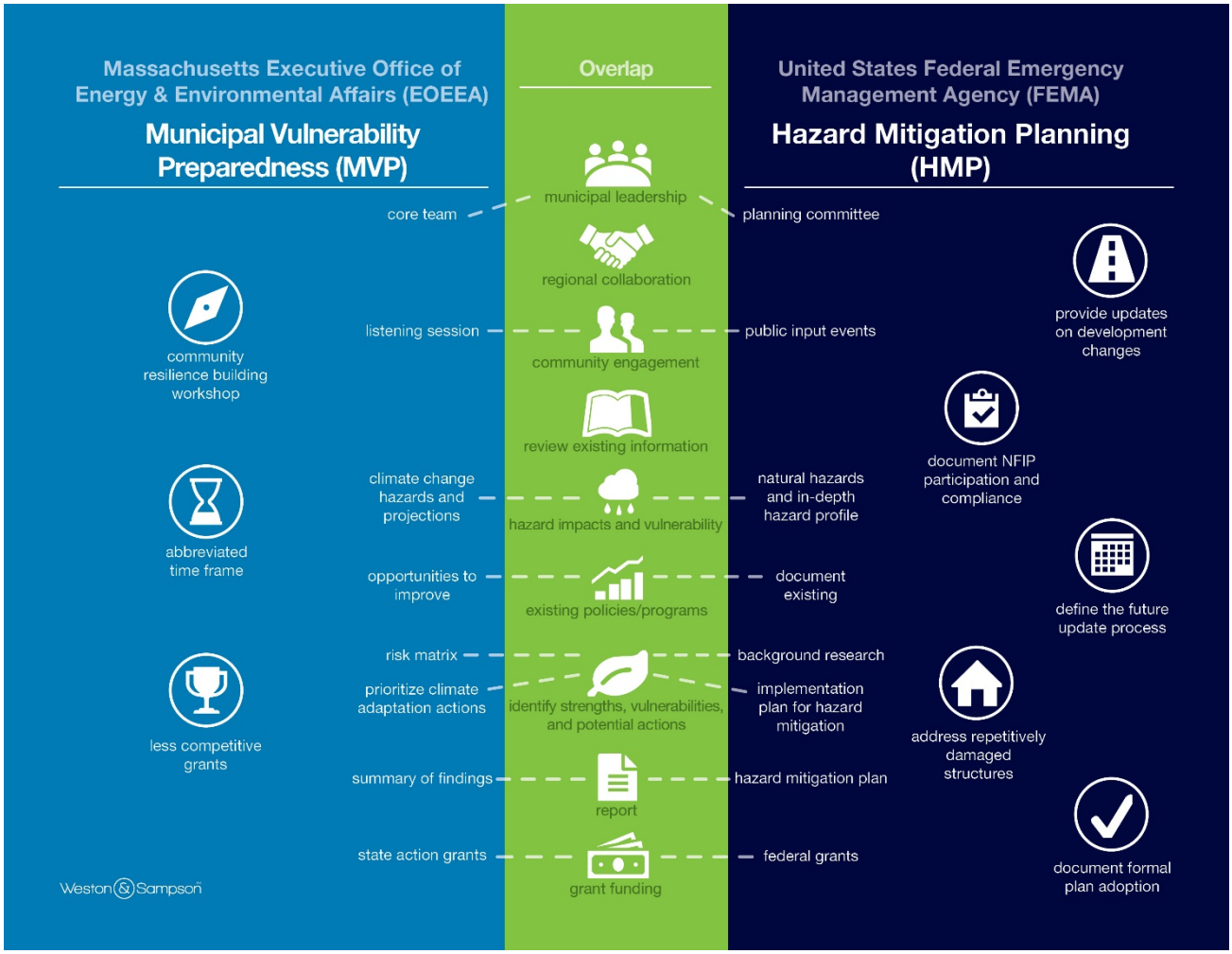


Figure 1-1: Commonalities and Differences between the MVP and HMP Processes

[10] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MVP Program Information."

1.4 Planning Process Summary

The joint HMP-MVP Plan involved updating the previous Hazard Mitigation Plan, analyzing the potential impacts of climate hazards, assessing the Town's capacity for hazard mitigation, and convening a Core Team of municipal leaders to lead the process and provide local expertise. The Core team met, attended the CRB Workshop and were invited to the public listening session, corresponded via email, and contributed insight during expert interviews. Additional stakeholder engagement was conducted through the in-person CRB Workshop, an online webinar, expert interviews, and an online survey.

To prepare for the development of this MVP-HMP Plan, the Town of Groton followed the process described in the Community Resilience Building Workshop Guidebook, which was developed by The Nature Conservancy.[11] The Guidebook provides a clear approach on how to organize the public process for mitigating the impacts of, and increasing resilience against, natural hazards and climate change. An important aspect of the natural hazard and climate change impact mitigation planning process is the discussion it promotes among community members about creating a safer, more resilient community. Developing a plan that reflects the Town of Groton's values and priorities is likely to produce greater community support and result in greater success in implementing mitigation strategies that reduce risk.

Community Resilience Building Workshop Guidebook

The Community Resilience Building Workshop Guidebook provides a process for developing resilience action plans. The process has been implemented and successful in over three hundred communities.[12] The process, outlined below, is rich in information and dialogue and results in actionable plans and strong collaboration.

The Community Resilience Building Workshop Guidebook's central objectives are to:

- Define top local natural and climate-related hazards of concern
- Identify existing and future strengthen and vulnerabilities
- Develop prioritized actions for the community
- Identify immediate opportunities to collaboratively advance actions to increase resilience

Federal regulation for HMP approval requires that stakeholders and the general public are provided opportunities to be involved during the planning process and in the plan's maintenance and implementation. Community members can therefore provide input that can affect the content and outcomes of the mitigation plan. The planning and outreach strategy used to develop this MVP-HMP Plan had three tiers:

[11] The Nature Conservancy, "Community Resilience Building Workshop Guide."
[12] The Nature Conservancy, "Community Resilience Building."

1. The Core Team, with representation from municipal leadership at the Town of Groton
2. Stakeholders who could be vulnerable to, or provide strength against, natural hazards and/or climate change
3. The public, who live and work in the Town

1.4.1 Core Team

The Town of Groton convened the Core Team to act as a steering committee for the development of the HMP-MVP Plan. The Core Team met on December 11, 2019 to review materials for the CRB Workshop, develop hazard mitigation and climate adaptation goals, and plan for the project's next steps. More information on this meeting is included in Appendix A.

The Core Team established goals for the plan, provided information on hazards affecting the Town, identified critical infrastructure, identified key stakeholders, reviewed the status of existing mitigation measures, assessed the Town's capacity to mitigate hazards alongside ongoing operations, and developed proposed mitigation measures for this plan. Members of the Core Team are listed in Table 1-2.

Table 1-2. Groton's Core Team

Name	Title
Takashi Tada	Planning Director
Nikolis Gualco	Conservation Administrator
Steele McCurdy	Fire Chief
Michael Luth	Chief of Police
Tom Delaney	DPW Director
Michelle Collette	Stormwater Inspector & ADA Coordinator
David Black	Teaching Chair, Groton School
Dan Scheibe	Head of School, Lawrence Academy
Russell Burke	Chair, Planning Board
Kevin Kelly	Manager, Groton Electric Light
Mark Haddad	Town Manager

The Groton Planning Board is the primary agency responsible for regulating development in the Town. Feedback to and from the Planning Board was ensured through the participation of the Planning Board Chair and the Town's Planning Director on the Core Team. The Planning Director and representatives from the Planning Board also attended the Community Resilience Building Workshop on January 16, 2020, as documented in Section 1.4.2. Additionally, the Town hosted a combined virtual Town Planning Board Meeting webinar and MVP Public Listening session on April 9, 2020, as documented in Section 1.4.3. This regular involvement ensured that the development of the Groton HMP-MVP report incorporated policies, strategies, and hazards identified by the Town's planning entities.

The Core Team developed the invitation list for the CRB Workshop at which key stakeholders were invited to help the Town identify hazards, vulnerabilities, strengths, and proposed actions to mitigate the impacts of natural hazards and climate change. The Core Team sought to include municipal leaders as well as politicians, representatives from local nonprofit organizations, local schools, other local jurisdictions, regional organizations, and state government. The Core Team also suggested or made available reports, maps, and other pertinent information related to natural hazards and climate change impacts in Groton. These suggested resources included:

- Town of Groton 2019-2026 Open Space and Recreation Plan (2019)
- Town of Groton 2018 Annual Town Report
- Groton Master Plan (2011)
- Town of Groton Zoning Map (2008)
- Town of Groton Street Index (2005)
- Town of Groton Water Resource Protection Districts (2003)
- National Flood Insurance Program (NFIP) Flood Insurance Rate Map (FIRM) for Groton, Middlesex County, Massachusetts[13]
- Nashua, Squannacook, and Nissitissit Rivers Stewardship Plan[14]
- Montachusett Region Natural Hazard Mitigation Plan 2015 Update[15]
- Massachusetts Climate Change Projections[16]
- Massachusetts Climate Change Adaptation Report[17]
- Massachusetts State Hazard Mitigation and Climate Change Adaptation
- National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information (NCEI)
- US Census Bureau Decennial Census (2010)
- US Census Bureau and American Community Survey 2014-2018, 5-year Estimates

1.4.2 Stakeholder Involvement: Community Resilience Building Workshop

Stakeholders with subject matter expertise and local knowledge and experience; including public officials, regional organizations, neighboring communities, environmental organizations, and local institutions; were invited to engage in a two-part Community Resilience Building (CRB) Workshop, held on January 16, 2020. During the first part of the Workshop, Weston & Sampson provided information about natural hazards and climate change and participants identified top hazards; infrastructural, societal and environmental features in the Town that are vulnerable to, or provide strength against, these challenges.

[13] Federal Emergency Management Agency (FEMA), "Flood Insurance Rate Map: Groton, Middlesex County, Massachusetts."
[14] Nashua River Wild and Scenic River Study Committee, "Nashua, Squannacook, and Nissitissit Rivers Stewardship Plan."
[15] Montachusett Regional Planning Commission (MRPC), "Montachusett Region Natural Hazard Mitigation Plan 2015 Update."
[16] Northeast Climate Science Center, "Massachusetts Climate Change Projections."
[17] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA) and Adaptation Advisory Committee, "Massachusetts Climate Change Adaptation Report."

Figure 1-2. Images of Local Features. Photos by Weston & Sampson

During the second part of the CRB Workshop, participants identified and prioritized key actions that would improve the Town's resilience to natural and climate-related hazards. Additional materials related to the CRB Workshop are included in Appendix C, including a list of community representatives who were invited via email by Groton's Land Use Director and Town Planner. The Workshop was advertised through an invitation letter and email blast sent by the Town Planner to roughly seventy invitees documented in the stakeholder list.

This broad representation of local and regional entities and agencies that have the authority to regulate development ensures that the HMP-MVP Plan aligns with operational policies and hazard mitigation strategies at different levels of government and implementation. A summary of key participants at the CRB Workshop is included below:

- Staff members including the Town Manager, Land Use Director and Town Planner, Groton Electric Light Manager, Water Superintendent, ADA Coordinator, Deputy Chief of Police, Fire Chief, and Conservation Administrator.
- Representatives from the Select Board, Planning Board, MBTA Advisory Board, Master Plan Implementation Committee
- Representatives from the Groton Conservation Trust, Invasive Species Committee, Historical Commission, Agricultural Commission, Conservation Commission, and Earth Removal Stormwater Advisory Committee.
- Representatives from the Recycling Committee and Sustainability Commission.
- The MVP Regional Coordinator.

Leadership from neighboring communities of Dunstable, Tyngsborough, Westford, Littleton, Ayer, Shirley, Townsend, and Pepperell were invited to participate in the Workshop but were unable to attend.

Figure 1-3. Images from the CRB Workshop. Photos by Weston & Sampson

1.4.3 Listening Session

Due to the public health crisis surrounding COVID-19, the public listening session, to gather information from the public and educate the residents on hazard mitigation and climate change in Groton, could not be conducted in person. As a solution, the Town hosted a virtual listening session on April 9th during a Town Planning Board Meeting that included the presentation of a video and the promotion of an online survey. The listening session was advertised through a promotional flyer, email blast to the stakeholder list, announcement in *The Groton Herald* newspaper, and post on the Town of Groton's website homepage. The video presented information related to the MVP program, climate change in Groton, local strengths and vulnerabilities, existing mitigation measures, and priority action items for future climate adaptation. The online survey collected feedback on the planning process and outcomes to-date.

The video and survey links were also posted on the Town's website and YouTube page to allow the community to participate on their own time if they were not able to attend the live, virtual session. The survey was advertised through a promotional flyer and an email blast to the stakeholder list. The survey period closed April 24th. More information about the virtual listening session, including a summary of survey responses, is available in Appendix D.

1.4.4 Report Layout

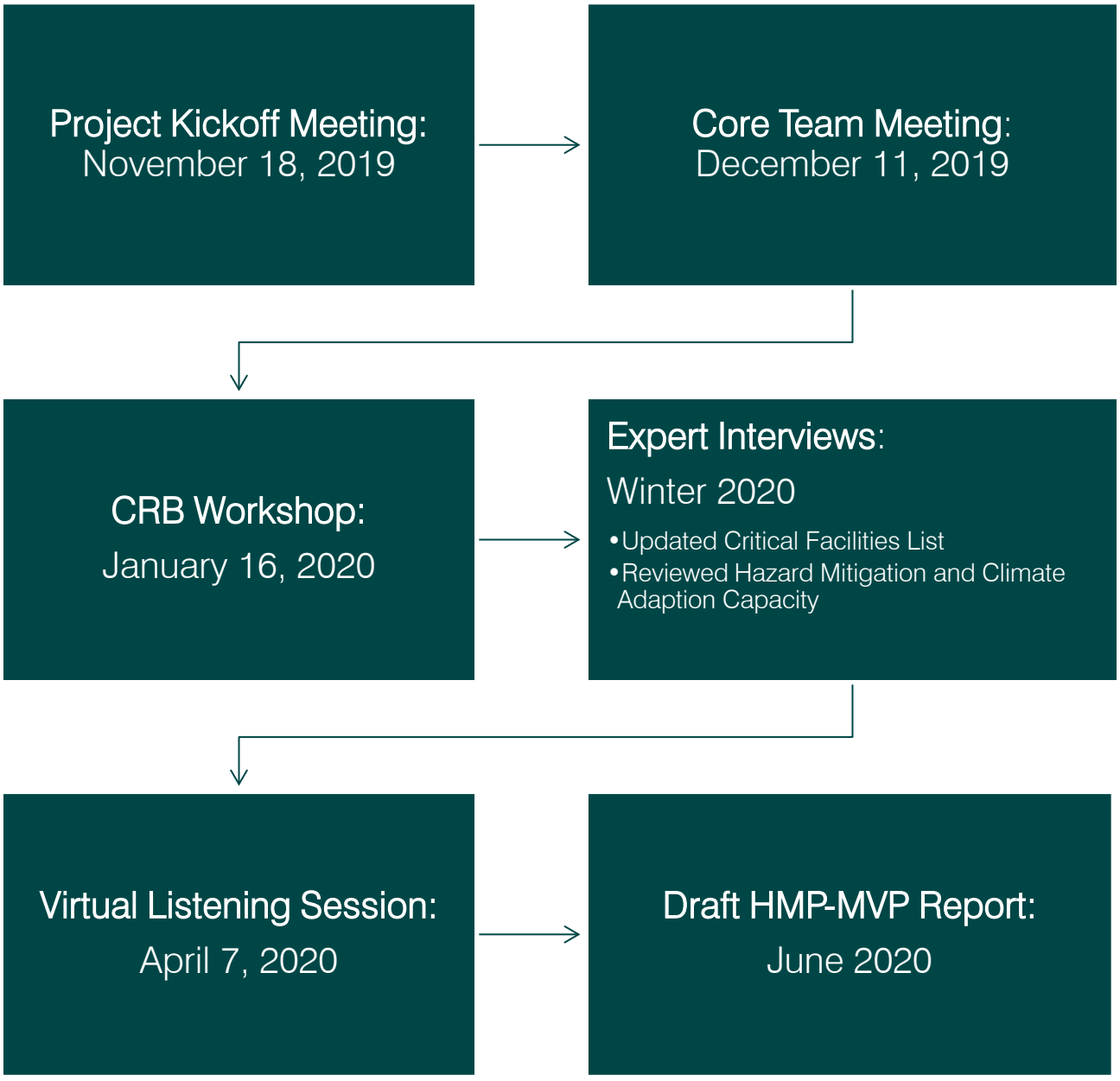
This report presents the results of the MVP Planning Process, which includes input derived from the Core Team, CRB Workshop, and virtual listening session, documentation of Town features and climate hazard profiles, and a vulnerability assessment. More information on each chapter is included below:

- Chapter 2 lists Groton's Hazard Mitigation and Climate Adaptation Goals.
- Chapter 3 documents the strengths and vulnerabilities of local features, which are assets or characteristics of Groton that may contribute to the Town's resilience or may be a considered a vulnerability. Features are categorized into several types; including societal, economic, infrastructure, land use, and environmental.
- Chapter 4 provides a more detailed assessment of the Town's vulnerability and strengths by hazard type. These hazard types include flooding, wind-related risk (hurricanes, tropical storms, tornados, nor'easters, and severe thunderstorms), winter weather, geological hazards (earthquakes and landslides), brushfires, extreme temperatures, and drought. Each hazard's historic occurrences and impact, frequency, level of risk, and climate change projections are described as part of these profiles.
- Chapter 5 describes existing mitigation measures in Groton.

- Chapter 6 provides an update of the progress made since the last HMP.
- Chapter 7 describes the priority action items identified during this process.
- Chapter 8 offers details for plan adoption, maintenance, and implementation.

1.5 Planning Timeline

The HMP-MVP planning process proceeded according to the timeline below.



2.0 HAZARD MITIGATION AND CLIMATE ADAPTATION GOALS

The Town of Groton's Core Team convened to review and discuss the hazard mitigation and climate adaptation goals for the HMP-MVP Plan. The following nine categorical goals were developed and endorsed by the Core Team after reviewing the 2015 update of the Montachusett Regional Natural Hazard Mitigation Plan.

Groton Overall Goal Statement

To protect public health, property, infrastructure, the environment, and cultural resources through a hazard mitigation and climate adaptation program that involves increased coordination, planning, education, and capital improvements.

Categorical Goal Statements

1. Shelters: To provide adequate shelter, water, food, and basic first aid to displaced residents in the event of a natural disaster.

2. Coordination: To increase coordination between departments, surrounding communities, regional efforts, and state agencies in pre-disaster planning and the implementation of hazard mitigation and climate adaptation projects.

3. Education: To increase awareness of hazard mitigation and climate adaptation among town officials, private organizations, businesses, and the general public.

4. Notification: To provide adequate information to residents in the event of a natural disaster.

5. Infrastructure: To protect public infrastructure, buildings, and essential services such as electric power, drinking water, and the sewer system from climate change impacts.

6. Vulnerable Populations: To building community and individual resilience, specifically focusing on vulnerable populations.

7. Natural Environment: To develop hazard mitigation and climate adaptation measures that employ nature-based solutions and protect the natural environment.

8. Development: To ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards under climate change projections.

9. Finance: Identify potential funding sources to support the implementation of climate adaptation strategies.

3.0 COMMUNITY PROFILE, LAND USE, AND DEVELOPMENT TRENDS

3.1 Community Profile

Figure 3-1. The Nashua River Rail Trail. Photo by W&S.

Residents often discuss the sense of community and place, involvement of residents, and open space and natural features among their favorite aspects of Groton.[18] Indeed, Groton has active community spaces and outdoor resources including the Groton Center and the second largest trail network in the State.[19] The Town has also experienced some recent population growth, from 10,406 residents documented in the 2006 Town Census, to 11,386 residents documented in the 2018 federal Census data.[20]

In the 1600s, Groton was home to the Nashaway Indians and was also the site of John Tinker's trading post. At that time, the area was known as Petapawag, meaning "swampy land." An influx of newcomers founded an expansive settlement called the Plantation of Groton in 1655, which included Groton, Ayer, parts of Pepperell, Shirley, Dunstable, Littleton, Hazard, Westford, and small portions of two New Hampshire towns, Nashua and Hollis. Groton's industrial past included a soapstone quarry, a hop-growing, a brick factory, a sawmill, a grist mill, and a pewter mill. In the past, the Town was organized with north, east, south, and west quadrants but West Groton is the only neighborhood name still used today. Throughout Groton, several historic structures from the 1700s and 1800s still stand today, including:

- Groton Historical Society Museum
- First Parish Church of Groton
- Groton's Old Burying Ground
- Old Baptist Church[21]

Tourism has also been part of Groton's history. Notably, the Lost Lake area was created through damming in the early 1900s and became a summer destination.[22] The Town is also home to iconic waterbodies that include the Nashua and Squannacook Rivers. Groton is in the Nashoba Valley area and, at over 33 square miles, is the largest town by area in Middlesex County. Groton has a varied topography with Town Hall situated 320 feet above sea level, and Chestnut Hill reaching the highest local peak at 516 feet above sea level.[23]

Today, Groton is strategically located near job centers that include Fitchburg, Lowell, and Boston. It is neighbored by Ayer, Littleton, Westford, Tyngsborough, Dunstable, Pepperell, Townsend, and Shirley.

[18] Invited Stakeholders, Groton Community Resilience Building (CRB) Workshop.
[19] Town of Groton, "Town of Groton 2019-2026 Open Space and Recreation Plan."
[20] United States Census Bureau, "2014-2018 American Community Survey. QuickFacts."
[21] Town of Groton, "A Brief History of Groton, MA."
[22] Town of Groton.
[23] Town of Groton, "About the Town of Groton, MA."

Groton is governed by a Town Manager and a Select Board and operates under the open Town Meeting system. The Town maintains a website at grotonma.gov.[24]

3.2 Societal Features

Groton's community spaces and services are strengths that can be leveraged in the event of an extreme event and may be particularly useful in reaching and assisting vulnerable populations. These spaces include the Groton Center and Groton Public Library. Vulnerable populations are residents whose everyday stressors make it harder to adapt and recover when shocks or hazards occur. In Groton, residents at risk of isolation and with barriers to building personal resilience are considered vulnerable. This could include elderly residents, children, and students. Groton has a significant student population with several public schools and private boarding schools, including the Groton School and Lawrence Academy. Please refer to Table 3-1 for more information on Groton's demographic characteristics.

Table 3-1. Groton Demographic Characteristics[25]

	Groton	Massachusetts
Population		
2018	11,386	6,902,149
2010	10,643	6,547,785
Age		
Under Age 18	23.8%	19.8%
Over Age 65	13.9%	16.5%
Households		
Owner-occupied housing unit rate	86.7%	62.3%
Language other than English spoken at home	7.3%	23.6%
Median household income	$126,883	$77,378
Additional Information		
Persons in Poverty	4.4%	10.0%
With a Disability	7.9%	5.3%

Societal Features, Strengths, and Vulnerabilities

As demonstrated by the table above, Groton has a higher percentage of children (residents under the age of 18) than the state. Groton's population has increased by about 5% since 2010, with a particular increase among senior citizens. Although the 5% increase is more rapid than was projected by the Metropolitan Area Planning Council (MAPC),[26] the State of Massachusetts also experienced a 5%

[24] Town of Groton.
[25] United States Census Bureau, "2014-2018 American Community Survey. QuickFacts."
[26] Town of Groton, "Town of Groton 2019-2026 Open Space and Recreation Plan."

increase in population between 2010-2020.[27] Groton's growing elderly population may be considered a vulnerability, as emergency services capacity will need to grow similarly to meet increasing demands. Participants at the CRB Workshop discussed these considerations while identifying key societal aspects of Groton that are most vulnerable to, or provide protection against, natural hazards and climate change impacts. Please refer to Table 3-2 for more information.

Table 3-2. Societal Features in Groton

Strengths	Vulnerabilities
• Public transit, including the Council on Aging van, and commuter rail connection in Ayer • Health Care facilities, including Seven Hills Pediatric Center • Assisted living facilities, including RiverCourt Residences Senior Living Community • Private boarding schools including Lawrence Academy and the Groton School. • Commercial and industrial centers, including West Groton, Town Center, and Four Corners Village. • Housing, although additional housing units are needed • Public schools: the High School is a shelter and the Middle School is a warming center • Mobility, including commuting routes, walking paths, and cycling options • Indian Hill Music Center, a nonprofit that will provide local jobs and public education opportunities. It is anticipated to open in 2022. A transportation study may be needed to assess the impact of the new development	• Elderly residents • Lost Lake neighborhood, which relies on private wells and has high density housing that increases fire risk. • Groton is a "Right to Farm" community, but that historic identity is at risk • Residents may be less likely to evacuate or use a public shelter if they cannot bring their pets • The Emergency Response Plan needs to be updated with information related to evacuation, communication, and access to resources and shelters • Boarding schools and student populations require emergency services support • West Groton has few access points • Public Schools: drinking water at the High School has had issues with iron.

[27] Rath, "Massachusetts' Population Is Growing, But Many Are Leaving."

Figure 3-2. Photos of Lawrence Academy and the Groton Center

3.3 Economic Features

In 2017, Groton's unemployment rate was 3.0%. This represented a significant decrease from the Town's 6.5% unemployment rate only seven years previously (towards the end of the economic recession). Most Groton residents (63.4%) are employed in management, business, science, and arts occupations. Eighty-two percent of residents drive on their own to work and nearby job centers, including Fitchburg (thirteen miles away), Lowell (fifteen miles away), and Boston (thirty-one miles away). Major employers in Groton include Delux Corp, Hollingsworth & Vose Co., and Groton Dunstable Regional School District. Smaller, but still significant, industries in the Town include agriculture (in 2012, about one quarter of Groton's land was farmed), eco-tourism, and other small businesses.[28] Communication between businesses and the Town will be key in advancing hazard mitigation planning efforts and ensuring that large employers are aware of local risks and have emergency protocols in place. More information on economic features in Groton is summarized below.

Table 3-3. Groton Economic Data[29]

	Groton	Massachusetts
In civilian labor force, total, percent of population age 16 years+, 2014-2018	66.2%	67.1%
Mean travel time to work (minutes), workers age 16 years+, 2014-2018	35.2	29.7
Median household income, 2014-2018	$126,883	$77,378
Companies in 2012	1,020	607,664

[28] Town of Groton, "Town of Groton 2019-2026 Open Space and Recreation Plan."
[29] United States Census Bureau, "2014-2018 American Community Survey. QuickFacts."

3.4 Infrastructure Features

Significant transportation infrastructure in or near Groton includes Route 119, Route 225, and Route 495. Route 119 and 225 have been impacted by flooding, including the March 2010 flood that closed bridges along these routes and cut off West Groton.[30] West Groton is bordered by the Squannacook and Nashua Rivers and has its own Water Department, Fire Station, and Post Office. Groton has four dams, including two high hazard dams.[31] More information on dams is included in Chapter 4.

The Town also has two water treatment plants, several wells, two water storage tanks, and multiple pump stations. Groton's public water is provided by wells supplied by natural aquifers. The Town Water Department wells are located near Lost Lake/Knops Pond and Baddacook Pond. Forty-one percent of residents receive water from the Groton Water Department, 13% receive water from the West Groton Water Supply District, and the remaining residents use on-site private wells. Pepperell's water supply wells are located close to the Groton town line and draw from the same aquifer. CRB Workshop participants expressed some concerns related to elevated iron, manganese, and emerging contaminants in Town.

Groton's sewage is treated at the Pepperell Wastewater Treatment Plant.[32] Backup power of all critical facilities providing water and sewer is essential. Electricity is provided by the customer-owned, municipal utility Groton Electric Light Department (GELD). GELD has provided power to the community since the early 1900s, and its infrastructure includes the Groton Transfer Station and the Groton Electric Substation. See Section 3.5 below for more information on critical facilities in Groton.

Discussion of Existing Infrastructure

Participants at the CRB Workshop identified key infrastructure features in Groton that are vulnerable to, or provide protection against, natural hazards and climate change impacts. Please refer to Table 3-4 for more information.

Figure 3-3. The Fire Station, Town Hall, and the Police Station. Photos by W&S and the Groton Police Department

[30] Groton Core Team, Core Team Meeting.
[31] Office of Dam Safety, "Dam Inventory."
[32] Town of Groton, "Town of Groton 2019-2026 Open Space and Recreation Plan."

Table 3-4. Infrastructural Features in Groton

Strengths	Vulnerabilities
• Municipal buildings, Police, Fire, DPW, and Groton Center. The Center has a list of vulnerable residents and list of locals who can help elderly residents with snow removal. • Shelters include the Center and local schools. • Groton Electric Light Department provides reliable service and maintenance	• Roads that flood, including Broadmeadow Road, West Main Street at the Nashua River, and Route 119 near Cady Pond. • Groton has a strong water supply but there is concern about future contamination. • Some residents rely on private wells, which could be impacted by drought. • Bridges, including two over the Nashua River. • Undersized culverts, including culverts at Cady Pond Brook and Route 119. • Groton Electric Light Department could improve resilience through underground power lines and the use of batteries and solar power. • Wastewater goes to Ayer and Pepperell. • Communication systems in the event of an emergency could improve. • There are two high-hazard, Town-owned dams in Groton (Squannacook River Dam, and the Lost Lake Dam).

3.5 Critical Facilities

Critical facilities are extremely essential components to the Town's function and protecting them from natural hazards is paramount. Critical facilities range in function from:

1. Resources that can be utilized to respond and recover from natural hazards
2. Facilities where additional assistance might be needed
3. Hazardous sites that could be dangerous if it is compromised during a natural disaster

Based on information on the previous Hazard Mitigation Plan, interviews with the Core Team and other experts, and input from stakeholders during the CRB Workshop, 104 critical facilities were identified in Groton. These facilities include emergency management buildings, Town facilities, shelters, a hospital, evacuation routes, water, sewer, and electric infrastructure, schools and childcare facilities, grocery and supplies stores, and other facilities. The full list of these structures is included in a table in Appendix C, and visualized in the map series in Appendix B.

3.6 Land Use and Environmental Features

The Town of Groton covers just over 33 square miles of land and water. Nearly forty percent of this area is protected open space, and the Town has the second largest trail system in Massachusetts. It is a rural

residential community that averages 30 new homes built annually over the last decade. Waterbodies provide significant space and recreational opportunities in Town, and waterbodies include:[33]

- Rivers: Nashua and Squannacook Rivers
- Watersheds: Merrimack River Watershed, which includes the Nashua River Subwatershed
- Ponds: Lost Lake/Knops Pond, Baddacook Pond, Cow Pond (Whitney Pond), Martins Pond, Duck Pond, and Massapoag Pond
- Beaches: Sargisson Beach

The graphic below illustrates a comparative breakout of land use in Groton.

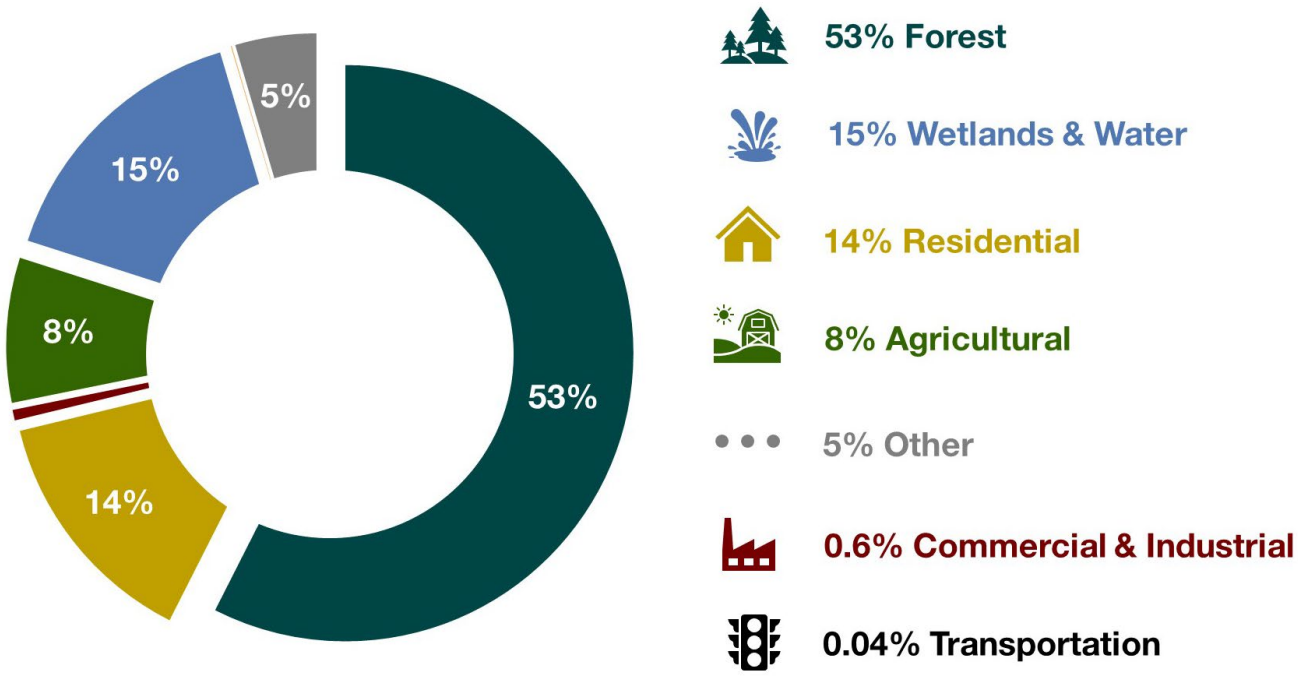


Figure 3-4. Land use in Groton[34]

Discussion of Environmental Features

Workshop participants identified key environmental features in Groton that are most vulnerable to, or provide protection against, natural hazards and climate change impacts. Please see Table 3-5 for more information.

[33] Town of Groton; Groton Core Team, Core Team Meeting.

[34] Montachusett Regional Planning Commission (MRPC), "Montachusett Region Natural Hazard Mitigation Plan 2015 Update."

Table 3-5. Environmental Features in Groton

Strengths	Vulnerabilities
• Wetlands provide habitat and water storage, and the Town's wetlands bylaw is forward-thinking. • The Nashua and Squannacook Rivers are scenic destinations. • Increased development can provide needed housing • Groton has the second largest trail network in Massachusetts. • Open space offers recreational opportunities • Forests sequester carbon and create habitat.	• Invasive species, including the Emerald Ash Boarer and Black Swallow Wort. • Algal blooms, including near the Lost Lake Dam. • Vector-borne diseases, including from ticks. • Contaminated sites. The Nod landfill was not properly capped. • The Nashua River has invasive Water Chestnut plants. • Increased development can encroach on natural resources. • Recent rescue operations along trails have highlighted the need for improved signage and education, particularly related to poor weather events. • Stormwater regulations could be improved. • Some species are rare and endangered. • Open space requires protection from hazards. • Forested land is a fire risk • Agriculture is part of the Town's historic heritage but faces financial and environmental challenges.

3.7 Recent and Potential Development

Development data was identified using input from the Groton Town Planner, and the Metropolitan Area Planning Council (MAPC) MassBuilds Database, which provides an inventory of recent, future, and potential development. The resulting documentation included four residential developments and one commercial development in Groton. Additionally, these developments included a total of 172 single family homes, 24 multi-family units, and 62,000 square feet of commercial space. Please refer to Table 3-6 below for more information.

Table 3-6. Current and Future Development in Groton

Name	Address	Development Type	Status	Additional Details
Groton Woods	Forest Drive	Residential	Completed in 2016	117 single family homes

Name	Address	Development Type	Status	Additional Details
Seven Hills at Groton	1-99 Hillside Avenue	Commercial	Completed in 2004	62,000 square feet of commercial space
Academy Hill	Magnolia Lane	Residential	Completed in 2018	46 single family homes and 24 multi-family homes
Residential Subdivision	372 Townsend Road	Residential	Planning	9 single family homes
Robin Hill Estates	Hummingbird Lane	Residential	Planning	Age-restricted residential

4.0 HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES

Each hazard profile in this chapter includes information on vulnerable areas, documentation of historic events, a risk and vulnerability assessment, and related climate change projections. The risk and vulnerability assessment examines hazard frequency, severity, and potential impact to the Town of Groton. Each hazard risk and vulnerability assessment uses previous occurrences and climate projections to identify high risk areas and the likelihood that a hazard will occur. The vulnerability analysis looks at various factors in the community, including existing and future buildings, infrastructure, and critical facilities. In some cases, an estimate of the potential dollar loss related to vulnerable structures in available. Land uses and development trends were also considered as part of the flood vulnerability assessment.

The hazard profiles were updated using information from the 2013 Massachusetts State Hazard Mitigation Plan,[1] the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP),[2] and additional research and assessment. The Core Team, expert interviews, CRB Workshop, and Listening Session results provided local accounts related to each hazard. Additionally, a Geographic Information System (GIS) and FEMA Hazus assessment was conducted to analyze the potential risk in Groton related to future flooding, hurricanes, and earthquake events.

4.1 State-wide Overview of Hazards

4.1.1 Massachusetts State Hazard Mitigation and Climate Adaptation

The 2013 Massachusetts State Hazard Mitigation Plan and the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) examined natural hazards that have the potential to impact the Commonwealth. The 2013 plan summarized the frequency and severity of hazards of greatest concern. The frequency classification ranges from very low to high. Severity classifications range from minor severity to catastrophic. The boxes below give further definitions for frequency and severity characterizations. Table 4-1 summarizes hazard frequency and severity in the State.

Definitions used in the Commonwealth of Massachusetts State Hazard Mitigation Plan[3]

Frequency

- *Very low frequency*: events that occur less frequently than once in 100 years (less than 1% probability per year)
- *Low frequency*: events that occur from once in 50 years to once in 100 years (1% to 2% probability per year)
- *Medium frequency*: events that occur from once in 5 years to once in 50 years (2% to 20% probability per year)
- *High frequency*: events that occur more frequently than once in 5 years (Greater than 20% probability per year)

[1] Commonwealth of Massachusetts et al., "State Hazard Mitigation Plan."

[2] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

[3] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Definitions used in the Commonwealth of Massachusetts State Hazard Mitigation Plan[4]

Severity

- *Minor*: Limited and scattered property damage; limited damage to public infrastructure and essential services not interrupted; limited injuries or fatalities.
- *Serious*: Scattered major property damage; some minor infrastructure damage; essential services are briefly interrupted; some injuries and/or fatalities.
- *Extensive*: Widespread major property damage; major public infrastructure damage (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and/or fatalities.
- *Catastrophic*: Property and public infrastructure destroyed; essential services stopped; numerous injuries and fatalities.

Table 4-1. Hazard Risk Summary for Massachusetts

Hazard	Frequency	Severity
Inland Flooding/Heavy Rain	High (1 flood disaster declaration event every 3 years; 43 floods per year of lesser magnitude)	Serious to Catastrophic
Dam failures	Very Low	Extensive to Catastrophic
Coastal Hazards	High (6 events per year over past 10 years)	Serious to Extensive
Tsunami	Very Low (1 event every 39 years on East Coast, 0 in MA)	Extensive to Catastrophic
Hurricane/Tropical Storm	High (1 storm every other year)	Serious to Catastrophic
High Wind (Severe Weather)	High (43.5 events per year)	Minor to Extensive
Tornadoes (Severe Weather)	High (1.7 events per year)	Serious to Extensive
Thunderstorms	High (20 to 30 events per year)	Minor to Extensive
Nor'easter	High (1 to 4 events per year)	Minor to Extensive
Snow and Blizzard (Severe Winter Weather)	High (1 per year)	Minor to Extensive
Ice Storms (Severe Winter Weather)	High (1.5 per year)	Minor to Extensive
Earthquake	Very Low (10-15% probability of magnitude 5.0 or greater in New England in 10 years)	Minor to Catastrophic
Landslide	Low (once every two years in western MA)	Minor to Extensive

[4] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

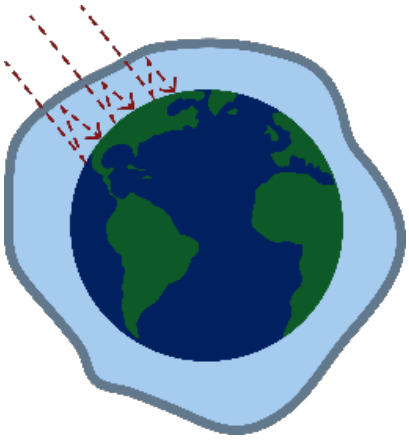
Hazard	Frequency	Severity
Brush Fires	High (at least 1 per year)	Minor to Extensive
Extreme Temperatures	High (1.5 cold weather and 2 hot weather events per year)	Minor to Serious
Drought	High (8% chance of "Watch" level drought per month [recent droughts in 2016 and 1960s])	Minor to Serious

Not all hazards included in the 2018 SHMCAP or the 2013 State Hazard Mitigation Plan apply to the Town of Groton. Given Groton's inland location, coastal hazards and tsunamis are unlikely to directly affect the Town. It is assumed that the entire Town of Groton and its critical facilities are exposed to earthquakes, high wind events, hurricanes, winter storms, temperature extremes, and snow and ice to a similar extent. Flood risk from riverine flooding is elevated in the vicinity of flood zones. Landslides are more likely in areas with more unstable soil types.

4.1.2 Federally Declared Disasters in Massachusetts

Tracking historic hazards and federally declared disasters that occur in Massachusetts, and more specifically Middlesex County, helps planners understand the possible extent and frequency of hazards. Historically, Massachusetts has experienced multiple hazards, including flooding, blizzards, and hurricanes. Since 1991, there have been twenty-two storms in Massachusetts that resulted in federal or state disaster declarations. Sixteen disaster declarations occurred in Middlesex County. Federally declared disasters present FEMA grant opportunities for regional recovery and mitigation projects. The hazard profiles detailed below contain further information about federally declared disasters.

4.1.3 Impacts of Climate Change



Many of the hazards that Groton is currently experiencing are projected to worsen due to climate change. Climate change is caused by the warming of the Earth's atmosphere. The Earth's atmosphere has naturally occurring greenhouse gases, like carbon dioxide (CO_2), that capture heat and contribute to the regulation of the Earth's climate. When additional greenhouse gases are released through burning fossil fuels (including oil, coal and gas), the Earth's temperature increases. The global temperature increase impacts jet streams and climate patterns. Due to these changes, the future Massachusetts climate is expected to reflect historic climate patterns of states south of New England, depending upon GHG emission scenarios. Temperatures will increase during both the summer and winter seasons. Climate change is likely to change Massachusetts' typical precipitation cycle, leading to more frequent storms, intense rainfall, and episodic droughts. Each hazard profile presented below includes information on how hazard frequency, intensity, and impacts are expected to shift with climate change.

4.1.4 Top Hazards as Defined in the CRB Workshop

Participants during Groton's Community Resilience Building (CRB) Workshop identified the top four hazards impacting the Town, which include:

Flooding

Extreme temperatures

Fire and drought

Extreme weather (Nor'easters, wind, and snow)

The CRB Workshop was designed to bring stakeholders together to brainstorm action items that will facilitate a climate resilient future while also recognizing the Town's unique characteristics. The CRB Workshop included small and large group discussions about Town features, historic hazards, and anticipated future climate change impacts. Drought was identified as a concern because of its impact on both private wells and the public water supply. Flooding was identified as the risk most likely to have impacted all residents. Participants also discussed the impact of extreme temperatures, and one attendee remarked that their grandchildren may live in a Massachusetts that feels more like Georgia. Participants stressed that the design of infrastructure and future development should consider these anticipated changes in climate. The sections below include more information about historic hazards, climate change projections, and anticipated impacts in Groton.

Figure 4-1: Participants at Groton's CRB Workshop. Photos by Weston & Sampson, 2020

4.2 Flood-Related Hazards

Flooding was one of the four main hazards identified by participants during Groton's CRB Workshop. The following sub-sections provide more information on historic flood events, locally identified flood areas, potential flood hazards, a vulnerability assessment, and information related to dam failure risk. The analysis of flood hazard areas was informed by the FEMA National Flood Insurance Program (NFIP) Flood Insurance Rate Map (FIRM), a GIS vulnerability analysis, information from Groton town staff, input collected during expert interviews, and accounts of past flood events provided by Groton MVP Workshop and Listening Session participants.

Causes of Flooding

Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, and winter storms. While Groton currently experiences these events, the impacts of climate change will likely lead to increasingly severe storms and impacts.

Flooding can include riverine (topping the banks of streams, rivers, ponds) and stormwater flooding (rainwater that does not properly infiltrate into the ground). Groton has significant topographic variations

including lowland areas around wetlands, forests in the east, and flat terrain and floodplain deposits in the west separated by a range of barrier hills. The elevation varies from mean sea level to 500 feet in the hills. Topographical variations and the prevalence of impervious surfaces can both contribute to runoff and flooding in Groton. Areas within the FEMA Flood Zones, repetitive flood loss sites, and local areas identified as flood prone can be more vulnerable to these conditions.

Stormwater Flooding

Stormwater flooding occurs when the rate of rainfall is greater than the stormwater management system can handle. This may be due to an undersized culvert, poor drainage, topography, high amounts of impervious surfaces, or debris that causes the stormwater system to function below its design standard. In these cases, the stormwater management system becomes overwhelmed, causing water to inundate roadways and properties. Stormwater flooding can occur anywhere in Town and is not limited to areas surrounding water bodies.

Most stormwater systems in Massachusetts are aging and have been designed with rainfall data that is no longer accurate. Figure 4-2 shows how anticipated rainfall during design storms has increased from 1961 to 2015, especially for the larger 24-hour, 100-year event. Green infrastructure or low impact development improvements can help reduce demand on the existing stormwater system by increasing infiltration on-site. Rain gardens and pervious pavement are two examples of possible strategies. Upsizing culverts with new rainfall data is also recommended.

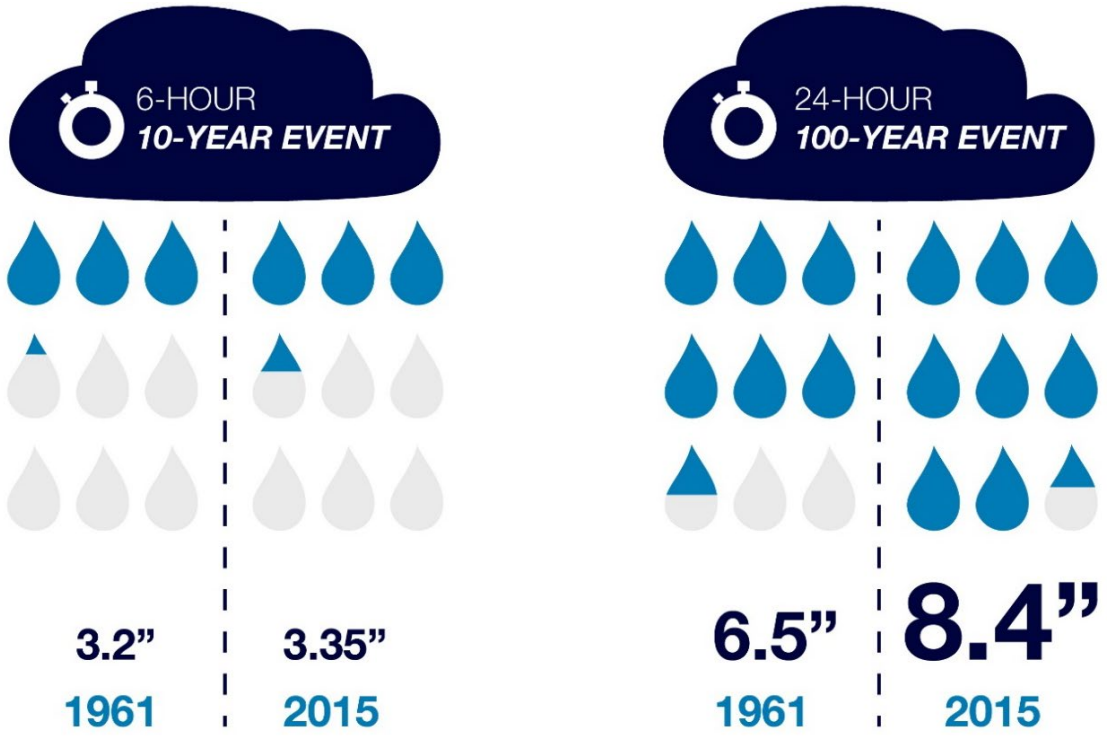


Figure 4-2: Design Storm Events in 1961 (TP-40) and 2015 (NOAA Atlas 14). The future design of infrastructure should consider anticipated increases in precipitation.

Impacts of Flooding

Potential impacts of flooding could include injury, fatality, property damage, and traffic disruption. Flood hazards are also linked to erosion, which can compromise receiving water quality, slope stability, and the stability of building foundations. These conditions put current and future structures and populations located near steep embankments at risk. Erosion can also undercut streambeds and scour around stream crossing, creating a serious risk to roadways.

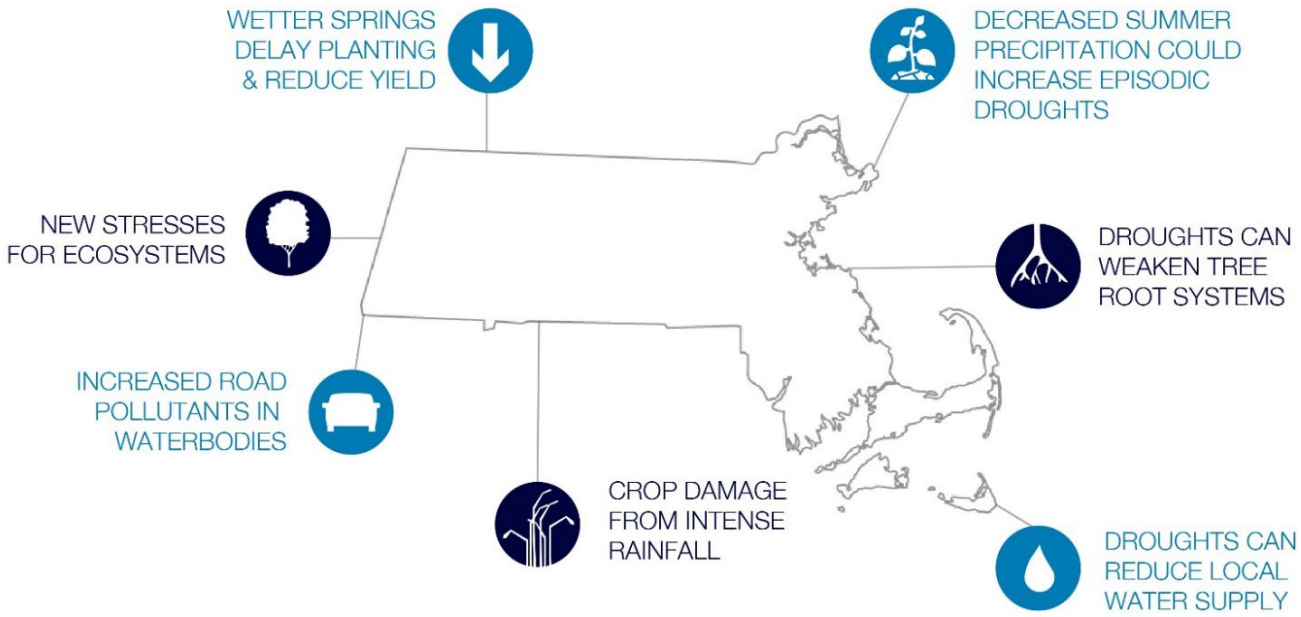


Figure 4-3: Potential Impacts of Increasing Precipitation

A series of expert interviews with representatives from municipal departments and local entities revealed more information about the impacts of flooding on Town operations. For example, the Groton Police Department does not have high water vehicles and having to drive around a flood could increase their response time significantly by 2-3 minutes. Flooding can block or complicate access to West Groton.

4.2.1 Areas Vulnerable to Flooding

Locally Identified Areas of Flooding

Town staff, local experts, and CRB Workshop participants helped identify local areas of flooding, which are summarized in Table 4-2. These areas may or may not overlap with FEMA-designated flood zones. However, these areas have been noted to flood during significant rain events. Identifying these areas is an important part of hazard mitigation planning. An awareness of vulnerable areas, particularly critical emergency routes, can help in prioritizing and implementing climate adaptation projects.

Table 4-2: Locally Identified Areas of Flooding

Name	Description
Broad Meadow Road	Described as the “litmus test” for flooding, as it floods first and is centrally located
West Main Street (Route 225)	Floods near the Nashua River and Wrangling Brook. Route 225 is one of the few access points to West Groton.

Name	Description
Route 119	Near the Cady Pond Brook culvert. Route 119 is one of the few access points to West Groton.
Martins Pond	Along Lowell Road south of Martins Pond and the beaver dam northeast of Martins Pond
Townsend Road	Near Park Drive in West Groton
Baddacook Pond	
Whitney (Cow) Pond	
Lost Lake/Knops Pond	
River Court Housing Complex	
Pepperell Street/Road	In Groton
Shirley Street	In Pepperell
Station Avenue	
Hill Road	

Flooding was a common issue discussed during the CRB Workshop. Low-lying areas of Groton are subject to periodic flooding caused by the overflow of several rivers, ponds, and brooks. Workshop attendees shared stories about areas that flood frequently, including Broad Meadow Road. Attendees also discussed the 2007 flooding of the Nashua and Squannacook Rivers, which damaged local roads. The March 2010 flood closed Routes 119 and 225 and cut off West Groton.

Figure 4-4: Participants at Groton's CRB Workshop. Photos by Weston & Sampson, 2020

Riverine Flooding

Riverine flooding can occur when streams, rivers, and ponds overtop their banks. Groton is home to a number of series of rivers, brooks, ponds, and other waterbodies that include:

- Watersheds: Merrimack River Watershed
- Sub-Watershed: Nashua River Sub-Watershed, Merrimack River Sub-Watershed
- Rivers: Nashua and Squannacook Rivers
- Brooks: Baddacook Brook, Cow Pond Brook, Flat Pond Brook, Gay Brook, James Brook, Martins Pond Brook, Nod Brook, Reedy Meadow Brook, Tuity Brook, Unkety Brook, Wrangling Brook

- Great Ponds: Lost Lake/Knops Pond, Whitney Pond (Cow Pond), Baddacook Pond, Martins Pond, Duck Pond, Massapoag Pond (shared with Dunstable and Tyngsborough), Long Pond (shared with Ayer)[5]

FEMA Flood Zones and Repetitive Loss Sites

FEMA Flood Insurance Rate Maps (FIRM) designate areas likely to experience flooding. FEMA-designated flood zones for Groton are included in Appendix B. Areas within these zones are more vulnerable to flood events. The definitions of these flood zones are provided below. The FEMA flood zones surround the water bodies listed above, as well as Meadow Brook, Marshall Brook, Darby Brook, Sanders Brook, Content Brook, and Collins Brook.[6]

Flood Insurance Rate Map Zone Definitions[7]

Zone A (1% annual chance): Zone A is the flood insurance rate zone corresponding to the 100-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Detailed hydraulic analyses are not performed for such areas, therefore, no BFEs (Base Flood Elevations) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone AE and A1-A30 (1% annual chance): Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone X (0.2% annual chance): Zone X is the flood insurance rate zone that corresponds to the 500-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

As defined by FEMA and the NFIP, a repetitive loss property is any insured property which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978.[8] There are no repetitive flood loss buildings in Groton.[9] It is important to remember that repetitive loss data does not fully represent the damage that Groton sustains from flooding. Repetitive loss data only includes buildings that receive the FEMA designation, which does not include all buildings that have incurred flood damage. Flooding events in Groton have been classified as a high frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard occurs more frequently than once in 5 years, a greater than 20% probability per year.[10]

[5] Town of Groton, Open Space and Recreation Committee, 2019-2026.
[6] Federal Emergency Management Agency (FEMA), "Flood Insurance Rate Map: Groton, Middlesex County, Massachusetts."
[7] Federal Emergency Management Agency (FEMA), "Flood Zones."
[8] Federal Emergency Management Agency (FEMA), "Definitions: Repetitive Loss Structure."
[9] Massachusetts Department of Conservation and Recreation (DCR), "Community Information System: Repetitive Loss for the Town of Groton."
[10] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Department of Conservation (DCR), "Massachusetts State Hazard Mitigation Plan."

Middlesex Flooding Events

NOAA's National Centers for Environmental Information Storm Events Database provides information on previous flood events for Middlesex County, including details of municipalities that were impacted by extreme events. Groton is included in the Middlesex County data. The storms are categorized by event type, including flood and flash flood events.[11] Flash flood events are considered by NOAA's Storm Events Database as "a life-threatening, rapid rise of water into a normally dry area beginning within minutes to multiple hours of the causative event (e.g., intense rainfall, dam failure, ice jam)." Floods are considered, "Any high flow, overflow, or inundation by water which causes damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, that poses a threat to life or property."[12]

Middlesex County had 129 flood events and 30 flash flood events between 2000 and 2019. No deaths or injuries were reported. The property damage totaled $53.439 million dollars (not adjusted for inflation). Incredibly, flooding during March 2010 caused more than 80% of the total property damage reported during this time period (over $35 million dollars). Property damages ranged from $1,000 to $26 million. Two events listed in the database were documented as county-wide impacts in May of 2006 with $5 million in damages.[13] Although not all of the flooding documented in the database directly affected Groton, the monetary impact of flooding is a proxy for the potential damage that could occur. Damages that occur regionally can also have an indirect impact on Groton, due to regionally dependent utilities, supply of goods, transportation networks, and economic impacts, among other considerations. Of the 129 flood events that occurred in Middlesex County between 2000 and 2019, two directly affected Groton. The date and details are listed below:

Table 4-2. Flooding Events in Groton[14]

Date of Flooding Event	Description
April 2, 2004	Widespread minor to moderate flooding impacted many rivers in southern New England, as a result of 2 to 4 inches of rain over a three-day period. Flooding of mainstem rivers occurred along the Squannacook River at West Groton.
March 14, 2010	Six to ten inches of rain resulted in major flooding across eastern Massachusetts and Rhode Island. Many streets were closed in Groton and its surrounding towns due to flooding. The Governor of Massachusetts declared a state of emergency and this was followed by a federal disaster declaration for seven Massachusetts counties.

Federal Declared Flood Disasters in Middlesex County

A disaster declaration is a statement made by a community when the needs required by a disaster or emergency is beyond the local capabilities. Ten disaster declarations were made in Middlesex County due to flooding between 2000 and 2019, as can be seen in Table 4-4 below.

[11] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."
[12] Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and National Weather Service, "Storm Data Preparation."
[13] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."
[14] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA).

Table 4-4. Previous Federal and State Disaster Declarations - Flooding[15]

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms & Flooding March 5-April 16, 2001	DR-1364	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Flooding April 1-30, 2004	DR-1512	FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Essex, Middlesex, Norfolk, Suffolk, Worcester
Severe Storms and Flooding October 7-16, 2005	DR-1614	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Middlesex, Essex, Suffolk
Severe Storm and Flooding April 15 - 25, 2007	DR-1701	Public Assistance	Middlesex, Plymouth, Barnstable, Dukes, Hampshire, Hampden, Franklin, Berkshire
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Flooding March 02- 03, 2018	DR-4372	Public Assistance	Middlesex, Norfolk, Bristol, Plymouth, Barnstable, Nantucket

[15] Federal Emergency Management Agency (FEMA), "Public Assistance Disaster Declarations"; Federal Emergency Management Agency (FEMA), "Disasters: Total Number of Declared Disasters"; Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

4.2.2 GIS Flooding Exposure Analysis

Hazard location and extent of riverine flooding was determined using the current effective FEMA Flood Insurance Rate Map (FIRM) data for Groton, which is dated 2010. For purposes of this exposure analysis, the following special flood hazard areas identified in the Town of Groton's current FIRMs included:

- Flood Zone AE – Regulatory Floodway
- Flood Zone A (AE, AH) – 1% Annual Chance Flood Hazard
- Flood Zone X (shaded) – 0.2% Annual Chance Flood Hazard

A flood exposure analysis was conducted for critical facilities and vulnerable populations throughout the municipality using MassGIS data, FEMA flood maps, and information gathered from the municipality. Table 4-5 below displays critical infrastructure in Groton that are located within either the 100-year or 500-year FEMA flood zone. Five critical facilities are located within the 100-year flood zone and one critical facility is located in the 500-year flood zone. These facilities are vital to the functionality of the Town, and it is important to protect them from flood hazards.

Table 4-5. Critical Facilities Located within the FEMA Flood Zone

Facility	Address	100-Year Flood Zone	500-Year Flood Zone
Elderly Services/Long Term Care Facility	8 West Main Street	X	
Pump Station	309 Townsend Road	X	
Public Water Supply	Townsend Road GP Wellfield	X	
Solid Waste Facility	71 Nod Road	X	X
Underground Storage Tank	Townsend Road	X	

During the workshop, stakeholders discussed concern related to Groton's vulnerable populations. The This may include residents experiencing social isolation, such as elderly residents and children. A GIS analysis found that 59 census blocks containing elderly or youth residents are located within the 100-year flood zone. More information related to this analysis is included in Appendix B.

The Town's existing tax parcel and property value data obtained from MassGIS were used to estimate the number of parcels (developed and undeveloped) and buildings located in identified hazard areas, along with their respective assessed values. The parcel data set provides information about the parcel size, land use type, and assessed value, among other characteristics. The parcel data was also classified into various land use types based on the Massachusetts Department of Revenue's Property Type Classification Code for Fiscal Year 2019.

An analysis was conducted on all developed parcels in the Town. To determine the vulnerability of each parcel and building, a GIS overlay analysis was conducted in which the flood hazard extent zones were overlaid with the parcel data and existing building footprint data. These developments were overlaid with historic flood zones to determine the parcels' vulnerability to flooding. They were categorized by land use type, and the exposure of each land use type was documented by the total area and percentage of parcels that overlap with a flood zone. The risk or impact of potential flooding was captured by summarizing the total property value in each parcel. 16% of the developed parcels in Groton are located

within the 100-year flood zone, and 18% are located within the 500-year flood zone. More information is included in Tables 4-6 and 4-7 below.

Table 4-6. Exposure of Developed Parcels to the 100-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	3273	7452	188	1048	14	$44,893,700
Commercial	78	854	7	234	27	$126,383,700
Industrial	6	86.7	2	43.6	50	$60,544
Government	1	3.32	N/A	N/A	N/A	N/A
Agricultural	N/A	N/A	N/A	N/A	N/A	N/A
Open Space	N/A	N/A	N/A	N/A	N/A	N/A
Total	3358	8396	197	1325	16	$171,337,944

Table 4-7. Exposure of Developed Parcels to the 500-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	3273	7452	235	1109	15	$56,043,150
Commercial	78	854	9	367	43	$127,681,800
Industrial	6	86.7	3	45.5	53	$1,479,500
Government	1	3.32	N/A	N/A	N/A	N/A
Agricultural	N/A	N/A	N/A	N/A	N/A	N/A
Open Space	N/A	N/A	N/A	N/A	N/A	N/A
Total	3358	8396	247	1522	18	$185,204,450

Recent developments or redevelopments within the past 10 years (2010 – 2020) were isolated and an additional exposure analysis was conducted on these parcels. The methodology for this exposure analysis is the same as described above. This data was pulled from the MassBuilds database[16] and confirmed by the Town Planner. The analysis showed that the Town of Groton does not have recently developed parcels in the 100-year or 500-year Flood Zone. This statistic is an indicator of the Town's success in encouraging new development to occur outside of flood prone areas.

Potential development areas that were noted by MassBuilds as being in the planning phase of development were reviewed by the Town Planner, and additional planned facilities were added. These locations were overlaid with FEMA flood zone maps to determine the vulnerability to flooding. These areas were categorized by land use type, which was downloaded from MassGIS. The analysis showed that there are no locally identified areas for potential developments in the 100-year or 500-year flood zones. The results are in accordance with the previous observation that there are no recently developed parcels in the FEMA flood zone.

[16] Metropolitan Area Planning Council (MAPC), "MassBuilds: Groton."

To further resiliency in the Town, a flood exposure analysis was completed on all vacant, developable parcels. The analysis utilized MassGIS data, FEMA flood maps, and information from the Town. The result identify future flooding that could occur on parcels if they were to be developed. The output of the ArcGIS overlay analysis showed all vacant, developable parcels that intersected with a flood zone. The number of parcels was totaled for each land use type within each of the FEMA Flood Zones. While there are 1,269 acres of land in Groton that are vacant and developable, 11% of that land is located within the 100-year flood zone, and 12% is located within the 500-year flood zone. More information is included in Tables 4-8 and 4-9 below.

Table 4-8. Exposure of Developable, Vacant Land to the 100-Year FEMA Flood Zone

Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	182	1087	14	140	13
Commercial	5	115	N/A	N/A	N/A
Industrial	3	66	1	6.10	9
Government	N/A	N/A	N/A	N/A	N/A
Agricultural	N/A	N/A	N/A	N/A	N/A
Open Space	N/A	N/A	N/A	N/A	N/A
Total	190	1269	15	146	11

Table 4-9. Exposure of Developable, Vacant Land to the 500-Year FEMA Flood Zone

Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	182	1087	11	147	14
Commercial	5	115	N/A	N/A	N/A
Industrial	3	66	1	6.10	9
Government	N/A	N/A	N/A	N/A	N/A
Agricultural	N/A	N/A	N/A	N/A	N/A
Open Space	N/A	N/A	N/A	N/A	N/A
Total	190	1269	12	153	12

4.2.3 Dams and Dam Failure

Dam failure is defined as a collapse of an impounding structure resulting in an uncontrolled release of impounded water from a dam.[17] Dam failures during flood events are of concern in Massachusetts, given the high density of dams constructed in the 19th century.[18]

Dams can fail due to overtopping caused by floods that exceed the capacity of the dam, deliberate acts of sabotage, structural failure of materials used in dam construction, movement and/or failure of the foundation supporting the dam, settlement and cracking of concrete or embankment dams, piping and internal erosion of soil in embankment dams, and inadequate maintenance and upkeep. Many dam failures in the United States have been secondary results of other disasters. The prominent causes are

[17] Department of Conservation and Recreation (DCR), "302 CMR 10.00: Dam Safety."
[18] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage.[19]

Climate change may indirectly affect dam breaches for a variety of reasons. Dams are typically designed based on historic water flows and known hydrology. Climate change projections indicate that the frequency, intensity, and amount of precipitation will increase in New England. Increased precipitation may push dams over capacity. Therefore, dams will have to be monitored for safety. There are several mechanisms in place to manage increases in water, such as slowly releasing water. It is advised that these events are monitored as it can add additional stress on the dam infrastructure.

Although dam failure does not occur frequently in Groton, it can cause property damage, injuries, and potentially fatalities. These impacts can be at least partially mitigated through advance warning to communities that would be impacted by dam failure. In addition, the breach may result in erosion to rivers and stream banks that are inundated. In Groton, dam failure is classified as a very low frequency event, which is defined by the 2013 State Hazard Mitigation Plan as occurring less frequently than once every 100 years (less than a 1% chance per year). Although there have been no recorded dam failures in Groton, a dam failure can still present a high level of risk and could result in a catastrophic event with extreme damage to property and potential loss of life.

According to town officials and the Massachusetts Department of Conservation and Recreation's (DCR) Office of Dam Safety, there are four dams in Groton. Information related to these dams is summarized in Table 4-10 below. This summary table includes the hazard classification for each dam, which is defined by DCR as:

> *High:* Dams located where failure or misoperation 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:* Dams located where failure or mis-operation may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s), or cause interruption of use or service or relatively important facilities.
>
> *Low:* Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

Table 4-10. Inventory of Dams in Groton[20]

Dam Name	Dam Owner	Hazard Potential Classification
Squannacook River Dam	Town of Groton, Board of Selectmen	High Hazard
Hollingsworth & Vose Co. Dam	Hollingsworth & Vose Company	Low Hazard
Lost Lake Dam	Town of Groton, Highway Department	High Hazard
Woods Mill Pond Dam	Martina Calnan	Low Hazard

[19] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

[20] Office of Dam Safety, "Dam Inventory."

As of February 2017, all dams classified as high hazard potential or significant hazard potential were required to have an Emergency Action Plan (EAP).[21] This plan must be updated annually and submitted to the Commissioner and the Massachusetts Emergency Management Agency. The plan should also be retained by the dam owner and the Town in which the dam is located. Guidelines and a template were established by the Office of Dam Safety to ensure that all EAPs follow the proper format.

4.2.4 Climate Change Impacts: Flooding

Middlesex County's observed annual precipitation in 2005 was 56.17 inches.[22] Extreme rain and snow events are becoming increasingly common and severe particularly in the Northeast region of the country (please refer to Figure 4-5 below). Large rain or snow events that happened once a year in the middle of the 20th century now occur approximately every nine months. Additionally, the largest annual events now generate 10% more rain than in 1948. Regionally, New England has experienced the greatest increase in frequency of extreme rain and snow events. These events now occur 85% more frequently than they did 60 years ago.[23] Massachusetts is expected to experience an 8% increase in extreme precipitation events by midcentury and a 13% increase in extreme precipitation by 2100.[24]

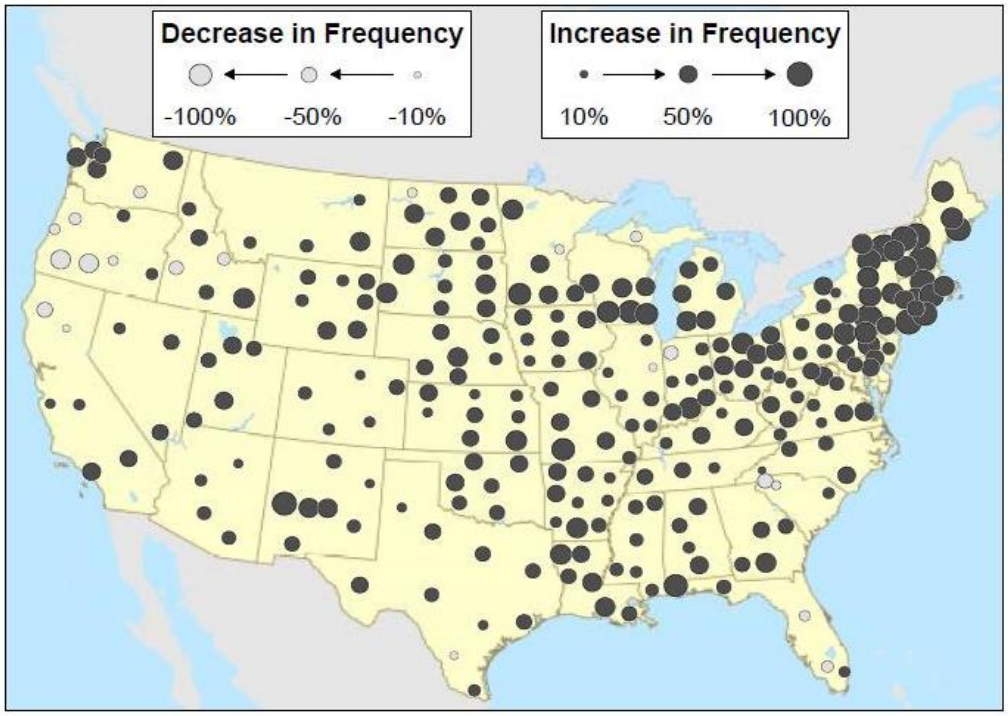


Figure 4-5. Changes in Frequency of Extreme Downpours[25]

[21] Massachusetts Department of Conservation and Recreation (DCR), "Emergency Action Plans."
[22] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Annual Total Precipitation: Middlesex County, MA."
[23] Madsen and Willcox, "When It Rains, It Pours: Global Warming and the Increase in Extreme Precipitation from 1948 to 2011."
[24] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA) and Adaptation Advisory Committee, "Massachusetts Climate Change Adaptation Report."
[25] Madsen and Willcox, "When It Rains, It Pours: Global Warming and the Increase in Extreme Precipitation from 1948 to 2011."

4.3 Wind Related Hazard

High winds can occur during hurricanes, tornadoes, nor'easters, and thunderstorms. The entire area of Groton is vulnerable to the impacts of high wind. All current and future buildings, critical facilities, and vulnerable populations are at risk during high wind events. Wind may down trees and power lines, cause property damage, and create hazardous driving conditions. While Groton's current 100-year wind speed is 99 mph[26], climate change will likely increase storm event frequency and severity.

Figure 4-6: Restoring power outage due to downed tree after a storm.

Source: Photo from GELD website

The Groton Fire Department discussed the challenges that can occur when downed trees block roads and prevent or delay access to certain areas. Although there are occasional issues with downed power lines, the Town of Groton's electric light company, Groton Electric Light Department (GELD), can quickly respond to power outages. Additionally, GELD is proactive in maintaining trees around powerlines. Some underground electric utilities are being installed. Respondents to the public survey that was shared after Groton's listening session discussed the impact of severe storms and wind events and identified the southern part of Groton as experiencing more power outages than the rest of Town.

4.3.1 Hurricanes and Tropical Storms

Tropical cyclones (including tropical depressions, tropical storms, and hurricanes) form over the warm waters of the Atlantic, Caribbean, and Gulf of Mexico. A tropical storm is defined as having sustained winds from 39 to 73 mph. If sustained winds exceed 73 mph, it is categorized a hurricane. The Saffir-Simpson scale ranks hurricanes based on sustained wind speeds from Category 1 (74 to 95 mph) to Category 5 (156 mph or more). Category 3, 4, and 5 hurricanes are considered "Major" hurricanes. Wind gusts associated with hurricanes may exceed the sustained winds and cause more severe localized damage.[27]

Hurricanes and tropical storms have a large spatial extent and are known to impact the entire town when one passes through this area. All existing and future buildings including critical facilities and populations may be at risk to the hurricane and tropical storm hazard. Impacts may include water damage in buildings from building envelope failure, business interruption, loss of communications, and power failure. Flooding is a major concern as slow-moving hurricanes can discharge tremendous amounts of rain on an area.

[26] American Society of Civil Engineers (ASCE), "ASCE 7 Hazard Tool: Groton, Massachusetts."

[27] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

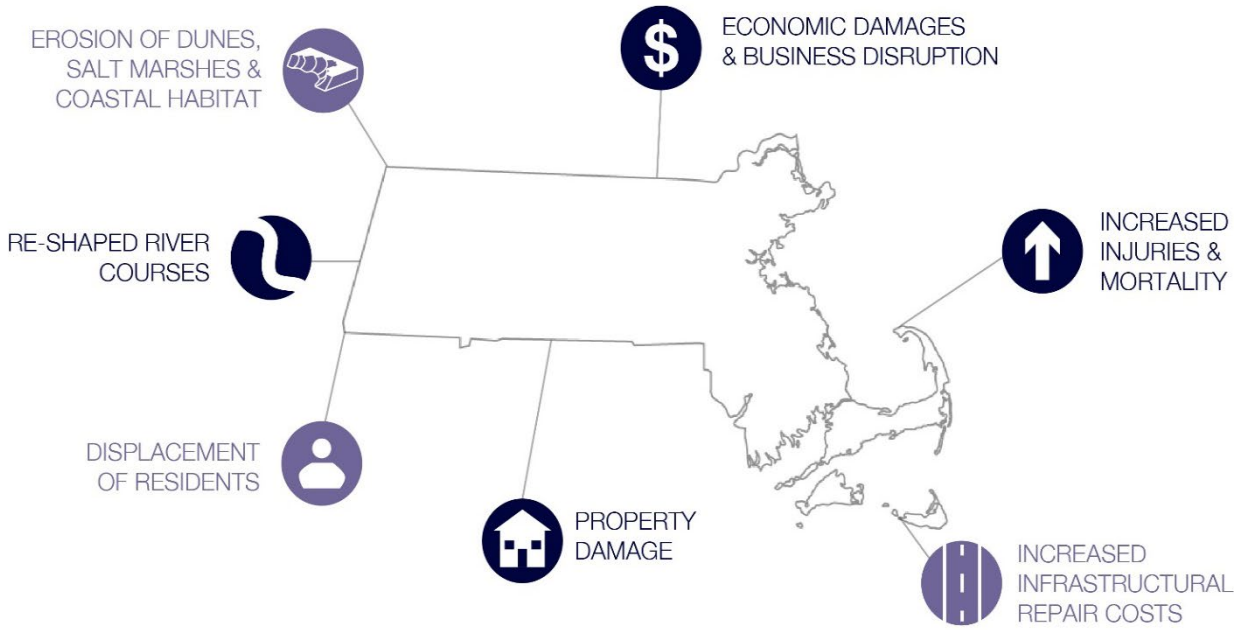


Figure 4-7: Potential impacts of extreme storms, including high wind events

The official hurricane season runs from June 1 to November 30. However, storms are most likely to occur in New England during August, September, and October.[28] The region has been impacted by hurricanes throughout its history, the earliest recorded in 1635. Between 1851 and 2012, Massachusetts experienced 13 hurricanes and two named tropical storms. The most recent FEMA disaster declaration in Massachusetts due to a hurricane was Hurricane Sandy in 2012. Hurricanes that have occurred in the region since 1938 are listed in Table 4-11 below. Four were Category 3 events.

Table 4-11. Hurricane Records for Eastern Massachusetts, 1938 to 2019[29]

Hurricane Event	Date
Great New England Hurricane	September 21, 1938
Great Atlantic Hurricane	September 14-15, 1944
Hurricane Doug	September 11-12, 1950
Hurricane Carol	August 31, 1954
Hurricane Edna	September 11, 1954
Hurricane Diane	August 17-19, 1955
Hurricane Donna	September 12, 1960
Hurricane Gloria	September 27, 1985
Hurricane Bob	August 19, 1991
Hurricane Katrina	September 13, 2005
Hurricane Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011

[28] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

[29] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."

Hurricane Event	Date
Hurricane Sandy	October 29-30, 2012
Hurricane Florence	September 18, 2018
Hurricane Dorian	September 7, 2019

The Saffir/Simpson scale categorizes or rates hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to provide an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on context.[30] More information is included in Table 4-12 below:

Table 4-12. Saffir/Simpson Scale[31]

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.

(Table originally created by NOAA)

Hurricane damage in Groton was estimated using a hurricane modeling software called Hazus Multi-Hazard (Hazus). Hazus is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. The Hazus hurricane model allows users to input specific parameters in order to model a defined hurricane magnitude, which is based on wind speed. The largest hurricane ever recorded in Massachusetts was a Category 3 hurricane, which occurred in 1954. For the purposes of this analysis, and in order to estimate potential damage, both a Category 2 and a Category 4 hurricane were modeled. Although there have been no recorded Category 4 hurricanes recorded in

[30] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[31] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

Massachusetts, a comparable storm was modeled to show the impact that could occur from this extreme scenario, which is something that could possibly happen in the future due to climate change.

In Massachusetts, the return period for a Category 2 hurricane is approximately 0.01 percent, and for a Category 4 hurricane it is approximately 0.005 percent. Hazus models hurricanes based upon their return period. Therefore, a Category 2 was modeled as a 100-year hurricane and a Category 4 was modeled as a 500-year hurricane. In order to model each of these hurricanes, the study region must first be defined. The Town of Groton was outlined using Town census tracts. The probabilistic scenario was used for Groton, which considers the associated impact of thousands of storms that have a multitude of tracks and intensities. The output shows the potential impact that could occur in Groton if either a Category 2 or a Category 4 hurricane passed by. Hazus is based on 2010 census data and 2014 dollars. The tables below show the estimated damage from both a Category 2 and a Category 4 hurricane in the municipality.

Table 4-13. Estimated Damages in Groton from Probabilistic Category 2 and Category 4 Hurricanes

	Category 2	Category 4
Building Characteristics		
Estimated total number of buildings	4,106	4,106
Estimated total building replacement value (Year 2014 $) (Millions of Dollars)	$2,234	$2,234
Building Damages		
# of buildings sustaining minor damage	42	390
# of buildings sustaining moderate damage	1.33	37
# of buildings sustaining severe damage	0.03	0.97
# of buildings destroyed	0	0.54
Population Needs		
# of households displaced	0	0
# of people seeking public shelter	0	0
Debris		
Building debris generated (tons)	5,720	21,522
Tree debris generated (tons)	5,564	20,499
# of truckloads to clear building debris (@25 tons/truck)	6	41
Value of Damages (Thousands of dollars)		
Total property damage	$9,437.40	$33,398.88
Total losses due to business interruption	$37.60	$955.85

In addition to the infrastructural damage, Hazus also calculated the potential societal impact of a Category 2 and Category 4 hurricane on the community. This calculation included monetary wage, capital-related costs, rental and relocation costs, expected damages to essential facilities, and damages by building material type. A full Hazus risk report for each hurricane category can be found in Appendix B.

Hurricanes are a town-wide hazard in Groton and are considered a high frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard occurs more frequently than once in 5 years, or a greater than 20% probability per year.

4.3.2 Tornadoes

A tornado is a narrow, violently rotating column of air that extends from the base of a cloud to the ground. Tornadoes are the most violent of all atmospheric storms. The following are common factors in tornado formation[32]:

- Very strong winds in the middle and upper levels of the atmosphere
- Clockwise turning of the wind with height
- Increasing wind speed in the lowest 10,000 feet of the atmosphere (i.e. 20 mph at the surface and 50 mph at 7,000 feet)
- Very warm, moist air near the ground, with unusually cooler air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornadoes can be spawned by tropical cyclones or the remnants thereof, and weak tornadoes can even form from little more than a rain shower if air is converging and spinning upward. The most common months for tornadoes to occur are June, July, and August. There are exceptions: The 1995 Great Barrington, Massachusetts tornado occurred in May; and the 1979 Windsor Locks, Connecticut tornado ioccurred in October.[33]

The Fujita Tornado Scale measures tornado severity through estimated wind speed and damage. The National Weather Service began using the Enhanced Fujita-scale (EF-scale) in 2007, which led to increasingly accurate estimates of tornado severity. Table 4-14 provides more detailed information on the EF Scale.

Table 4-14. Enhanced Fujita Scale[34]

F Number	Fastest ¼ mile (mph)	3-second gust (mph)	EF Number	3-second gust (mph)	EF Number	3-second gust (mph)
0	40 – 72	45 – 78	0	65 – 85	0	65 – 85
1	73 – 112	79 – 117	1	86 – 109	1	86 – 110
2	113 – 157	118 – 161	2	110 – 137	2	111 – 135
3	158 – 207	162 – 209	3	138 – 167	3	136 – 165
4	208 – 260	210 – 261	4	168 – 199	4	166 – 200
5	261– 318	262 – 317	5	200 – 234	5	Over 200

[32] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

[33] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA).

[34] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Massachusetts experiences an average of 1.7 tornadoes per year. The most tornado-prone areas of the state are the central counties. Tornadoes are comparatively rare in eastern Massachusetts, although Middlesex County is considered an at-risk location.[35] The most devastating tornado in Massachusetts in the history of recorded weather occurred in Worcester in 1953, killing 94 people, injuring more than 1,000, and causing more than $52 million in damages (more than $460 million in current dollars). The most recent tornadoes in Massachusetts occurred in 2011 in Springfield, 2014 in Revere, and 2016 in Concord.[36] There have been 18 recorded tornados in Middlesex County since 1955. One fatality and six injuries were reported. Table 4-15 below provides the detailed information.

Table 4-15. Tornado Records for Middlesex County, 1955 to 2020[37]

Date	Fujita	Fatalities	Injuries	Damage
10/24/1955	1	0	0	$2,500
6/19/1957	1	0	0	$25,000
6/19/1957	1	0	0	$250
7/11/1958	2	0	0	$250,000
8/25/1958	2	0	0	$2,500
7/3/1961	0	0	0	$25,000
7/18/1963	1	0	0	$25,000
8/28/1965	2	0	0	$250,000
7/11/1970	1	0	0	$25,000
10/3/1970	3	1	0	$250,000
7/1/1971	1	0	1	$25,000
11/7/1971	1	0	0	$250
7/21/1972	2	0	4	$2,500,000
9/29/1974	3	0	1	$250,000
7/18/1983	0	0	0	$250
9/27/1985	1	0	0	$250
8/7/1986	1	0	0	$250,000
8/22/2016	1	0	0	$1,000,000

Although tornadoes are a potential town-wide hazard in Groton, the National Oceanic and Atmospheric Administration (NOAA) only includes documentation of one tornado track that crossed through Town. On September 29, 1974, a category 3 (Fujita Scale) tornado was recorded in Middlesex county, and caused one injury and $250,000 in property damage. The tornado track was recorded starting in the vicinity of Chandler Street and McKenzie Circle, and ending near Lumber Lane.[38] If another tornado were to occur in Groton, damages would depend on the track of the tornado and would be most likely be

[35] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[36] Morrison, "Tornadoes of Massachusetts Past"; Epstein, "This Morning's Tornado in Concord, Explained."
[37] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."
[38] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database - Event Details - Tornado September 29, 1974."

high due to the prevalence of older construction and the density of development that exist. Structures built before current building codes may be more vulnerable. Evacuation, sheltering, debris clearance, distribution of food and other supplies, search and rescue, and emergency fire and medical services may be required. Critical evacuation and transportation routes may be impassable due to downed trees and debris, and recovery efforts may be complicated by power outages. Tornado events in Groton are a very low frequency event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur less than once in 100 years (a less than 1% chance per year). Tornadoes are difficult to simulate well in climate models because of their small size. However, it is predicted that the frequency of tornadoes in eastern Massachusetts will rise in the future due to climate change.

4.3.3 Nor'easters

A nor'easter is characterized by large counterclockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, waves, and rain along the East Coast. The term nor'easter refers to their strong northeasterly winds blowing in from the ocean. These winter weather events are among the season's most ferocious storms, often causing erosion, flooding, and structural damage.[39]

Nor'easters generally occur on at least an annual basis, typically in late fall and early winter. Some years bring up to four nor'easter events. This is currently the most frequently occurring natural hazard in the state. The storm radius is often as much as 100 miles and sustained wind speeds of 20 to 40 mph are common, with short-term gusts of up to 50 to 60 mph. High winds during a hurricane can last from 6 to 12 hours, while conditions during a nor'easter can last from 12 hours to three days.[40] Previous nor'easters events are listed in Table 4-16. Notably, the severe Coastal Storm in 1991 led to a federal disaster declaration.

Table 4-16. Nor'easter Events for Massachusetts, 1978 to 2020[41]

Nor'easter Event	Date
Blizzard of 1978	February 1978
Severe Coastal Storm ("Perfect Storm")	October 1991
Great Nor'easter of 1992	December 1992
Blizzard, Nor'easter	January 2005
Coastal Storm, Nor'easter	October 2005
Severe Storms, Inland and Coastal Flooding	April 2007
Winter Storm and Nor'easter	January 2011
Severe Storm and Snowstorm	October 2011
Severe Winter Storm, Snowstorm, and Flooding	April 2013
Severe Winter Storm, Snowstorm, and Flooding	April 2015
Severe Winter Storm and Flooding	March 2018
Severe Winter Storm and Snowstorm	March 2018

[39] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[40] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA).
[41] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."

Some of the historic events described in Section 4.2 Flood-Related Hazards were preceded by Nor'easters, including the 1991 "Perfect Storm." The Blizzard of '78 was another notable storm; this event closed down the entire state and made access to certain areas impossible. More recently, the blizzard of 2013 left nearly 400,000 Massachusetts residents without power.[42] A series of winter storms in 2015 and 2018 also caused significant snowfall amounts. A FEMA Major Disaster Declaration was issued to provide recovery assistance to Massachusetts counties including Middlesex County.[43]

The Town of Groton is vulnerable to high winds, snow, and extreme rain during Nor'easters. These impacts can lead to property damage, downed trees, power service disruptions, surcharged drainage systems, and localized flooding. These conditions can impact evacuation and transportation routes and complicate emergency response efforts. Due to its inland location, Groton is not subject to the coastal hazards often associated with nor'easters. Nor'easters in Groton are high frequency events. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard occurs more frequently than once in 5 years, or a greater than 20% probability per year.

4.3.4 Severe Storms and Thunderstorms

Thunderstorms in Massachusetts are usually accompanied by rainfall; however, during periods of drought, lightning from thunderstorm cells can result in fire ignition. Thunderstorms with little or no rainfall are rare in New England but have occurred.[44]

Thunderstorms are typically less severe than other events discussed in this section. However, thunderstorms can cause local damage and are a town-wide risk in Groton. Thunderstorms can include lightning, strong winds, heavy rain, hail, and sometimes tornados. Thunderstorms typically last for about 30 minutes and can generate winds of up to 60 mph.

Table 4-17. Previous Federal and State Disaster Declarations - Thunderstorms

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms/Flooding October 20-25, 1996	DR-1142	FEMA Hazard Mitigation Grant Program	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
Heavy Rain and Flooding June 13-July 6, 1998	DR-1224	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms & Flooding March 5-April 16, 2001	DR-1364	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms and Flooding October 7-16, 2005	DR-1614	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties

[42] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MA Climate Change Clearinghouse."
[43] Federal Emergency Management Agency (FEMA), "FEMA-DR-4379-MA-March 13-14, 2018 Severe Winter Storm."
[44] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Middlesex, Essex, Suffolk
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester

NOAA's National Centers for Environmental Information offers thunderstorm data for Middlesex County, which includes Groton. Between 2000 and 2019, 371 thunderstorm events caused a total of $3,902,550 in property damages. Seven injuries and no deaths were reported. Nine of these events originated in Groton.

Winds associated with thunderstorms can knock down trees resulting in power outages and blocked evacuation and transportation routes. Extreme rain during thunderstorms can cause inland flooding around waterbodies or due to surcharged drainage systems. Thunderstorms are considered high frequency events in Groton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard may occur more frequently than once in 5 years (a greater than 20% chance per year).

4.3.5 Climate Change Impacts: High Winds

While Groton's current 100-year wind speed is 99 mph,[45] climate change will likely increase the number of extreme wind events and their severity. Additionally, rising sea temperature could lengthen the hurricane season and fuel stronger hurricane events. The National Climate Assessment Report notes that hurricane "intensity, frequency, and duration have all increased since the early 1980s." This source predicts the continuing intensity and associated rainfall with rising temperatures. This would result in greater losses due to increased flooding, associated building damages and business interruption impacts.[46] The anticipated increase in frequency and intensity of severe thunderstorms may also increase the risk of tornadoes.[47]

4.4 Winter Storms

Winter storm events are atmospheric in nature and can impact the entire planning area. All current and future buildings and populations are considered to be at risk of winter storms, which have a variety of potential impacts. Heavy snow loads may cause roofs and trees to collapse, leading to structural damage. Deaths and injury are also possible impacts. Additional impacts can include road closures, power outages, business interruption, business losses (i.e. due to road closures), hazardous driving conditions, frozen pipes, fires due to improper heating, and second-hand health impacts caused by shoveling (such as a heart attack). Public safety issues are also a concern, as streets and sidewalks

[45] American Society of Civil Engineers (ASCE), "ASCE 7 Hazard Tool: Groton, Massachusetts."
[46] Walsh and Wuebbles, "National Climate Assessment - Chapter 2: Our Changing Climate."
[47] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

can become difficult to pass. This issue may be especially difficult for vulnerable populations such as elderly residents who may have trouble crossing at intersections due to large accumulations of snow. Impassable streets can also complicate emergency response efforts during an extreme event.

Figure 4-8: Snow in Groton. Photos from Groton, MA Facebook

Winter storms are a potential town-wide hazard in Groton. These events can include wind, heavy snow, blizzards, and ice storms. Blizzards and ice storms in Massachusetts can range from an inconvenience, to extreme events that cause significant impacts and require a large-scale, coordinated response. Examples of winter storms that warranted disaster declarations are summarized in Table 4-18 below.

Table 4-18. Previous Federal and State Disaster Declarations[48]

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Blizzard January 7-13, 1996	DR-1090	No funding reported	All 14 Massachusetts Counties
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm and Snowstorm January 11-12, 2011	DR-1959	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk
Severe Storm and Snowstorm October 29-30, 2011	DR-4051	FEMA Public Assistance; FEMA Public Assistance Snow Removal; FEMA Hazard Mitigation Grant Program	Berkshire, Franklin, Hampden, Hampshire, Middlesex, Worcester

[48] Federal Emergency Management Agency (FEMA), "Disasters: Total Number of Declared Disasters."

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Snowstorm March 13-14, 2018	DR-4379	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Essex, Middlesex, Norfolk, Suffolk, Worcester

4.4.1 Heavy Snow and Blizzards

A blizzard is a winter snowstorm with sustained wind or frequent wind gusts of 35 mph or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the criteria. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20°F. A severe blizzard is categorized as having temperatures near or below 10°F, winds exceeding 45 mph, and visibility reduced by snow to near zero.[49]

Winter storms include multiple risks, such as wind, ice, and heavy snow. The National Weather Service defines "heavy snow" as snowfall accumulating to 4" or more in 12 hours or less; or snowfall accumulating to 6" or more in 24 hours or less.[50] Please refer to Section 4.3.3 Nor'easters for more information on another example of severe winter weather.

There is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service[51] characterizes and ranks high-impact northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. NESIS has five categories, as shown in Table 4-19. The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economics. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score, which varies from 1 for smaller storms to over 10 for extreme storms. The raw score is converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over

[49] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[50] National Oceanic and Atmospheric Administration (NOAA) and National Weather Service, "Glossary: Heavy Snow."
[51] Kocin and Uccellini, "The Northeast Snowfall Impact Scale (NESIS)."

large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events.[52]

Table 4-19 NESIS Categories[53]

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+	Extreme

The current winter snowfall record in Eastern Massachusetts is 108.6 inches during the 2014-2015 season.[54] NOAA's National Centers for Environmental Information Storm Events Database provide information for blizzards, winter weather, heavy snow, and winter storms. There were 250 winter events between 2000 and 2019 in Middlesex County totaling $2,059,000 dollars of damage. The greatest damage was during this time frame was a storm in 2011 that caused $926,000 of damage.

The Groton DPW provides standard snow plowing, sanding, and salting operations. A representative from the Housing Authority, which conducts snow removal at its own properties, has experienced challenges in identifying locations to move snow. During Groton's MVP Workshop in January 2020, participants discussed severe winter weather and mitigation opportunities including increased snow clearing, providing accessible warming centers, tree trimming, and studying renewable power alternatives including solar power or battery backup. Backup power sources are imperative to the Town in the event of power outages due to severe winter weather.

Blizzards are classified as high frequency events in Groton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur more than once in five years (a greater than 20% chance of occurring each year).

4.4.2 Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects creating ice build-ups of ¼ inch or more that can cause severe damage. An ice storm warning, now included in the criterion for a winter storm warning, is for severe icing. This is issued when ½ inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the weighing down of power lines and trees. Icy roads can also complicate emergency response efforts during an extreme event. Ice storms are classified as high frequency events in Groton. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard occurs more frequently than once in 5 years, or a greater than 20% probability per year.

[52] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[53] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[54] National Oceanic and Atmospheric Administration (NOAA) and National Weather Service, "Boston Breaks Record Seasonal Snowfall."

Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. Sleet differs from hail: sleet is a wintertime phenomenon, while hail usually falls during thunderstorms in the spring and summer.[55]

NOAA's National Centers for Environmental Information Storm Events Database offers data on hail events, ice storms and sleet Middlesex County. There were 131 hail events, 3 ice storms, and no reported sleet hazards between 2000 and 2019. No deaths or injuries were reported. Over $6.2 million dollars in damages were incurred.

4.4.3 Climate Change Impacts: Winter Storms

There is evidence suggesting that nor'easters along the Atlantic coast are increasing in frequency and intensity. Future Nor'easters may become more concentrated during the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain.[56] Climate projections indicate that climate change will result in more precipitation during the winter in the Northeast.[57] This trend may result in more frequent and/or more severe winter storms.

4.5 Geological Hazards

Geologic hazards can include earthquakes, landslides, sinkholes, and subsidence. Town officials did not identify any local areas that were previously recorded as being vulnerable to geologic hazards, which included landslide areas and previous damage from earthquakes. It was noted that while there have been reported brushfires in Groton, and the Town Center and Lost Lake Neighborhood are at a higher degree of risk, it is not a large occurrence.

4.5.1 Earthquakes

An earthquake is the vibration, sometimes violent, of the earth's surface that follows a release of energy in the earth's crust due to fault fracture and movement. The magnitude or extent of an earthquake is a seismograph-measured value of the amplitude of the seismic waves. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare the size of earthquakes. The Richter scale is the most widely known scale that measures earthquake magnitude. It has no upper limit and is not a direct indication of damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, can have the same magnitude as an earthquake in a remote area that causes no damage. Table 4-20 summarizes Richter scale magnitudes and corresponding earthquake effects.[58]

Table 4-20. Richter Scale and Effects[59]

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally, not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage

[55] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[56] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[57] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MA Climate Change Clearinghouse."
[58] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[59] Louie, "What Is Richter Magnitude?"

Richter Magnitudes	Earthquake Effects
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 km across where people live.
7.0- 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred meters across.

Earthquakes occur occasionally in New England as compared to other parts of the country but are oftentimes so small that they are not felt. The first recorded earthquake was noted by the Plymouth Pilgrims and other early settlers in 1638. Of the over 5,000 earthquakes recorded in the Northeast Earthquake Catalog through 2008, 1,530 occurred within the boundaries of the six New England States, with 366 earthquakes recorded for Massachusetts between 1627 and 2008. Historically, moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt approximately twice per year.[60] A summary of historic earthquakes in Massachusetts is included in Table 4-21 below:

Table 4-21. Historical Earthquakes in Massachusetts, 1727-2020

Location	Date	Magnitude
MA - Cape Ann	11/10/1727	5
MA - Cape Ann	12/29/1727	NA
MA - Cape Ann	2/10/1728	NA
MA - Cape Ann	3/30/1729	NA
MA - Cape Ann	12/9/1729	NA
MA - Cape Ann	2/20/1730	NA
MA - Cape Ann	3/9/1730	NA
MA – Boston	6/24/1741	NA
MA - Cape Ann	6/14/1744	4.7
MA – Salem	7/1/1744	NA
MA - Off Cape Ann	11/18/1755	6
MA - Off Cape Cod	11/23/1755	NA
MA – Boston	3/12/1761	4.6
MA - Off Cape Cod	2/2/1766	NA
MA – Offshore	1/2/1785	5.4
MA - Wareham/Taunton	12/25/1800	NA
MA – Woburn	10/5/1817	4.3
MA – Marblehead	8/25/1846	4.3
MA – Brewster	8/8/1847	4.2

[60] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Location	Date	Magnitude
MA – Boxford	5/12/1880	NA
MA – Newbury	11/7/1907	NA
MA – Wareham	4/25/1924	NA
MA - Cape Ann	1/7/1925	4
MA – Nantucket	10/25/1965	NA
MA – Boston	12/27/1974	2.3
MA – Nantucket	4/12/2012	4.5
MA – Newburyport	2/20/2013	2.3
MA – Freetown	1/9/2014	2.0
MA – Bliss Corner	2/11/2014	2.2
MA – off Northshore	8/18/2014	2.0
MA – Rockport Coast	6/1/2016	2.2
MA – Nantucket	8/18/2018	2.4
MA – Templeton	12/21/2018	2.1
MA – Gardner	12/23/2018	2.2
MA – Rockport	4/27/2019	2.1
MA – North Plymouth	12/3/2019	2.1

Ground shaking or ground motion is the primary cause of earthquake damage to man-made structures. Ground motion from earthquakes is amplified by soft soils and reduced by hard rock. Ground motion is measured by maximum peak horizontal acceleration expressed as a percentage of gravity (%g). Peak ground acceleration in the state ranges from 10 %g to 20 %g, with a 2% probability of exceedance in 50 years. Figure 4-8 below provides additional information.

Groton is located in an area with a PGA of 16 %g with a 2% probability of exceedance in 50 years (Figure 4-8). Compared to the rest of the United States, Massachusetts overall has a low risk of earthquakes. However, a serious earthquake in Massachusetts is possible. No earthquake epicenters have been recorded within Groton.

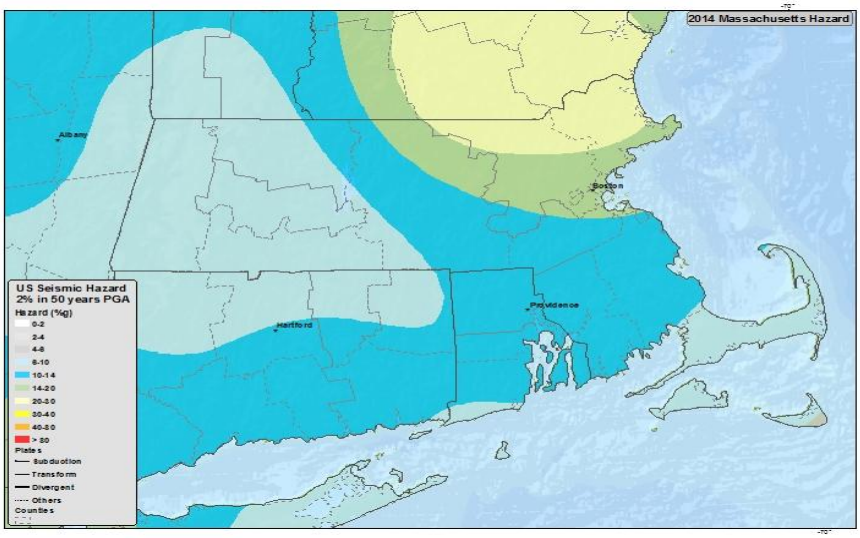


Figure 4-9. 2014 Seismic Hazard Map- Massachusetts (USGS)

It can be assumed that all existing and future buildings and populations are at risk to an earthquake hazard. Impacts from earthquakes can be from slight to moderate building damage, to catastrophic damage and fatalities, depending on the severity of the earthquake event. Events may cause minor damage such as cracked plaster and chimneys, or broken windows, or major damage resulting in building collapse. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations. Although new construction under the most recent building codes generally will be built to seismic standards, much of the development in the town pre-dates the current building code. If an earthquake occurs, the entire region, not just the town, would face significant challenges. Based on the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the degree of exposure "depends on many factors, including the age and construction type of the structures where people live, work, and go to school; the soil type these buildings are constructed on; and the proximity of these building to the fault location." Furthermore, the time of day exposes different sectors of the community to the hazard.

Earthquakes often trigger fires and the water distribution system may be disrupted, thus posing a risk for public health and safety. Earthquakes can lead to business interruptions, loss of utilities and road closures which may isolate populations. People who reside or work in unreinforced masonry buildings are vulnerable to liquefaction (liquefaction is the phenomenon that occurs when the strength and stiffness of a soil is reduced by earthquake).

Potential earthquake damage was modeled for Groton. The Hazus earthquake model allows users to input specific parameters in order to model a defined earthquake magnitude, with the epicenter located at the center of the municipality. In this analysis, two earthquakes were modeled: a magnitude 5.0 and a magnitude 7.0 earthquake. While large earthquakes are rare in Massachusetts, there was a magnitude 5.0 earthquake recorded in 1963. There is a possibility for larger scale earthquakes to occur in Massachusetts at some point, therefore a magnitude 7.0 earthquake was modeled as well to demonstrate the damage that could occur.

In order to model each of these earthquakes, the study region must first be defined. The Town of Groton was outlined using Town census tracts. The arbitrary event scenario was used for Groton, which allows the user to input the magnitude, depth, with, and epicenter of the earthquake. This must be done for each earthquake magnitude chosen. The output shows the potential impact that could occur in Groton if either a magnitude 5.0 or a magnitude 7.0 earthquake occurred with the epicenter located in the center of Town. Hazus is based on 2010 census data and 2014 dollars. Table 4-22 shows the estimated damage from both a magnitude 5.0 and a magnitude 7.0 earthquake in the municipality.

Table 4-22. Estimated Damage in Groton from Magnitude 5 and 7 Earthquakes

	Magnitude 5.0	Magnitude 7.0
Building Characteristics		
Estimated total number of buildings	4,106	4,106
Estimated total building replacement value (Year 2014 $)(Millions of dollars)	$2,234	$2,234
Building Damages		
# of buildings sustaining slight damage	1,214	121
# of buildings sustaining moderate damage	620	854
# of buildings sustaining extensive damage	156	1,217
# of buildings completely damaged	38	1,906
Population Needs		
# of households displaced	64	1,767
# of people seeking public shelter	32	899
Debris		
Building debris generated (tons)	39,000	328,000
# of truckloads to clear building debris (@25 tons/truck)	1,560	13,120
Building-Related Economic Loss (Millions of dollars)		
Income Losses	$32.18	$198.28
Capital Stock Losses	$278.43	$2130.24

In addition to the infrastructural damage, Hazus also calculated the potential social impact of a magnitude 5.0 and magnitude 7.0 earthquake on the community. This calculation included utility system inventory, building damage by construction type, damage to essential facilities and transportation systems, and casualty estimates. A full HAZUS risk response report for each earthquake category can be found in Appendix B.

Earthquakes are classified as a low frequency event in Groton. As defined by the 2013 State Hazard Mitigation Plan, these events occur from once in 50 years to once in 100 years (or a 1% to 2% probability per year). According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the probability of a magnitude 5.0 or greater earthquake centered in New England is about 10-15% in a 10-year period.

4.5.2 Landslides

Landslide include a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity, acting on an over steepened slope, is the primary reason for a landslide, there are other contributing factors. These contributing factors can include erosion by rivers or ocean waves over steepened slopes; rock and soil slopes weakened through saturation by snowmelt or heavy rains; earthquake created stresses that make weak slopes fail; excess weight from accumulation of rain or snow; and stockpiling of rock or ore from waste piles or man-made structures.[61]

Landslides occur throughout the United States, causing an estimated $1 billion in damages and 25-50 deaths each year. Any area composed of very weak or fractured materials resting on a steep slope will likely experience landslides. Although the physical cause of many landslides cannot be removed,

[61] United States Geological Survey (USGS), "Landslides 101."

geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards.[62] Landslides can damage buildings and infrastructure and cause sedimentation of water bodies. Landslide intensity can be measured in terms of destructiveness, as demonstrated by Table 4-23 below.

Table 4-23. Landslide Volume and Velocity

Estimate Volume (m^3)	Expected Landslide Velocity		
	Fast moving (rock fall)	Rapid moving (debris flow)	Slow moving (slide)
<0.001	Slight intensity	--	--
<0.5	Medium intensity	--	--
>0.5	High intensity	---	--
<500	High intensity	Slight intensity	--
500-10,000	High intensity	Medium intensity	Slight intensity
10,000 – 50,000	Very high intensity	High intensity	Medium intensity
>500,000	--	Very high intensity	High intensity
>>500,000	--	--	Very high intensity

Source: Cardinali et al. 2002

Groton Town Center is at an elevation of 300 feet above sea level.[63] No significant landslides have been recorded for Groton or Middlesex County.[64] Local officials indicate that there are occasionally localized issues of erosion during construction, as a result of development, or as a result of clearing vegetation. Landslides are classified as low frequency events in Groton. According to the 2013 State Hazard Mitigation Plan, these events occur from once in 50 years to once in 100 years (or a 1% to 2% probability per year).

4.6 Fire Related Hazards

Fire risk is influenced by fuel (the type of material), terrain and weather. Strong winds can exacerbate extreme fire conditions, especially wind events that persist for long periods, or ones with significant sustained wind speeds that quickly promote fire spread through the movement of embers or exposure within tree crowns. Fires can spread quickly into developed areas.

A wildfire can be defined as any non-structure fire that occurs in the vegetative wildland, including grass, shrub, leaf litter, and forested tree fuels. Wildfires can be caused by natural events, human activity or in an intentional controlled manner, and often begin unnoticed, but spread quickly, igniting brush, trees, and homes.[65] The State Hazard Mitigation and Climate Adaptation Plan states:

> *"The ecosystems that are most susceptible to the wildfire hazard are pitch pine, scrub oak, and oak forests, as these areas contain the most flammable vegetative fuels. Other portions of the*

[62] United States Geological Survey (USGS).
[63] Town of Groton, Open Space and Recreation Committee, 2019-2026"
[64] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[65] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Commonwealth are also susceptible to wildfire, particularly at the urban-wildland interface…. Interface communities are defined as those in the vicinity of contiguous vegetation, with more than one house per 40 acres and less than 50 percent vegetation, and within 1.5 miles of an area of more than 500 hectares (approximately 202 acres) that is more than 75 percent vegetated."

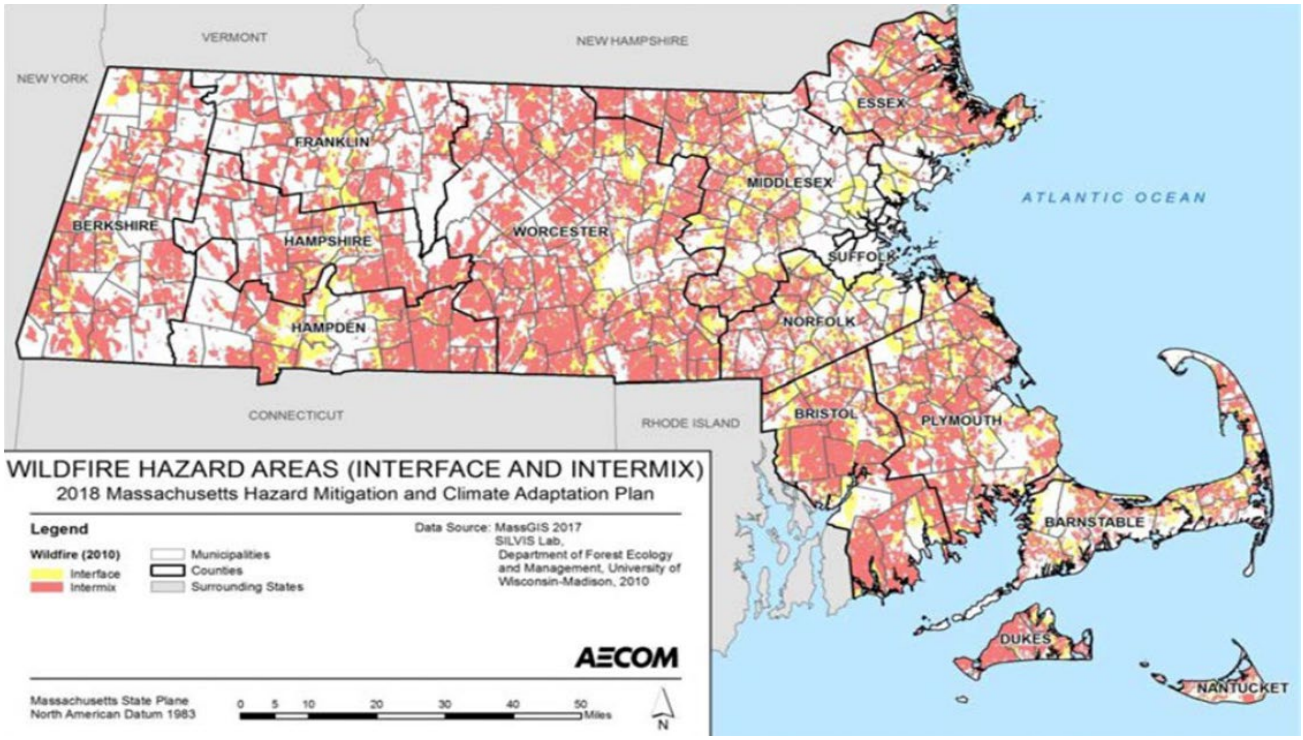


Figure 4-10: Wildfire Hazard Areas Statewide

Since wildfires are not common in Massachusetts, this plan focuses on brush and urban fires. Brush fires can lead to property damage and even death, although they have not resulted in any major property damage or deaths in Groton. All individuals whose homes or workplaces are located in brush fire hazard zones are exposed to this hazard. The most vulnerable members of this population are those who would be unable to evacuate quickly, including those over the age of 65, households with young children, residents with mobility limitations, and residents with limited financial resources.[66] Secondary effects from brush fire include contamination of reservoirs; destroyed power, gas, water, broadband, and oil transmission lines. Brush fires can also contribute to flooding as they strip slopes of vegetation, thereby exposing them to greater amounts of runoff which may cause soil erosion and ultimately the chance of flooding. Additionally, subsequent rains can worsen erosion because brush fires burn ground vegetation and ground cover.

4.6.1 Potential Brush Fire Hazard Areas

Although they are usually minor, the Groton Fire Department responds to a fair amount of brush fires. In 2017, Groton experienced 8 fires, which included 7 structure fires, and 1 brush fire or other. This number was significantly lower than the 25 fires experienced in 2017. The total monetary loss due to

[66] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

fires in 2017 was $113,640, and in 2018 was $34,850.[67] Figure 4-10 below shows the locations of historical brush fires and the number of acres burned in Massachusetts between 2001 and 2009.

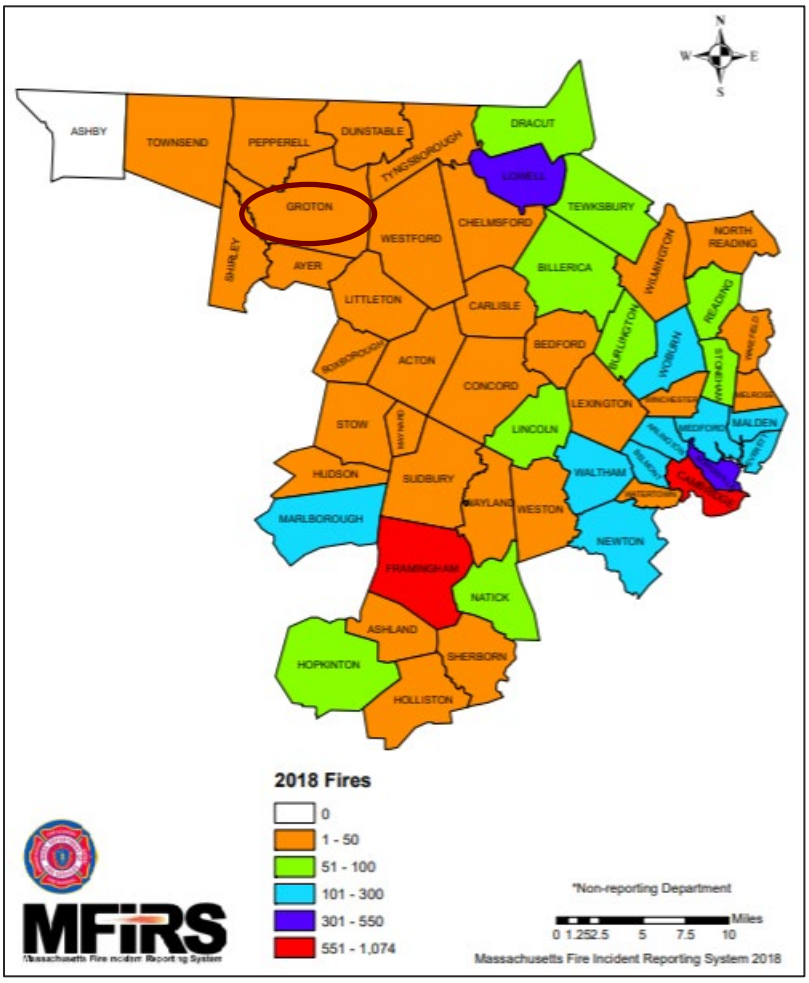


Figure 4-11: Middlesex County Fires: Groton is outlined in red

Source: MFIRS, 2018

Brush fires are classified as medium frequency events in Groton. As defined by the 2013 State Hazard Mitigation Plan, these events occur between once in five years to once in 50 years (a 2% to 20% chance of occurring per year).

4.7 Extreme Temperatures

Massachusetts has four clearly defined seasons. Extreme temperatures fall outside of the ranges typically experienced during these seasons. Extreme temperatures are considered a town-wide hazard in Groton. These events can include both temperatures over and under seasonal averages. Extreme temperature events can range from brief to lengthy.

[67] Massachusetts Fire Incident Reporting System (MFIRS), "2017 & 2018 Fire Experience by Community."

4.7.1 Extreme Cold

Extremely cold temperatures are measured using the Wind Chill Temperature Index provided by the National Weather Service (NWS). The updated index was implemented in 2001 and helps explain the impact of cold temperatures on unexposed skin. Figure 4-12 below provides more information.

Extremely cold temperatures can create dangerous conditions for homeless populations, stranded travelers, and residents without sufficient insulation or heat. The homeless, the elderly, and people with disabilities are often most vulnerable. In Groton, 13.9% of the population are over 65 years old and 7.9% of the population has a disability.[68] Cold weather events can also have significant health impacts such as frostbite and hypothermia. Furthermore, power outages during cold weather may result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas which can lead to increased risk of carbon monoxide poisoning.

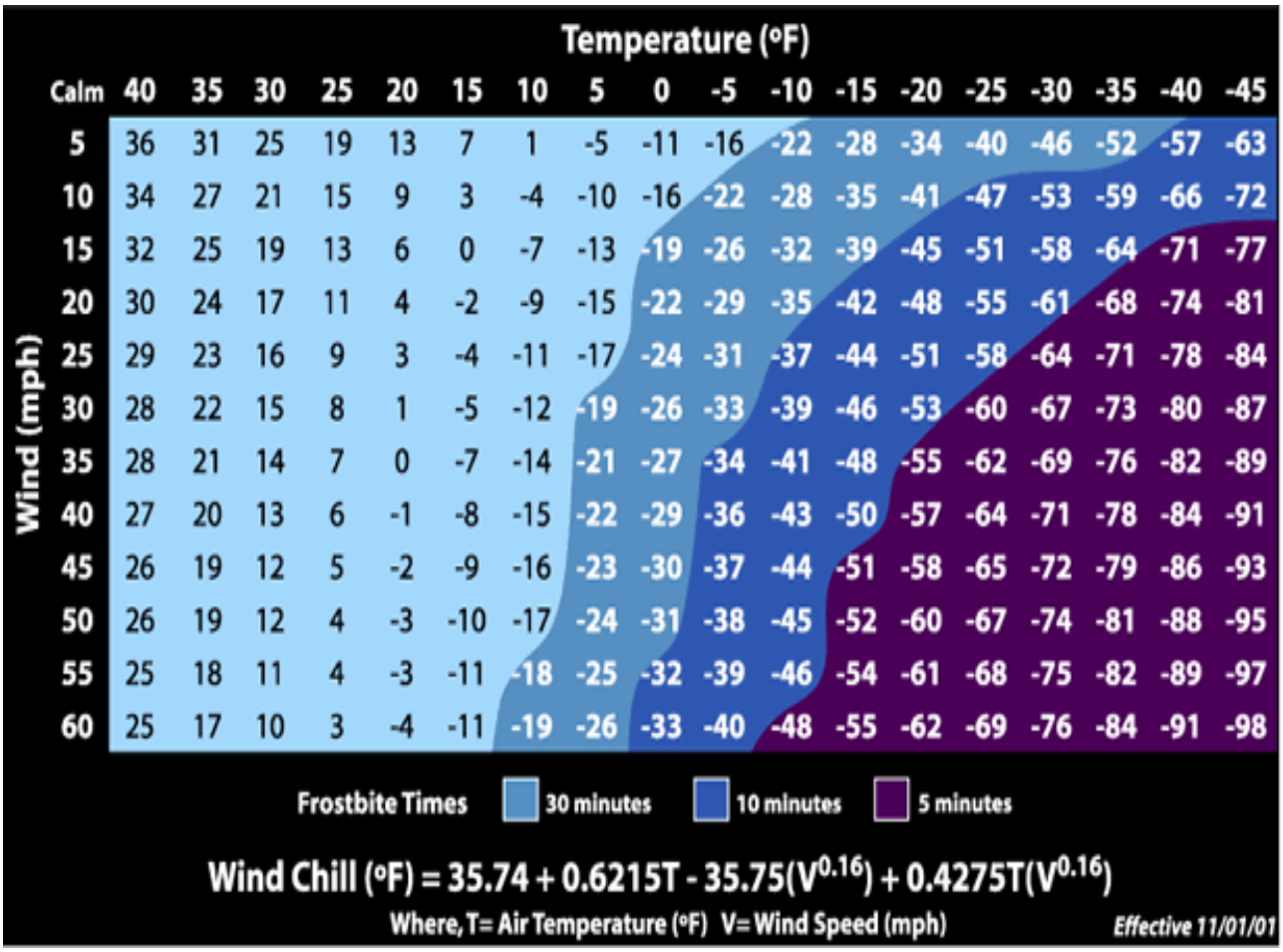


Figure 4-12. Windchill Temperature Index and Frostbite Risk

Source: National Weather Service

NOAA's National Centers for Environmental Information Storm Events Database provides data for extreme cold events. Between 2000 and 2019, Middlesex County experienced three extreme cold and wind chill events, which caused no fatalities, injuries, or property damage.

[68] United States Census Bureau, "QuickFacts: Groton Town, Middlesex County, Massachusetts."

4.7.2 Extreme Heat

The NWS issues a Heat Advisory when the Heat Index (Figure 4-13) is forecast to reach 100-104˚ F for two or more hours.[69] The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach or exceed 105˚F for two or more hours. Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. From 1979-2012, excessive heat exposure caused in excess of 8,000 deaths in the United States.[70] During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

Temperature (°F)																	
Relative Humidity (%)		80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
	40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
	45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
	50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
	55	81	84	86	89	93	97	101	106	112	117	124	130	137			
	60	82	84	88	91	95	100	105	110	116	123	129	137				
	65	82	85	89	93	98	103	108	114	121	128	136					
	70	83	86	90	95	100	105	112	119	126	134						
	75	84	88	92	97	103	109	116	124	132							
	80	84	89	94	100	106	113	121	129								
	85	85	90	96	102	110	117	126	135								
	90	86	91	98	105	113	122	131									
	95	86	93	100	108	117	127										
	100	87	95	103	112	121	132										

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke or Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.

Figure 4-13. Heat Index Chart

(Source: https://www.weather.gov/safety/heat-index)

The Town of Groton does not collect data on heat occurrences. The best available local data are for Middlesex County, through the National Environmental Information Center. NOAA's National Centers for Environmental Information Storm Events Database provides data on excessive heat. Between 1998 and 2019, Middlesex County experienced three extreme heat days, which did not result in injury or property damage. One event did result in a fatality in 2013. Please refer to Table 4-24 for more information.

Table 4-24: Middlesex County Heat Occurrences, 1998-2018

Date	Deaths	Injuries	Damage ($)
7/6/2010*	0	0	0
7/7/2010	0	0	0
7/5/2013	1	0	0
Total	1	0	0

** Excess Heat Occurrences (105°F+)*[71]

[69] Massachusetts Emergency Management Agency (MEMA), "Extreme Heat Safety Tips."

[70] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

[71] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."

Increased temperatures will impact all locations within Groton. Extreme temperatures can create "heat islands" as dark-colored asphalt and roofs store the heat from the sun. Increased temperatures can lead to a longer growing season, which in turn leads to a longer pollen season. Warmer weather can also support the migration of invasive species and lead to an increase in vector-borne diseases. Increasing temperatures can also worsen air pollution, which can lead to negative health impacts such as respiratory problems.

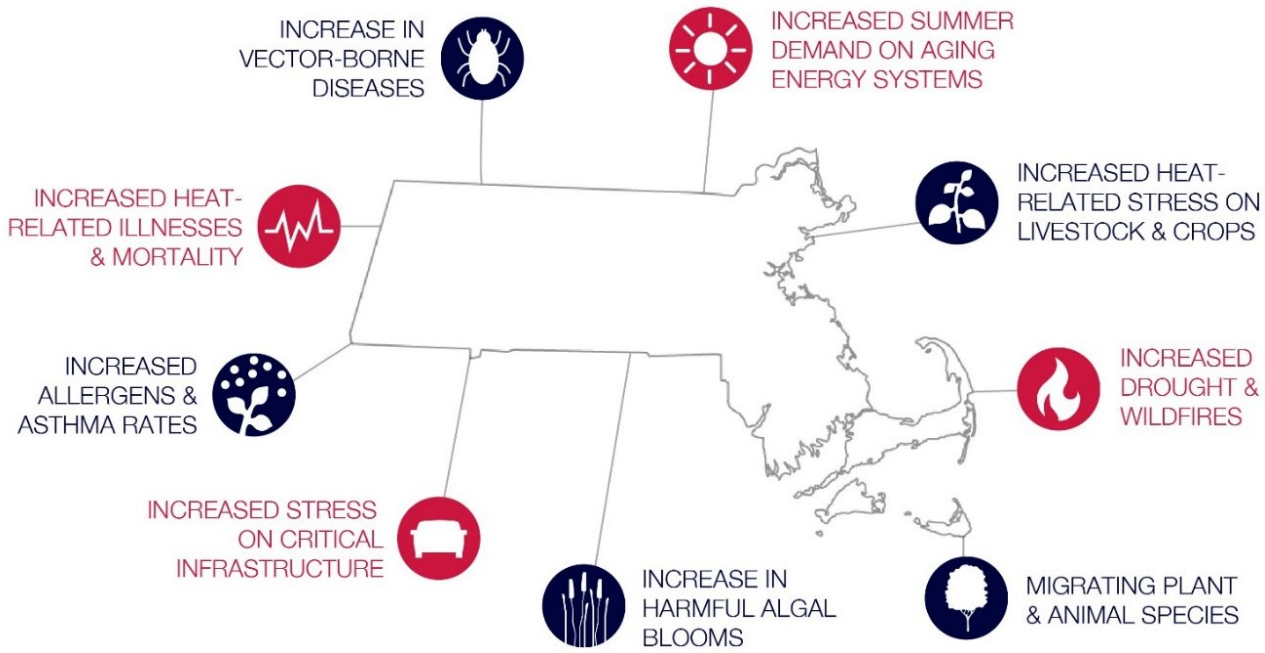


Figure 4-14: Potential Impacts from Increasing Temperatures

According to the Centers for Disease Control and Prevention, the populations most vulnerable to extreme heat impacts include the following:

- People over the age of 65 (e.g., with limited mobility),
- Children under the age of five,
- Individuals with pre-existing medical conditions that impair heat tolerance,
- Low-income individuals who cannot afford proper cooling,
- Residents experiencing homelessness,
- Individuals with respiratory conditions,
- The general public who may overexert themselves during extreme heat events.

On July 6, 2013, a postal worker in MA collapsed and died as the Heat Index reached 100°F.[72] Because most heat-related deaths occur during the summer, people should be aware of who is at greatest risk and what actions can be taken to prevent a heat-related illness or death. The populations at greater risk are the elderly, children, and people with certain medical conditions, such as heart disease. In Groton, children under eighteen years old make up 23.8% of the population, and 13.9% are over 65 years old.[73] However, even young and healthy individuals can succumb to heat if they participate in strenuous

[72] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

[73] United States Census Bureau, "QuickFacts: Groton Town, Middlesex County, Massachusetts."

physical activities during hot weather. Some behaviors also put people at greater risk: drinking alcohol, taking part in strenuous outdoor physical activities in hot weather, and taking medications that impair the body's ability to regulate its temperature or that inhibit perspiration.[74]

Based on Figure 4-15 below, compiled in 2019 by the Massachusetts Department of Public Health Bureau of Environmental Health (BEH), Groton has a population density of 320 per square mile.[75] The total number of population vulnerability measures in each Census Tract (2010) is 2. These population vulnerability measures include low income, low English proficiency, non-white (Hispanic and non-Hispanic ethnicities), and elderly.

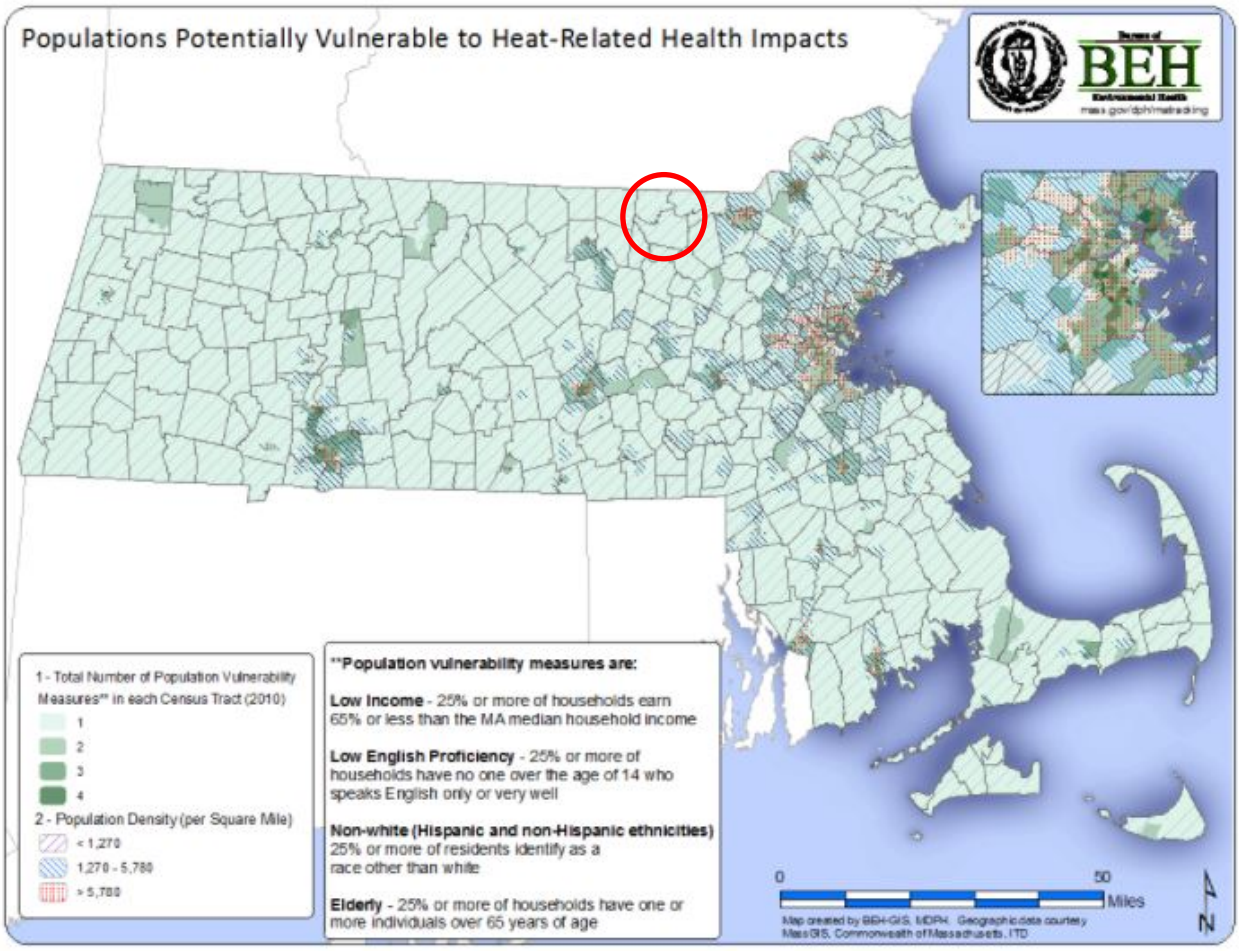


Figure 4-15: Populations Potentially Vulnerable to Heat Related Health Impacts (Groton is outlined in red)
(Image by the Massachusetts Department of Public Health, Bureau of Environmental Health, 2019)

Extreme temperatures are classified as medium frequency events. As defined by the 2013 State Hazard Mitigation Plan, these events occur from once in five years to once in 50 years (or a 2% to 20% probability per year). According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan,

[74] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[75] United States Census Bureau, "2014-2018 American Community Survey. QuickFacts."

between four and five heat waves (3 or more consecutive days of 90˚F+ temperatures) occur annually in Massachusetts.[76]

4.7.3 Climate Change Impacts: Extreme Temperatures

Between 1961 and 1990, Boston experienced an average of one day per year in excess of 100°F. That could increase to six days per year by 2070, and 24 days per year by 2099. Under these conditions by the end of the century, Massachusetts's climate would more closely resemble that of Maryland or the Carolinas (refer to Figure 4-16 below). These changes in temperature would also have a detrimental impact on air quality and public health concerns including asthma and other respiratory conditions.[77]

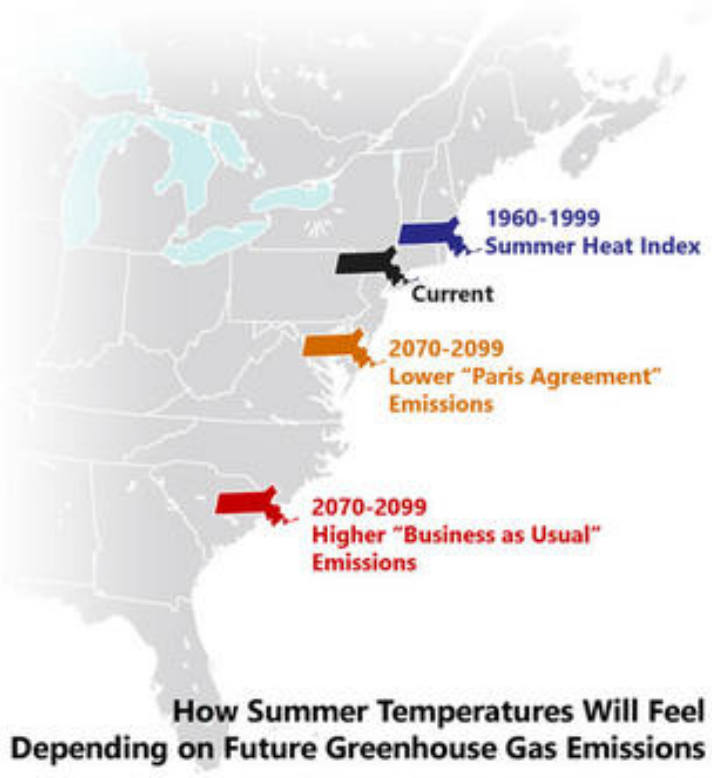


Figure 4-16. Diagram showing Massachusetts' climate change due to increasing temperatures.
Source: MassAudubon

4.8 Drought

Drought is an extended period of deficient precipitation. Drought conditions occur in virtually all climatic zones, yet its characteristics vary significantly from one region to another since it is relative to the normal precipitation in that region. Agriculture, the water supply, aquatic ecosystems, wildlife, and the economy are vulnerable to the impacts of drought.[78]

[76] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[77] Frumhoff et al., "Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions."
[78] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

Although Massachusetts is relatively small, it has a number of distinct regions that experience significantly different weather patterns and react differently to the amounts of precipitation they receive. In accordance with the Massachusetts Drought Management Plan (2019), the Drought Management Task Force will make recommendations to the Secretary of Energy & Environmental Affairs about the location and severity of drought in the Commonwealth. The Drought Management Plan divides the state into seven regions: Western, Central, Connecticut River Valley, Northeast, Southeast, Cape Cod, and Islands Region.[79] Groton is part of the Northeast region.

Five levels of drought have been developed to characterize drought severity: Normal, Advisory, Watch, Warning, and Emergency; these correspond to Level 0 – Normal, Level 1 - Mild Drought, Level 2 - Significant Drought, Level 3 - Critical Drought, and Level 4 - Emergency Drought. The drought levels are based on the severity of drought conditions and their impacts on natural resources and public water supplies.

The Drought Management Plan specifies the agency response and interagency coordination and communication corresponding to the various drought levels. During normal conditions, data are routinely collected and distributed. There is heightened vigilance with additional data collection during an advisory, and increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which use of emergency supplies become necessary or in which the Governor may exercise his authority to require mandatory water restrictions.[80]

A variety of drought indices are available to assess the various impacts of dry conditions. The Commonwealth uses a multi-index system to determine the severity of a drought or extended period of dry conditions. A determination of drought level is based on seven indices: Standardized Precipitation Index, Precipitation (percent of normal), Crop Moisture Index, Keetch-Byram Drought Index (KBDI), Groundwater levels, Stream flow levels, and Index Reservoir levels.

Drought level is determined monthly based on the number of indices which have reached a given drought level. A majority of the indices would need to be triggered in a region in order for a drought designation to move to a more severe level. Drought levels are declared on a regional basis for each of the six regions in Massachusetts. Drought levels may also be made county by county or be watershed-specific. The end of a drought is determined by precipitation and groundwater levels since these have the greatest long-term impact on streamflow, water supply, reservoir levels, soil moisture and potential for forest fires.[81]

[79] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[80] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).
[81] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

Figure 4-17 illustrates statewide drought levels in Massachusetts from 1850 to 2012, using the Standardized Precipitation Index (SPI).

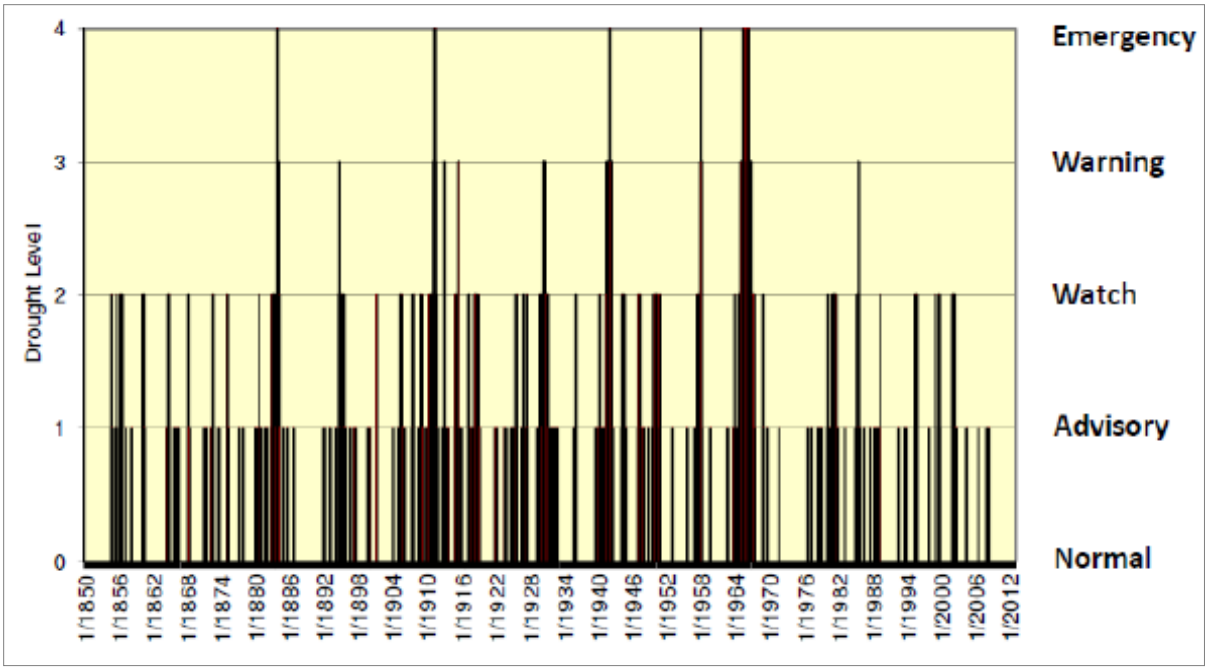


Figure 4-17: Statewide Drought Levels Using SPI Thresholds, 1850 to 2012.

Table 4-25 below summarizes a history of Massachusetts droughts between 1879 and 2017.[82]

Table 4 25. Droughts in Massachusetts Based on Instrumental Records

Date	Area Affected	Recurrence Interval (years)	Remarks
1879 to 1883	–	–	–
1908 to 1912	–	–	–
1929 to 1932	Statewide	10 to >50	Water-supply sources altered in 13 communities. Multistate.
1939 to 1944	Statewide	15 to >50	More severe in eastern and extreme western Massachusetts. Multistate.
1957 to 1959	Statewide	5 to 25	Record low water levels in observation wells, northeastern Massachusetts.
1961 to 1969	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.

[82] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Date	Area Affected	Recurrence Interval (years)	Remarks
1980 to 1983	Statewide	10 to 30	Most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin. Multistate.
1985 to 1988	Housatonic River Basin	25	Duration and severity unknown. Streamflow showed mixed trends elsewhere.
1995	–	–	Based on statewide average precipitation.
1998 to 1999	–	–	Based on statewide average precipitation.
2001 to 2003	Statewide	–	Level 2 drought (out of 4 levels) was reached statewide for several months.
2007 to 2008	Statewide except West and Cape and Islands regions	–	Level 1 drought (out of 4 levels)
2010	Connecticut River Valley, Central and Northeast regions	–	Level 1 drought (out of 4 levels)
2014	Southeast and Cape and Islands regions	–	Level 1 drought (out of 4 levels)
2016-2017	Statewide	–	Level 3 drought (out of 4 levels).

(EEA and EOPSS, 2018)

There are five drought emergencies on record in Massachusetts: 1883, 1911, 1941, 1957, and 1965-1966. The 1965-1966 drought is considered the most severe Massachusetts drought in modern times, given its length. On a monthly basis over the 162-year period of record, there is a one percent chance of being in a Drought Emergency.[83] Drought warning levels not associated with drought emergencies would have occurred in 1894, 1915, 1930,1985, 2016, and 2017. On a monthly basis over the 162-year period of record, there is a two percent chance of being in a drought warning level.[84]

[83] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR).

[84] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR); Massachusetts Department of Conservation and Recreation (DCR), "Recent Drought History."

Drought watches not associated with higher levels of drought generally would have occurred three to four times per decade between 1850 and 1950. The drought emergency declarations dominated the 1960s. There were no drought watches or above in the 1970s. In the 1980s, there was a lengthy drought watch level of precipitation between 1980 and 1981, followed by a drought warning in 1985. A frequency of drought watches at a rate of three years per decade resumed in the 1990s (1995, 1998, 1999). In the 2000s, drought watches occurred in 2001 and 2002. The overall frequency of being in a drought watch is eight percent on a monthly basis over the 162-year period of record.[85] There were six drought watches in Massachusetts in 2002, five drought watches in 2016, and two drought watches in 2017.[86] Figure 4-18 presents an example of drought conditions in the six drought regions.

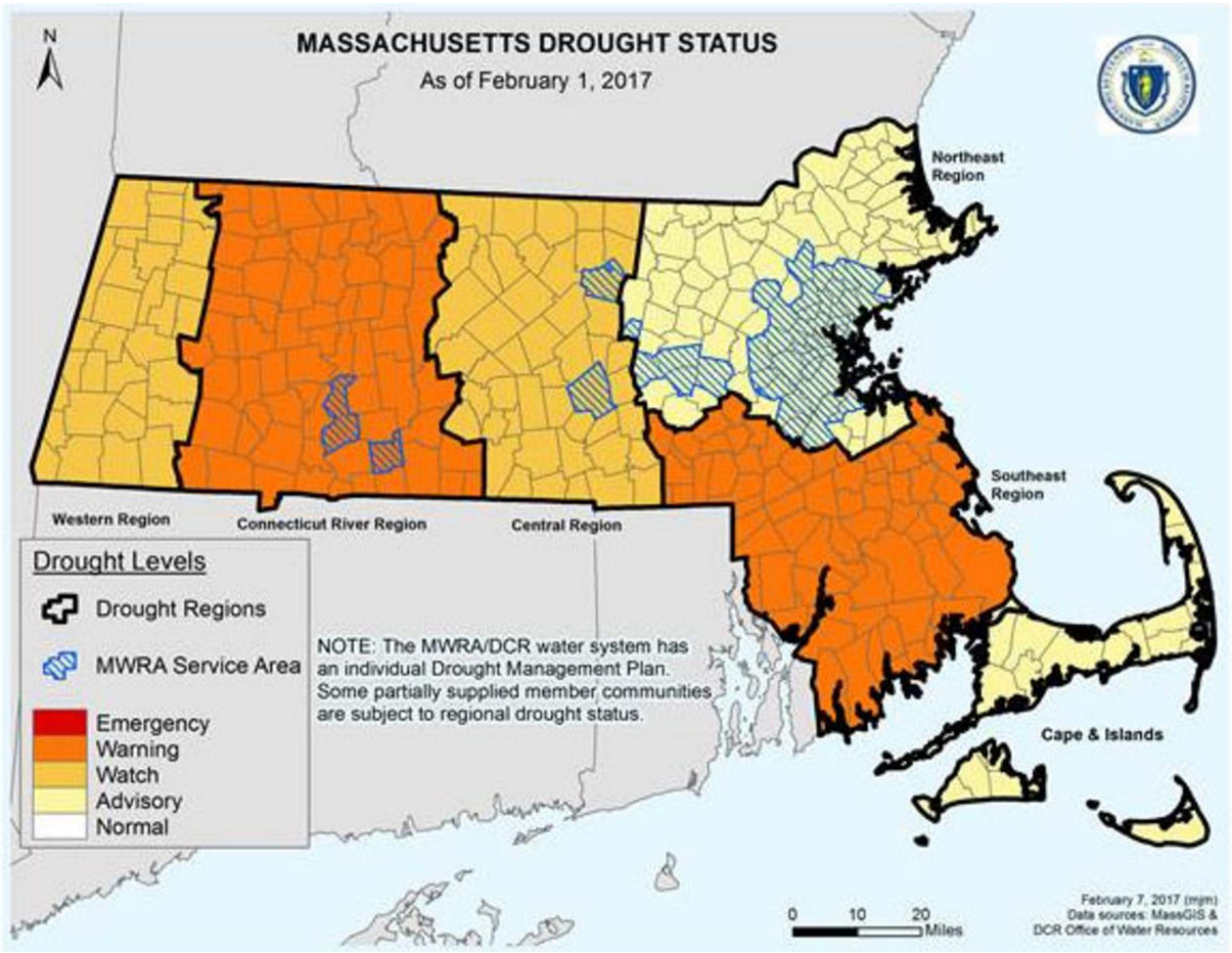


Figure 4-18. Massachusetts Drought Status, February 2017.

Image by the Massachusetts Department of Conservation and Recreation

Drought is a potential town-wide hazard in Groton and is a concern among stakeholders. As noted previously, temperature is projected to increase and may lead to exacerbated drought conditions especially in summer and fall months. Droughts can also increase fire risk: fires can be caused by lightning, and a 2014 study found that the frequency of lightning strikes could increase by more than

[85] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

[86] Massachusetts Department of Conservation and Recreation (DCR), "Recent Drought History."

10% for every degree Celsius of warming.[87] During Groton's MVP Workshop and expert interviews, stakeholders discussed the connections between multiple hazards and their potential impact on the town. One example given was the potential for a severe drought to increase the risk of brush fires. Additionally, the Fire Department explained that drought impacts can cause wear and tear on their equipment, additional expenses, and may require calling in off-duty staff.

A long-term drought could lead to impacts to Groton's water resources. It could also have significant adverse impacts to the Town's water supply in case the ponds dry out due to severe drought. Droughts are classified as a low frequency natural hazard event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, these events can occur between once in 50 years to once in 100 years (a 1% to 2% chance of occurring per year).

4.8.1 Climate Change Impacts: Drought

Under climate change, drought conditions will be exacerbated with projected increasing air temperatures and changes in precipitation. Between 1970 and 2000, the median number of consecutive dry fall days in Massachusetts was 11.4 days. This is in comparison to a projected median of 13.5 consecutive days by the end of the century.[88] The occurrence of droughts lasting one to three months could increase by as much as 75% by the end of the century, under the high emissions scenario.[89]

[87] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."
[88] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MA Climate Change Clearinghouse."
[89] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA) and Adaptation Advisory Committee, "Massachusetts Climate Change Adaptation Report."

5.0 EXISTING MITIGATION MEASURES

The Town of Groton is already taking measures to mitigate local hazards and prepare for climate change. Chapter 5 documents the Town's current operations and discusses potential improvements. FEMA's *Local Mitigation Planning Handbook* categorizes hazard mitigation measures into four types as displayed in Table 5-1 (FEMA, 2013). Groton uses multiple types of mitigation actions to improve the preparedness and resilience of the Town's residents and local features.

Table 5-1. FEMA's Types of Mitigation Actions

Measure	Action	Examples
Local Plans and Regulations	These actions include government authorities, policies, or codes that influence the way land and buildings are developed and built.	• Comprehensive plans • Land use bylaws • Subdivision regulations • Development review • Building codes and enforcement • NFIP Community Rating System • Capital improvement programs • Open space preservation • Stormwater management regulations and master plans
Structure and Infrastructure Projects	These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. This could apply to public or private structures as well as critical facilities and infrastructure. This type of action also involves projects to construct manmade structures to reduce the impact of hazards.	• Acquisitions and elevations of structures in flood prone areas • Utility undergrounding • Structural retrofits. • Floodwalls and retaining walls • Detention and retention structures • Culverts • Safe rooms
Natural Systems Protection	These are actions that minimize damage and losses and preserve or restore the functions of natural systems.	• Sediment and erosion control • Stream corridor restoration • Forest management • Conservation easements • Wetland restoration and preservation
Education and Awareness Programs	These are actions to inform and educate citizens, elected officials, and property owners about hazards and potential ways to mitigate them. A greater understanding and awareness of hazards and risk among local officials, stakeholders, and the public is more likely to lead to direct actions.	• Radio or television spots • Websites with maps and information • Real estate disclosure for properties in the floodplain • Presentations to school groups or neighborhood organizations • Mailings to residents in hazard-prone areas. • Participation in the National Weather Service's StormReady community preparedness program

Measure	Action	Examples
		• Participation in Firewise Communities through the National Fire Protection Association's community preparedness program

(*FEMA*, 2013)

Groton proactively prepares for natural hazards through a range of mitigation measures. The Town's ongoing hazard mitigation and climate adaptation plans are presented in the tables below, which are organized by hazard type. The mitigation actions are presented on the left and possible improvements are presented on the right. These mitigation actions were identified through research, feedback from the Core Team, CRB Workshop participants, and additional stakeholder interviews.

5.1 Existing Multi-Hazard Mitigation Measures

Mitigation Actions	Improvements
Northern Middlesex Regional Emergency Planning Committee – Under the Emergency Planning and Community Right to Know Act of 1986, communities are required to establish Emergency Planning Committees to develop a response plan for chemical emergencies. Groton is a part of Northern Middlesex regional emergency planning committee (REPC), which includes Ashby, Ayer, Dunstable, Harvard, Littleton, Pepperell, Shirley, Townsend, and Westford. In accordance with this legislation, the Town of Groton has identified locations where hazardous materials are stored, used, and transported. This work is led by Groton's local Emergency Planning Committee.[1]	None at this time
Comprehensive Emergency Management Plan (CEMP) Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. This plan addresses mitigation, preparedness, response, and recovery from a variety of natural and man-made emergencies. Included in this plan is important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. The Groton Emergency Management Agency is responsible for updating the Town's CEMP.[2]	Update CEMP
List of Critical Facilities – The list of critical facilities was updated during this planning process.	Maintain an updated list of Critical Facilities
Certified Emergency Response Team (CERT) – A team of trained volunteers organized by the Fire Department who can be called upon to assist and respond during emergencies. Groton does not have a CERT team but may pursue this as a future action.	Expand the volunteer base and introduce CERT program.

[1] Town of Groton, "Local Emergency Planning Committee," 2020, grotonma.gov/government/boards-and-committees/local-emergency-planning-committee/.

[2] Town of Groton, "Emergency Management Agency," accessed June 22, 2020, grotonma.gov/government/boards-and-committees/emergency-management-agency/.

Worcester Regional Medical Reserve Corp – The Worcester Regional MRC is one of 38 Medical Reserve Corps units in Massachusetts. It is a non-profit volunteer run organization that provide medical care, counseling, and other community services after a disaster to communities including Groton.[3]	None at this time
Smart911 – Allows residents to receive emergency notifications and alerts from the Town and create an optional "safety profile" for their household. Residents can sign up for free on the Smart911 website. A link is provided on the Town's website.[4]	None at this time.
Emergency Shelters – The Groton Senior Center is the Town's primary shelter, is ADA accessible, and is equipped with a backup generator. Additional shelters include the Groton Dunstable Regional High School, Groton Dunstable Regional Middle School (North), Florence Roche School, and the Grotonwood Baptist Camp and Conference Center. There is a need to inventory shelter supplies and develop a needs list and storage requirements.	Expand outreach about the location and accessibility of emergency shelters. Develop a shelter plan for residents with pets.
Backup Generators – Most significant municipal buildings have generators. The Water Department needs generators for all water facilities, especially the Baddacook and Whitney Pump Stations, and the Partridgeberry Woods Wastewater Pump Station. The Water Department has one trailer-mount generator that can serve one facility at a time.	Install backup generators at critical facilities, including water and wastewater pump stations.
Permits for Construction – Permits are required from the Building Department to ensure the building code and utility connections are properly made. Permits are also sent to the Water and the Fire Department to inspect certain aspects of all new construction for fire prevention safety.	None at this time
Multi-Department Review of Developments – Depending upon the type of development, extent of construction, and location, multiple departments may review site plans prior to approval. This may include the Planning Board, Building Department, Board of Health, Department of Public Works, Conservation Commission, Water Department, Select Board, Historical Commission, and Zoning Board of Appeals.	None at this time
Massachusetts State Building Code – The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads. The Town of Groton complies with the State building code.	None at this time
Open Space and Recreation Plan (OSRP) 2019 –The Town has a rich history of open space, preservation, and recreational planning. The OSRP was updated in 2019 and aims to protect	Include more specific information on climate change data, anticipated

[3] Medical Reserve Corps of Massachusetts, "Find an MRC Unit," Medical Reserve Corps of Massachusetts, accessed June 22, 2020, mamedicalreservecorps.org/find-an-mrc-unit.

[4] Town of Groton, "Notifications and Alerts," 2020, grotonma.gov/government/notifications-and-alerts/.

open space resources, provide healthy recreational opportunities, and enhance the resilience of Groton's natural environment.	hazard impacts, and recommended action items in the next update of the OSRP.
Zoning Bylaws – Chapter 218 of the Town Code of Bylaws, "Zoning Bylaw of the Town of Groton, Massachusetts," regulates the use, size, height, appearance, location and occupancy of buildings and structures. Zoning can be used as a tool to promote affordable housing, climate resilient facilities, and sustainable development.	The Stormwater Management bylaw was adopted in 2015. Update other applicable zoning bylaws to incorporate climate resilient considerations.
Rules and Regulations for Site Plan Review – The Town's General Bylaw outlines rules and regulations in Division 4: Miscellaneous Regulations, Part 5 Site Plan Review, Article IX Regulations. Special permits are required for construction of large residential, commercial, institutional, municipal, and industrial developments or expansions. The regulations were last updated in 2007.[5]	Update rules and regulations for site plan review with climate change considerations
Communication Infrastructure – The Town communications with residents through social media (including Facebook pages for the Town, Library, Police, and Fire Departments), Town website, email blasts, *The Groton Herald* newspaper, and through the distribution channels of community groups and facilities including the Groton Senior Center.	Continue to explore communication strategies to reach vulnerable populations
Council on Aging Database – the COA works with the Groton Police, Fire, and Emergency Services to maintain a database of vulnerable residents who may require support during a crisis.	Continue to keep this database updated.
GIS – The Town maintains a GIS website through the MapGeo platform, which includes layers related to topography, aerial imagery, zoning, historic districts, land use, resource protection, FEMA flood zones, and residential sales by year.[6]	None at this time.

5.2 Existing Town-Wide Mitigation for Flood Related Hazards

Groton employs a number of practices to help minimize potential flooding, reduce impacts from flooding, and proactively maintain existing drainage infrastructure. Existing Town-wide mitigation measures are described below on the left, and paired with recommended improvements on the right:

Mitigation Actions	Improvements
Participation in the NFIP – Groton participates in the National Flood Insurance Program (NFIP). The NFIP is a Federal program administered by FEMA enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages. NFIP	Work with FEMA to update the Town's Flood Insurance Rate Map (FIRM).

[5] Town of Groton, "Part 5 Site Plan Review," Town of Groton, MA Code, accessed June 22, 2020, https://ecode360.com/9082128.

[6] MapGeo, *Town of Groton, MA*, accessed June 22, 2020, grotonma.mapgeo.io/datasets/properties?abuttersDistance=300&latlng=42.616309%2C-71.576977&panel=themes&zoom=12.

offers flood insurance to communities that comply with the minimum standards for floodplain management. Groton participates in the NFIP with 32 policies in force as of January 28th, 2020.[7] FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website. The Town complies with the NFIP by enforcing floodplain regulations. Groton's Flood Insurance Rate Map (FIRM) was last updated in 2010. NFIP uses a Community Rating System (CRS) to award communities that go beyond the minimum standards with lower flood insurance premiums for property owners. The incentives are awarded upon a credit system for various activities. Points are awarded to communities that prepare, adopt, implement, and update a comprehensive flood hazard mitigation plan using a standard planning process. As of May 2019, Groton is not currently participating in the CRS Program.[8]	
FEMA FIRMS – Flood Insurance Rate Maps (FIRM) denote areas of the 100- and 500-year floodplains, which are used for the NFIP and other regulatory controls. For example, the Building Inspector and the Groton Conservation Commission enforce a federal law requiring elevation above the 100-year flood level of new and substantially improved residential structures in the floodplain. The floodplains are also used in wetland protection and floodplain control regulation. The FEMA FIRMS were last updated in 2010.	Work with FEMA to update the Town's Flood Insurance Rate Map (FIRM). Then, update regulations referencing the 2010 map. Consider requiring regulatory controls out to the 500-year floodplain to account for climate change.
Street Sweeping – The purpose of street sweeping is to limit sediment and other fine particulates on impervious surfaces from entering catch basins and to remove and prevent the accumulation of sediment along road and driveway edges. Sweeping is done on all roads with curbs and sidewalks at least once a year during the spring.	Evaluate any additional staffing needs.
Stormwater System Maintenance – Maintenance is done regularly. The regulations were substantially overhauled in 2015. The Earth Removal Stormwater Committee is responsible for stormwater permitting and enforcement. The Conservation Commission also has a role under the Wetlands Protection Act.	None at this time.

[7] Massachusetts Department of Conservation and Recreation (DCR), "Community Information System: Repetitive Loss for the Town of Groton," September 12, 2019.

[8] Federal Emergency Management Agency (FEMA), "Appendix F: Community Rating System," 2019.

NPDES Phase II Stormwater Program or Municipal Separate Storm Sewer System (MS4) Permit– The Town continues to implement NPDES stormwater program that includes measures for public education and outreach, illicit discharge detection and elimination, construction and post-construction controls, and Town-wide good housekeeping and stormwater maintenance procedures. The Town continues to implement its NPDES Phase II stormwater program, which includes public education programs. The Town also has a Stormwater Management Plan as part of their Small Municipal Separate Storm Sewer Systems (MS4) permit.	None at this time.
Massachusetts Stormwater Management Standards and Handbook – Massachusetts administers stormwater standards through provisions of the Wetlands Protection regulations, 310 CMR 10.00 for wetland notices of intent and surface water discharge permits. The Conservation Commission regulates this at the local level. The Massachusetts Stormwater Handbook provide guidance on how to meet the regulations and manage stormwater pollution and is being currently updated by MassDEP.	None at this time
Stormwater Management — Low-Impact Development – Chapter 198 "Stormwater Management – Low impact Development" is included under the Town's General Bylaw. The chapter aims to protect public health through minimum requirements to control the adverse effects of increased post-development stormwater runoff and nonpoint source pollution.	Last update was done in 2006. Update the bylaw with climate resilient considerations and encourage nature-bases stormwater controls.
Floodplain Overlay District (FOD) – The Town's Floodplain District (Article II of the Zoning Bylaws) is defined by the 100-year floodplain as designated by FEMA in Groton's 2010 FIRM. The Floodplain Overlay District regulates certain activities within a flood zone enhancing federal/state laws.	Update the Floodplain Overlay District if the FEMA FIRM is updated. Consider increasing the FOD to include the 500-year floodplain, in preparation for anticipated climate change impacts.
Massachusetts Wetlands Protection Act and Local Wetlands Protection – The Commonwealths' Wetlands Protection Act (Chapter 131, Section 40 MGL) regulates the protection of resource areas in and around wetlands, including land subject to flooding. This regulates development and activity within a 100-foot buffer around wetlands, and a 200-foot buffer around riverfront areas. The Wetlands Protection Act is locally enforced by the Conservation Commission. The Town further regulates wetlands through the Town Wetlands Protection Regulations (Chapter 215). The last update was amended in 2015.	Update the local Wetlands Protection Regulations with climate change resiliency language
Community Outreach and Education – The Senior Center communicates with its community through their newsletter, Facebook page, meetings, and presentations at the Senior Center. The Police also work with the Senior Center to reach elderly residents The Town communicates with residents through a variety of means, including online, through social media.	More efficient outreach and education program needed for the vulnerable populations.

Emergency Collaboration – The Water Department currently has emergency interconnection with the Town of Westford through Mutual Aid Agreement.	None at this time.

5.3 Existing Dam Mitigation Measures

There are four dams in Groton. Two are privately owned and are classified as low hazard dams, and two are owned by the Town and classified as high hazard dams. Flood mitigation measures can help mitigate potential flooding caused by dams overtopping. More information is available in Chapter 4.

Mitigation Actions	Improvements
Dam Maintenance – The Department of Public Works manages regular dam maintenance.	Inspect and complete regular dam maintenance.
DCR Dam Safety Regulations and Inspections – All jurisdictional dams are subject to the Division of Conservation and Recreation's dam safety regulations (302 CMR 10.00). The dams must be inspected regularly, and reports filed with the DCR Office of Dam Safety. The Town owns two high hazard dams which are inspected every two to three years. Last inspection was done in 2019.	Ask private dam owners for the most recent emergency action plan and inspection reports.
Permits Required for Construction – State law requires a permit for the construction of any dam.	None at this time

5.4 Existing Town-Wide Mitigation for Wind-Related Hazards

Groton minimizes the impact of high winds through enforcing the Massachusetts Building Code and conducting tree maintenance. Existing Town-wide mitigation measures are described below on the left and recommended improvements are on the right.

Mitigation Actions	Improvements
Massachusetts State Building Code – The Town enforces the Massachusetts State Building Code whose provisions are generally adequate to protect against most wind damage. The code's provisions are the most cost-effective mitigation measures against tornados given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages could be high. Town follows the State Building Code and handles wind-related damages as needed.	None at this time.
Tree Maintenance – Groton Electric Light Department (GELD) has a program to trim and remove hazardous trees that pose a potential threat to the power lines. Emergency tree pruning and the removal of public shade trees is conducted by the Tree Warden.	Develop a tree maintenance plan to balance necessary hazardous tree removal and minimize excessive tree cutting

5.5 Existing Town-Wide Mitigation for Winter-Related Hazards

Groton mitigates and responds to extreme winter weather conditions. Existing Town-wide mitigation measures are described below on the left and paired with recommended improvements on the right.

Mitigation Actions	Improvements
Winter Parking Ban –Town's winter parking ban goes into effect every year on November 15th and continues through April 15th. This ban prohibits overnight parking of motor vehicles on any public way. This parking ban allows the Town to plow and open roads in a more efficient and timely manner. Illegally parked vehicles are ticketed.	None at this time.
Snow and Ice Procedures – The Department of Public Works provides standard snow plowing operations on main arterials, including salting. When a snowstorm begins the Department responds by treating all roads with deicing chemicals. Plowing operations begin when there is an accumulation of 2 to 4 inches of snow on road surfaces. Depending upon the severity of the storm, Town forces are assisted by hired contractors to expedite the process of snow removal.[9]	None at this time.
Sidewalk Policy – the Town maintains the sidewalks in the Town center and the West Groton area. Sidewalks are cleared as soon as possible after roads are plowed.	None at this time.
Fire Hydrants – Fire hydrants are managed by the Groton Water Department. The Department asks residents to clear the snow away from hydrants near their property so that the hydrant will be accessible in the event of an emergency.	Purchase GPS units to aid the Fire Department in locating hydrants under snow drifts.
Fuel Assistance – Available to renters and homeowners meeting income guidelines through the Low-Income Home Energy Assistance Program (LIHEAP). Eligible renters and homeowners can apply for assistance at the Groton Housing Authority.[10]	None at this time

5.6 Existing Town-Wide Mitigation for Drought-Related Hazards

The public drinking water supply is adequate at this time, but the Town is aware of anticipated climate change impacts related to drought. The Town regularly requires water conservation as described below.

Mitigation Actions	Improvements
Water Restriction – The Mandatory Water Conservation Program runs from May 1st through October 1st every year. This include outdoor water use and outdoor watering.[11]	The 2019 OSRP recommended expanding public education around water conservation

[9] Thomas Delaney and Troy Conley, "Town of Groton Department of Public Works Snow & Ice Procedures," 2017, portal.grotonma.gov/storage/Department_of_Public_Works/Snow_Policy_2017.pdf.

[10] Housing and Community Development, "Learn about Low Income Home Energy Assistance Program (LIHEAP)," Mass.gov, accessed June 22, 2020, https://www.mass.gov/service-details/learn-about-low-income-home-energy-assistance-program-liheap.

[11] Lauren Crory, "Mandatory Water Conservation Program," *Groton Water & Sewer Departments* (blog), June 2, 2020, grotonwater.org/2020/06/02/mandatory-water-conservation-program-3/.

5.7 Existing Town-Wide Mitigation for Fire-Related Hazards

Existing Town-wide mitigation measures to respond to fire-related hazards are described below to the left and paired with recommended improvements on the right.

Mitigation actions	Improvements
Open Burning Permits – The Department of Environmental Protection (MassDEP) regulation (310 CMR DEP 7.07) allows open burning from January 15th to May 1st and is to be conducted between 10 am and 4 pm at least 75 feet away from all buildings. Open Burning Permits from the Fire Department can be obtained online through the Town Website.	None at this time.
Prescribed Fire – The Fire Department is working with Conservation Commission to assess options for using prescribed fire for invasive control and grassland restoration. The benefits of prescribed fire have been documented extensively. Prescribed fires can be an alternative to the use of chemicals and can allow forests to regenerate.	Continue to work with the Conservation Commission on this initiative
Public Education – The Fire Department offers public education to vulnerable population through Student Awareness of Fire Safety (SAFE) program. The Police Department also has an ongoing public education program in schools. The REPC participates in the program as required by EPA regulations.	Continue public education efforts and evaluate strategies to better reach vulnerable populations.
Supplies – The Fire Department does not have backup firefighting supplies and does not have a Master List of current supplies.	Develop an inventory of supplies to identify current resources and needs.
Statewide Fire Mobilization Plan – The state has a fire mobilization plan. Groton falls under Northeast Region 1, District 6 (Northern Middlesex). The fire mobilization plan includes plan of actions in case of structure fire, wildfires, arranging ambulances, and details about alarm run cards.	None at this time.
"Senior SAFE" program – Groton received a grant funding for FY 2020 for the Senior SAFE Program (S.A.F.E. and Senior SAFE Awards), which aids in providing fire safety to seniors through the fire department. It also aims to improve safety in senior housing.[12]	Look to secure other grants for continued outreach to vulnerable populations.
Brush Clearing – The Tree Warden works with DPW, GELD, and local volunteers to conduct regular brush clearing. Brush fire is classified as a low frequency event in Town, but increasingly frequent droughts may worsen fire risk.	None at this time

[12] Commonwealth of Massachusetts Executive Office of Public Safety and Security Department of Fire Services, "List of FY 2020 SAFE and Senior SAFE Awards," n.d., 7.

5.8 Existing Town-Wide Mitigation for Extreme Temperature-Related Hazards

Existing Town-wide mitigation measures to respond to extreme temperature-related hazards are described below to the left and paired with recommended improvements to the right.

Mitigation actions	Improvements
Public Shade Trees – The Tree Warden receives funds appropriated by Town Meeting to plant shade trees for the purpose of shading public ways. The Tree Warden's work is supported by the Town's 1974 Scenic Roads bylaw and by a local volunteer organization, The Friends of the Trees.	Strategically plant trees in areas with less tree canopy.

5.9 Existing Town-Wide Mitigation for Geologic Hazards

The Town of Groton does not have any local measures to mitigate geologic hazards but does enforce the Massachusetts State Building Code.

Mitigation actions	Improvements
Massachusetts State Building Code for Seismic Standards – The State Building Code contains a section on designing for earthquake loads (780 CMR 1612.0). Section 1612.1 states that the purpose of these provisions is "to minimize the hazard to life to occupants of all buildings and non-building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake". This section goes on to state that due to the complexity of seismic design, the criteria presented are the minimum considered to be "prudent and economically justified" for the protection of life safety. The code also states that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, is not economically achievable for most buildings. Section 1612.2.5 establishes seismic hazard exposure groups and assigns all buildings to one of these groups according to a Table 1612.2.5. Group II includes buildings which have a substantial public hazard due to occupancy or use and Group III are those buildings having essential facilities which are required for post-earthquake recovery, including fire, rescue and police stations, emergency rooms, power-generating facilities, and communications facilities.	None at this time.

5.10 Existing Town-Wide Climate Mitigation Measures

Climate mitigation measures reduce greenhouse gas emissions through improving energy efficiency, reducing energy usage, investing in renewable energy, and carbon sequestration. Climate mitigation strategies will reduce the intensity of climate change over the next century.

Mitigation actions	Improvements
Groton Electric Light Department (GELD) – Groton is one of the few towns in the State that has its own utility company. It is a municipal utility, owned by the residents of the Town of Groton. GELD offers a free energy audit to customers interested in improving the efficiency of their homes. Customers can also borrow a GELD Watt Meter to assess how much electricity their individual appliances are using, or if one of their appliances is running inefficiently. Twice a year, GELD offers energy-efficient bulbs for $1 each (half their cost) and subsidizes the different in cost. GELD also offers insulator gaskets to be placed behind a resident's slight switch or outlet to prevent heat loss.	CRB Workshop participants recommended offering incentives for energy reduction, exploring peak demand pricing for all residents (the current system is voluntary) and increasing options for GELD to buy energy from solar during peak usage.
Green Communities Program – Groton received the Green Communities Designation in January 2020. As part of this designation, The Town will pledge to decrease municipal energy use and pursue renewable energy development. The Town was awarded $138,830 through this program. As of February 2020, specific projects were to be determined.	Submit project proposal.
Sustainability Commission – the Commission recommends and undertakes initiatives related to energy conservation, including developing a Town Sustainability Plan. The Commission also coordinates sustainable objectives pursued by multiple local groups and conducts public outreach and education.	None at this time.
Complete Streets Funding Program – The MassDOT Complete Streets Funding Program provides technical assistance and construction funding to eligible municipalities. Eligible municipalities must pass a Complete Streets Policy and develop a Prioritization Plan. The Town of Groton adopted the implementation plan and created a multi-disciplinary Complete Streets Committee. Using the grant money, the Town has installed lighted crosswalk signage at almost every crosswalk on Main Street and this has dramatically improved pedestrian safety up and down Main Street.	Continue to implement the Complete Streets Policy to accommodate the full range of users on Groton's roadways, walkways, trails, and transit systems.

5.11 Mitigation Capabilities and Local Capacity for Implementation

Under the Massachusetts system of "Home Rule," the Town of Groton is authorized to adopt and from time to time amend a number of local Bylaws and regulations that support the Town's capabilities to mitigate natural hazards. These include the Zoning Bylaws, Stormwater Bylaws, Site Plan Review Regulations, Wetlands Bylaws. Local Bylaws may be amended to improve the Town's capabilities, and changes to most regulations simply require a public hearing and a vote of the authorized board or commission. The Town of Groton has recognized several existing mitigation measures that require implementation or improvements, and has the capacity based on these Home Rule powers within its local boards and departments to address them. The Town also has the ability to expand on and improve the existing policies and programs listed above.

6.0 STATUS OF MITIGATION MEASURES FROM THE 2015 DRAFT PLAN

6.1 Implementation Progress on the Previous Plan

The Town of Groton has taken steps to integrate findings from the 2015 HMP into the following policy, programs, and plans: the 2019-2026 Town of Groton Open Space and Recreation Plan, and the Annual Town Reports published between 2016 and 2019.

Additionally, Groton Town staff and Core Team members reviewed the mitigation measures identified in Montachusett Region Natural Hazard Mitigation Plan 2015 Update. The Core Team provided information on whether priority mitigation actions had been implemented or deferred since 2015. The deferred measures were evaluated to determine if the measure should be carried forward into the 2020 HMP-MVP Plan. The decision to retain a measure was based on the members' assessment of the continued relevance or effectiveness of the measure in addressing vulnerabilities. Table 6-1 below summarizes the status of these mitigation measures. This information is intended to assist Groton in prioritizing the proposed measures, which will provide guidance on how to best allocate the Town's resources.

Table 6-1. Status of Mitigation Measures from the 2015 HMP

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Work with Neighboring Communities to Establish a Community Emergency Response Team (CERT) to respond to all-natural hazards, thus mitigating any damage more effectively.	Not done yet.	Yes
Identify existing shelters that are earthquake resistant and outside of the floodplain (and dam inundation) areas to ensure that shelters are available to the public during these types of hazards to reduce or eliminate risk to human life.	In progress. The 2020 HMP-MVP Plan includes a hazard map identifying critical infrastructure within the 100- and 500-year floodplains. The 2020 Plan also completed a Hazus risk analysis to assess the potential impact of magnitude 5.0 and 7.0 earthquakes in Groton. More information is included in Chapter 4 and Appendix B.	Yes
Increase awareness by educating property owners regarding actions that they can take to reduce risk to property by hosting an Open House at the Fire Department, develop and distribute an educational pamphlet on Fire Safety and Prevention (SAFE PROGRAM) (SENIOR SAFE) and wildfire prevention.	Completed. Groton participates in the Student Awareness of Fire Safety (SAFE) and Senior SAFE Programs.	No
Increase hazard education and risk awareness to public by collecting, updating, and	In progress. The Town shared information with the public related	Yes

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
disseminating information on Local Radio/TV Stations to educate the public and alert them of emergency information including shelter locations and other instructions related to all-natural hazards	to climate hazards during the MVP Planning process. This is an ongoing action.	
Inventory supplies at existing shelters and develop a needs list and storage requirements to ensure the available of adequate supplies during a natural hazard. Supplies must be adequate to eliminate or reduce risk to human life.	**Not done yet**. There is no current inventory of supplies or needs list.	Yes
Develop a priority list and possibly seek funding through the Hazard Mitigation Grant Program (HMGP) for the replacement of undersized culverts throughout Town to reduce or eliminate flooding risk.	**In progress.** The Town applied for an MVP Action Grant for a Broad Meadow Road Flood Assessment & Mitigation project, which would involve assessing options for culvert upgrades.	Yes
Identify all structures throughout the town that need to be elevated above the Base-Flood elevation. Once identified, educate those property owners regarding options for mitigation.	**Not done yet.** Structures have been identified. Education on flood mitigation options for property owners is still needed.	Yes
Educate property owners regarding options for mitigating their properties from flooding through outreach programs that address measures that residents can take (i.e., installing backflow valves, securing debris, etc.)	**Not done yet.** Please see the above action item.	Yes, will be combined with the above action.
Continue participation in the National Flood Insurance Program to enable property owners to purchase insurance protection against flood losses.	**In progress.** The Town received updated information from DCR related to Groton's NFIP participation as part of conducting the MVP Planning process. Participation in the NFIP is an ongoing action.	Yes
Identify areas with potential for brush fires to track community vulnerability by developing and maintaining a database.	**In progress.** The Town uses GIS as part of this effort. The 2020 HMP-MVP plan also includes a section on Fire-Related Hazards. Please see Chapter 4 for more information.	Yes

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Expand residential parking bans to enable snow removal from all streets.	**Completed.**	No
Identify shelters and publicize locations to reduce or eliminate risk to human life.	**In-progress.** The 2020 HMP-MVP Plan includes an updated list of shelters. This action will be combined with the fourth action listed in this table.	No, this action was also captured in the fourth action listed in this table.
Utilize interactive mapping application prepared by MRPC/CMRPC to update critical infrastructure and simulate real time evacuation scenarios to mitigate hazards to the public.	**In-progress.** The Town updated its critical infrastructure list as part of this planning effort.	Yes
Install "beaver diverters" and water control devices to mitigate flooding caused by beaver dams.	**In-progress.** The Town installs beaver deceivers as needed. This is an ongoing action.	Yes
Implement recommendations regarding natural hazard mitigation in existing planning documents including the master plan, five-year action plan of the open space and recreation plan and the emergency evacuation plan.	**In progress.** Open Space and Recreation Plan was updated in 2019 and includes a section on climate change.	Yes

7.0 HAZARD MITIGATION AND CLIMATE ADAPTATION STRATEGY

7.1 Identification of Hazard Mitigation and Climate Adaptation Strategies

The Town developed a list of priority hazard mitigation and climate adaptation strategies through multi-faceted approach. Strategies were discussed and developed upon review of the:

- Hazard and climate change risk assessment.
- Existing measures and the capacity to mitigate and respond to hazardous events.
- Progress on the previous plan.
- Input from stakeholders.

Stakeholders were engaged through Core Team meetings, the CRB Workshop, expert interviews, and the virtual public listening session. Table 7-1 below represents the Town's priority action items. Each of these action items was analyzed for its estimated cost, timeframe, and implementation responsibility, which informed prioritization. A description of each prioritization category is included below:

General Objective – An overarching aim related to one or several mitigation actions. The general objective may be achieved through a variety or combination of mitigation actions.

Mitigation Action - A brief description of each mitigation measure identified in this plan.

Implementation Responsibility – Most mitigation measures will require a multi-department approach where several Town departments share responsibility. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department. The lead department for each action item is bolded. Some action items may require collaboration with State agencies or private entities. Section 7.2 specifically addresses regional collaboration.

Implementation Time Frame – The time frames represented below are assigned based on the length of time necessary to complete the project. The timeframe is noted in years. The time frames are divided into the categories below.

- >1 year
- 1-3 years
- 3-5 years
- 5-10 years
- 10+ years
- Ongoing

Estimated Implementation Cost – The estimated cost is provided using the breakdown below. All costs are estimates and would need to be updated at the time of design and construction. When applicable, costs have been divided between preliminary assessments and cost of construction.

- $: <$10,000
- $$: $10,000-$100,000
- $$$: $100,000-$250,000
- $$$$: $250,000-$500,000
- $$$$$: $500,000+

Figure 7-1. Priority action items presented during Groton's virtual Public Listening Session Webinar

Potential funding – Sources of funding are identified in Table 7-1 and further summarized in Table 7-2. The "Potential Funding Sources" column in Table 7-1 focuses on projects that would be competitive for each funding source. The Town's General Fund is considered a default potential funding source, unless the Town can pursue additional funding.

While acronyms are used in Table 7-1, the full names of potential funding sources can be found in Table 7-2. An additional description of municipal funding is available in Section 7.3.

Priority – Designation of highest high, high, medium, or low priority was based on overall potential benefits. A Highest High (HH) Priority action is very likely to have political and public support, necessary maintenance can occur following the project, and was emphasized as a priority by stakeholders during the planning process. A High (H) Priority action is very likely to have political and public support, and necessary maintenance can occur following the project. A Medium (M) Priority action may have political and public support and necessary maintenance had potential to occur following the project. A Low (L) Priority action may not have political and public support for implementation or the necessary maintenance support following the project.

As part of a public survey distributed after Groton's virtual listening session, residents were asked how the Town should prioritize climate adaptation and hazard mitigation measures. Most respondents (56%) felt that asset type (infrastructure, buildings, or natural systems) should be considered first, followed by the impact to public safety, and funding. Please see Appendix D for more information about the results of this public survey.

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
Roadways, Bridges, Culverts, Stormwater Drainage	Address flooding and improve drainage on Broadmeadow Road and Route 119.	• DPW	1-3	$$$$	H-H	MVP Action Grant, FEMA BRIC, DER Culvert Replacement Municipal Assistance Grant, 2019 Town Meeting Appropriation
	Develop new regulations to ensure roadways, culverts, bridges, and stormwater infrastructure design consider climate change.	• DPW • Planning	1-3	$	H-H	MVP Action Grant, General Fund
	Upgrade existing culverts and stormwater infrastructure where necessary using future precipitation data. Develop a priority list of undersized culverts.	• DPW	1-3	$$$$	H-H	FEMA BRIC, DER Culvert Replacement Municipal Assistance Grant
	Increase maintenance and drainage ditch cleaning. Update O&M Plan with climate change considerations.	• DPW	1-3	$$	H-H	General Fund
	Elevate roads and bridges to reduce flooding. Bridge design should reduce storm debris collection.	• DPW	5-10	$$$$$	H	FEMA BRIC, Chapter 90 Program, Municipal Small Bridge Program
	Create alternative plans for evacuation routes if flooded.	• DPW	5-10	$$	H	FEMA EMPG, General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	Assess the latest emerging pavement technology to reduce buckling and potholes under new climate trends.	• DPW	1-3	$	L	General Fund
	Continue to install beaver deceivers as needed to mitigate flooding caused by beaver dams.	• DPW	1-3	$$	L	General Fund
	Maintain current plows to facilitate snow removal.	• DPW	1-3	$$	M	General Fund
Water Supply and Distribution	Evaluate water supply demand projections under drought conditions and current supply's ability to meet future needs. Evaluate options for additional storage or emergency supply.	• Water Department • West Groton Water Supply District	1-3	$$$$	H-H	Water Management Act Grant
	Extend water line and increase cisterns in the Lost Lake Neighborhood.	• Water Department	5-10	$$$$	M	DWSRF, General Fund
	Increase access to water in places without hydrants that are also more vulnerable to brushfires.	• Water Department • West Groton Water Supply District	5-10	$$$	H-H	FEMA BRIC
	Develop a water conservation program that may include regulating irrigation systems or developing a water conservation rate pay system.	• Water Department • West Groton Water Supply District	1-3	$	H-H	Water Department
	Increase public education about	• Water Department	1-3	$	H	

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	water restrictions and lawn sprinklers, and health risks related to pollutants of concern.	• **West Groton Water Supply District** • Planning				Water Department, General Fund
	Build a resilient water treatment facility outside of the floodplain with green infrastructure stormwater controls.	• **DPW** • **Water Department**	5-10	$$$$	H	FEMA BRIC
	Assess interbasin wastewater transfers and impact on groundwater levels.	• **DPW** • Sewer Commission	1-3	$$	H	General Fund
	Develop a fertilizer management plan to minimize contaminants that could be spread by floods.	• **Agricultural Commission** • Water Department	1-3	$	L	Section 319 Nonpoint Source Competitive Grants Program, General Fund
	Address PFAS and elevated iron and manganese.	• **DPW**	1-3	$$$$$	H	MA DEP PFAS Treatment Grant, General Fund
Bylaws, Regulations, and Planning	Revise stormwater management regulations and wetland regulations to require or recommend the use of climate data and to encourage stormwater infiltration.	• **DPW** • Planning	1-3	$	H-H	MVP Action Grant, MS4 Municipal Assistance Grant Program, General Fund, EEA Planning Assistance Grant
	Develop and adopt Smart Growth zoning and development regulations. Use Smart Growth policies to provide a range of housing	• **Planning**	1-3	$	H	EEA Planning Assistance Grants, EPA Smart Growth Grant, HUD CDBG, General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	types, including affordable housing.					
	Include climate change considerations and hazard mitigation recommendations in Town planning efforts, including updates of the OSRP and Master Plan.	• **Planning**	1-3	$	H	MVP Action Grant, General Fund
	Assess municipal properties for Low Impact Development or green infrastructure opportunities.	• **Planning** • Conservation Commission • Building	1-3	$$	H-H	MVP Action Grant, General Fund
	Update FEMA FIRM and continue Groton's participation in the NFIP.	• **Planning**	1-3	$	H-H	General Fund
Invasive Species (Emerald Ash Borer, Water Chestnut, stressed natives)	Design standards and management plans that are wildlife friendly and protect at risk species (native and endangered).	• Planning Department • **Conservation Commission**	1-3	$	L	MVP Action Grant, Private Funds, General Fund
	Conduct public education and outreach on emerging threats. Leverage volunteers and work with neighbors, including Pepperell.	• **Health Department** • Conservation Commission • Planning Department	1-3	$	H-H	MVP Action Grant, General Fund
	Assess best practices for invasive plant removal. Consider mechanical strategies, training volunteers, and creating a "Rent a	• Planning Department • **Conservation Commission**	1-3	$	M	General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	Goat" program to remove invasive plants. Conduct outreach to private landowners.					
	Increase measures to control mosquitos and ticks and raise public awareness related to vector-borne diseases. Create a fact sheet, trail signage, and publicize local locations that sell DEET and Permethrin.	• **Health Department**	1-3	$	M	MVP Action Grant, General Fund
Emergency Response Plan	Educate people on the need to sign up for Smart911 and to sign up for the COA database of vulnerable populations.	• **Emergency Management** • Council on Aging	1-3	$	H	General Fund
	Enhance emergency response planning, practice, and maintenance. Coordinate with partners through Mutual Aid Agreements.	• **Emergency Management**	1-3	$	H	FEMA EMPG, General Fund
	Utilize interactive mapping application prepared by MRPC/CMRPC to update critical infrastructure and simulate real time evacuation scenarios to mitigate hazards to the public.	• **Emergency Management** • Planning	1-3	$	H	General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	Create an Emergency Action Plan for local farms and livestock.	• **Agricultural Commission** • Emergency Management	1-3	$	L	General Fund
	Recruit and train volunteers for the CERT program, Fire Department, and emergency shelter staffing.	• **Emergency Management**	1-3	$$	H	Citizen Corps Program, FEMA BRIC, EMPG, General Fund
	Provide pet-friendly shelters with specialized equipment, including cages and carriers.	• **Emergency Management**	1-3	$$	L	EMPG, General Fund
	Increase shelter space. Consider the new Elementary School as an option.	• **Emergency Management** • Planning • Health Department	1-3	$$	M	General Fund
	Review shelters for needed facility updates, including storage needs. Storage may be available at the Indian Hill Music Center.	• **Emergency Management**	1-3	$	H	EMPG, General Fund
	Inventory shelter supplies and develop a needs list.	• **Emergency Management**	1-3	$	H	EMPG, General Fund
	Improve communication related to shelter locations and availability, evacuation plan, and accessibility to resources.	• **Emergency Management** • Health Department • Planning	1-3	$	M	General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
Schools	Develop or coordinate emergency response plans with public and private schools.	• **Emergency Management** • Planning • Groton-Dunstable Regional School Committee • Groton School • Lawrence Academy	1-3	$	M	FEMA EMPG, General Fund
	Install air conditioners in parts of the schools, for example in the gyms.	• **Public Schools**	1-3	$$	H	General Fund
	Develop climate change curriculum, including information on green infrastructure and water conservation.	• Groton-Dunstable Regional School Committee • Groton School • Lawrence Academy	1-3	$	M	General Fund
Electric Grid/Energy	Identify priority locations (critical facilities and town property/buildings) for solar and battery backup.	• DPW • **GELD**	3-5	Study - $$ Construction - $$$$$	H	Green Communities Designation & Grant Program, MVP Action Grant
	Relocate power lines underground during the construction of new roads or infrastructure.	• DPW • **GELD**	3-5	$$$$	H	General Fund
	Incentivize energy efficiency and explore peak demand pricing.	• **GELD**	1-3	$$	H	General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	Expand GELD's renewable energy portfolio. Purchase eight megawatt storage batteries for power.	• GELD	1-3	$$	H	Green Communities Designation & Grant Program, General Fund
	Install seamless switch for generators during peak hours to promote energy saving and reduce demand.	• GELD	5-10	$$$	L	General Fund
Wastewater	Conduct educational outreach on sewer best management practices including what not to flush.	• DPW • Sewer Commission	1-3	$	H	General Fund
	Assess options for an onsite wastewater management system or program.	• Sewer Commission • DPW	5-10	$	H	General Fund
Communication	Improve cell coverage.	• Cell phone companies	3-5	$$$	H	Private Funds, General Fund
Dams	Pursue funding for dam removal. Coordinate with Shirley. Remove Rivercourt Dam when funding is available.	• DPW • Conservation Commission	1-3	$	H	EEA Dam and Seawall Repair or Removal Program, MET, DER Priority Projects
	Increase public outreach and education on dam safety.	• DPW • Conservation Commission	1-3	$	H	EEA Dam and Seawall Repair or Removal Program, MET, DER Priority Projects
Public Transit	Create a carpooling platform and more sidewalks to decreases car usage.	• Planning • Complete Streets Committee	1-3	$$$	M	General Fund
	Install electric charging stations and prepare	• Planning • Sustainability Commission	3-5	$$$	M	Mass EVIP Fleets Incentives Funding

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	regulations for electric vehicles.					
	Offer a bus service connection from Lowell to the Indian Hill Music Center.	• Planning • LRTA	5-10	$$$	L	Private Funds, LRTA
	Increase parking spaces at the Ayer commuter rail for more access to commuter rail.	• Planning • Ayer • MBTA	3-5	$$$	M	MBTA
Open Space and Forested Land	Develop a fire prevention and vegetation management plan to include controlled burns, cleaning debris, and creating a wood bank of recently downed trees.	• Fire Department • Conservation Commission • DPW • Town Forest Committee	1-3	$	H	General Fund
	Identify critical land around reserves and assess options for easements or land acquisition.	• Conservation Commission • Planning	5-10	Study - $ Land acquisition - $$$	M	Community Forest Grant program, LAND Grant Program, MA Land & Water Conservation Fund Grant Program
	Create detailed trail signage and conduct public education about staying safe on trails.	• Trails Committee • Planning • Emergency Management	1-3	$$	H	MassTrails Grant, MA Land & Water Conservation Fund Grant Program
	Work with volunteers to maintain open space and trails. Partners with schools and universities.	• Trails Committee • Conservation Commission • Planning	1-3	$$	M	Nonprofit Funding, General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
Wetlands	Pursue land acquisition to protect wetlands from encroachment.	• **Conservation Commission** • Planning	3-5	$$$	H	LAND Grant Program, MVP Action Grant
	Increase groundwater infiltration near wetlands.	• Planning • **Conservation Commission** • DPW	3-5	$$	M	DWSP
Land Use and Development	Educate homeowners on fire safety.	• **Conservation Commission**	1-3	$	H	Senior SAFE, General Fund
	Develop and maintain a database of areas at high fire risk.	• **Fire Department**	1-3	$	H	General Fund
	Create a resiliency plan specific to the Lost Lake neighborhood.	• **Emergency Management** • Planning	1-3	$	M	General Fund
	Conduct outreach to residents in the 100-year floodplain regarding options for flood mitigation.	• **Emergency Management** • **Planning**	1-3	$	M	General Fund
Agriculture	Reduce the use of pesticides/ herbicides/ insecticides, especially on farms near river.	• **Conservation Commission** • **Agricultural Commission**	5-10	$	M	Section 319 Nonpoint Source Competitive Grants Program
	Follow best management practices for long-term planning and diversification.	• Conservation Commission • **Agricultural Commission**	5-10	$	M	General Fund
Vulnerable Residents	Migration/Climate Refugees: scale emergency services as population increases.	• **Emergency Management** • Planning	10+	$	L	General Fund

Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions

General Objective	Mitigation Action	Implementation Responsibility	Time Frame (years)	Cost	Priority	Potential Funding Sources
	Equip all assisted living facilities with air conditioning.	• Council on Aging	1-3	$$	M	General Fund HUD CDBG
	Assist seniors with snow removal.	• Council on Aging • DPW	1-3	$	M	General Fund
	Seven Hills Hospital and Group Home: ensure open communication and coordination with town.	• Health Department • Seven Hill Management • Emergency Management	1-3	$	L	General Fund
Contaminated Sites	Cut trees growing on site at Nod Landfill and cap the landfill adequately because it is located on floodplain.	• Conservation Commission • DPW	5-10	$$$$$	L	EPA Brownfields Grant, Massfields Brownfields Fund
	Continue ongoing remediation with Conductor Lab.	• Conservation Commission • Planning	5-10	$$$$	L	EPA Brownfields Grant, Massfields Brownfields Fund

7.2 Regional Partnerships

Mitigating natural hazards is not confined to a local issue. The systems that serve these communities are often complex systems of storm drains, roadway infrastructure, pump stations, dams, and other facilities owned and operated by a wide variety of agencies, including Massachusetts Department of Transportation (MassDOT), Massachusetts Emergency Management Association (MEMA), and the Department of Conservation and Recreation (DCR). The planning, construction, operation, and maintenance of these structures are integral to the hazard mitigation and climate adaptation efforts of communities. These agencies also operate with the same budgetary and staffing constraints as communities. Similarly to municipalities, they must make decisions about numerous competing priorities. In order to implement many of these mitigation measures, all parties will need to work together towards a mutually beneficial solution. Groton will continue collaborating with neighboring Towns to mitigate natural hazards and prepare for extreme events.

7.3 Potential Funding Sources

The identification of funding sources is preliminary and may vary depending on numerous factors. These factors include, but are not limited to, if a mitigation measure is conceptual or has been studied, evaluated, or designed. In most cases, the measure will require a combination of funding sources. The funding sources identified are not a guarantee that a specific project will be eligible for, or receive, funding. Upon adoption of this plan, the local representatives responsible for implementation should begin to explore potential funding sources in more detail.

Traditional funding sources within the Town of Groton, such as funding from the operating and capital budgets, may be able to cover some of the costs associated with the action items detailed in Table 7-1. State revolving funds and other no- or low-interest loans may also be of interest. There is a great variety of funding available for Massachusetts municipalities, both through the state and federal governments. A full list of funding opportunities can be found on the Community Grant Finder webpage. The Community Grant finder provides a streamlined interface where municipalities can easily learn about grant opportunities.

Table 7-1 in the previous section identifies potential funding sources for each action item. However, combining several action items into a single grant proposal may make an application more competitive, depending on the grant's criteria. Therefore, Table 7-2 below outlines more information on potential funding sources, to assist the Town in matching grants with appropriate project types.

Table 7-2: Potential Funding Sources

Category	*Grant*	*Description*	*Limitations & Stipulations*
Community Development	MassWorks Infrastructure Program	Provides grants for public infrastructure projects that support and accelerate housing production, spur private development, and create jobs	None
Community Development	HUD Community Development Block Grant Programs (CDBG)	To develop viable urban communities by providing decent housing and a suitable living environment, and expanding economic opportunities.	None.
Emergency Management and Planning	FEMA Flood Mitigation Assistance Grant Program (FMA)	Implement cost-effective measures that reduce or eliminate the long-term risk of flood damage	For buildings and other structures insured under the National Flood Insurance Program (NFIP).
Emergency Management and Planning	FEMA Hazard Mitigation Grant Program (HMGP)	Provides funding after a disaster to significantly reduce or permanently eliminate future risk to lives and property from natural hazards	Available after a presidentially declared disaster
Emergency Management and Planning	FEMA Building Resilient Infrastructure & Communities (BRIC)	Provides funds for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event, with a focus on infrastructure	None

Table 7-2: Potential Funding Sources

Category	*Grant*	*Description*	*Limitations & Stipulations*
		projects and "community lifelines." Replaced FEMA's Pre-Disaster Mitigation (PDM) Program.	
Emergency Management and Planning	MEMA Citizen Corps Program (CCP) Grant	Supports local Community Emergency Response Teams (CERT) and Volunteers in Police Service (VIPS) in preparing for all-hazards. Can be used for planning activities, equipment, training, and exercises.	Reimbursement-based grant program
Emergency Management and Planning	Emergency Management Performance Grant (EMPG)	Supports local emergency management agencies in implementing the National Preparedness System and national Preparedness Goal of a secure and resilient nation. Funds projects related to logistics/distribution management planning, evacuation plan/annex, disaster financial management, catastrophic disaster housing, resilient communities, and implementing community lifelines.	Reimbursable
Emergency Management and Planning	FEMA Public Assistance (PA) Program	FEMA reimburses government agencies and nonprofits for disaster response and recovery costs, including debris removal, emergency protective measures, and repair of publicly owned facilities.	75% reimbursable, after a disaster declaration
Energy	MA DOER Green Communities Designation and Grant Program	The designation allows communities to access grants for clean, affordable, and resilient energy projects	Municipalities must pledge to cut municipal energy use by 20% over 5 years and meet four other criteria
Energy	MA Electric Vehicle Incentive Program (MassEVIP) Fleets Incentives	Helps public entities acquire electric vehicles and install charging stations for their fleets	None.
Environment	EPA Smart Growth Grants	Support activities that improve the quality of development and protect human health and the environment.	Grants are only offered occasionally
Environment	Water Management Act Grant	Funds planning projects to identify implementation actions to improve ecological conditions, conservation	80% reimbursement rate

Table 7-2: Potential Funding Sources

Category	Grant	Description	Limitations & Stipulations
		projects and drought resiliency planning, and withdrawal mitigation projects that increase porosity and water quality.	
Environment	US Forest Service Community Forest Grant Program	Funding to acquire private forest land threatened by conversion and establish community forests	Private forest lands, Forest lands, and Full Fee Purchases are eligible, as defined by the CFP
Environment	MA DER Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value	Projects must meet the goals of the MA Stream Crossing Standards
Environment	Federal Clean Water Act, 604b Grant Program: Water Quality Management Planning	Funds nonpoint source assessment and planning projects, including projects related to green infrastructure	None
Environment	Federal Clean Water Act, Section 319 Nonpoint Source (NPS) Competitive Grants Program	Implementation projects that address the prevention, control, and abatement of NPS pollution.	Must address activities identified in the MA NPS Management Plan
Environment	MassDEP Water Quality Monitoring Grant Program	Enhance MassDEP surface water quality assessment data by building or expanding capacity for bacteria monitoring data collection.	Non-profit organizations must apply
Environment	EEA Planning Assistance Grants	Funds zoning for sustainable housing production, regulations that reduce energy use and GHG emissions, and zoning that results in permanent land conservation.	None.
Environment	Local Acquisitions for Natural Diversity (LAND) Grant Program	Helps cities and towns acquire land for conservation and passive recreation	Reimbursement rate: 52-70%
Environment	Massachusetts Land and Water Conservation Fund Grant Program	Funding for the acquisition, development, creation and/or renovation of parks, trails, and conservation areas.	Municipality must have an up-to-date OSRP
Environment	Municipal Vulnerability Preparedness (MVP) Action Grant	Provides support to implement climate change resiliency priority projects. Project types include planning,	None

Table 7-2: Potential Funding Sources

Category	Grant	Description	Limitations & Stipulations
		assessment and regulatory updates; nature-based solutions; and resilient redesigns and retrofits for critical facilities and infrastructure.	
Environment	MassDEP Restoration Grants	Funding for restoration projects. Opportunities are announced as settlement funds become available.	None
Environment	MS4 Municipal Assistance Grant Program	Funds community efforts to meet the requirements of the 2016 MS4 permit and reduce stormwater pollution through partnerships	Two or more municipalities subject to the 2016 Small MS4 General Permit must apply together
Environment	EEA Dam and Seawall Repair or Removal Program	Intended to promote public health, public safety, and ecological restoration.	None
Environment	Massachusetts Environmental Trust (MET)	Grants to support projects that protect and restore natural resources, including dam removal.	None
Environment	DER Priority Projects	Funds cranberry bog wetland restoration, streamflow restoration, and urban stream revitalization projects.	Projects can include dam removal, but not as a standalone project.
Environment	EPA Drinking Water State Revolving fund (DWSRF)	A federal-state partnership to help ensure safe drinking water and provide financial support to water systems.	Six categories of projects are eligible
Environment	MA DEP PFAS Treatment Grant	Supports designs for treatment of drinking water in PFAS-impacted communities.	Future grant rounds may be offered, contingent upon the availability of funding.
Environment	Drinking Water Supply Protection (DWSP) Grant Program	Financial assistance for protection of existing DEP-approved public drinking water supplies, protection of planned future public drinking water supplies, and protection of planned future public drinking water supplies.	50% reimbursement rate.
Environment	EPA Brownfields Grant Funding Program	Funding for brownfields assessment, cleanup, revolving loans, environmental job training, technical assistance, training, and research.	None.
Environment	MassDevelopment Brownfields Redevelopment Fund	Finances the environmental assessment and remediation of brownfield sites in Economically	None.

Table 7-2: Potential Funding Sources

Category	*Grant*	*Description*	*Limitations & Stipulations*
		Distressed Areas (EDAs) of the Commonwealth.	
Environment	Parkland Acquisitions and Renovations for Communities (PARC) Grant Program	Assists municipalities in acquiring and developing land for park and outdoor recreation purposes. Can be used to acquire parkland, build a new park, or renovate an existing park.	52-70% reimbursement rate.
Environment	MassTrails Grants	Grants to design, create, and maintain the diverse network of trails, trail systems, and trails experiences.	None.
Environment	National Fish and Wildlife Foundation Grants	Provides funding to projects that sustain, restore, and enhance the nation's fish, wildlife, plants, and habitats.	Grants are available to support actions identified in the NFWF initiative's business plan
Public Safety	Senior SAFE	Supports fire and life safety education for seniors	None
Public Safety	Student Awareness of Fire Education (S.A.F.E.)	Grants for local fire departments to teach fire and life safety to schools	None
Public Works and Transportation	Chapter 90 Program	Reimbursable grants for capital improvements such as highway construction, preservation and improvement projects that extend the life of capital facilities.	None
Public Works and Transportation	Community Transit Grant Program	Funding to meet the transportation and mobility needs of seniors and people with disabilities	Depends on project type
Public Works and Transportation	Complete Streets Funding Program	Technical assistance for creating a Complete Streets Prioritization Plan and construction funding for implementation	Eligible communities must pass a Complete Streets Policy and develop a Prioritization Plan
Public Works and Transportation	Municipal Small Bridge Program	Funding for small bridge replacement, preservation, and rehab projects	Bridges with spans between 10' and 20'

8.0 PLAN ADOPTION AND MAINTENANCE

8.1 Plan Adoption

The Town of Groton 2020 HMP-MVP Plan was adopted by the Select Board on December 24, 2020. See Appendix E for documentation. The plan was approved by FEMA on January 4, 2021 for a five-year period that will expire on December 30, 2025. See Appendix F for documentation.

8.2 Plan Implementation

The Core Team will use Table 7-1 indicating the time frame, responsible party and priority as an implementation plan for taking action to mitigate hazards and improve the Town's climate resilience. Table 7-2 layouts out various grant and funding mechanisms for the Core Team. The Core Team will be held accountable through the tracking mechanisms explained in the following sections. The HMP-MVP Plan will also inform future planning and budgeting processes.

8.3 Plan Maintenance

8.3.1 Tracking Progress and Updates

FEMA's initial approval of this plan is valid for five years. During that time, the Town will need to continue to track progress, document hazards, and identify future mitigation efforts. This can be achieved through a combination of two methods:

1. Meetings: The Core Team, coordinated by Town Planner, Takashi Tada, will meet once a year during regularly scheduled leadership meetings to monitor plan implementation. The Core Team will be amended as needed but will include representatives from the Department of Public Works, Police Department, Fire Department, Conservation Commission, and others. These meetings will provide an opportunity for identifying funding and implementation opportunities, capital planning needs related to hazard mitigation, and progress.

2. Surveys: The coordinator of Core Team, Takashi Tada, will also prepare and distribute a survey every two years. The survey will be made available to all Core Team members and any other interested local stakeholders. The questions in the survey will reference the tables of existing and proposed action items listed in the HMP-MVP Plan. The survey will assist in determining any necessary changes or revisions to the plan that may be needed. In addition, it will provide written documentation of status updates, accomplishments, and progress related to the action items listed in the HMP-MVP Plan. The surveys will also help document new hazards or problem areas that have been identified since the 2020 Plan. The information collected through the survey will be used to formulate an update and/or addendum to the plan.

8.3.2 Continuing Public Participation

The adopted plan will be posted on the Town's website. The posting of the plan on the Town's web site will provide a mechanism for citizen feedback, such as an e-mail address for interested parties to send comments. The Town will encourage local participation whenever possible during the next five-year planning and implementation cycle. The Core Team will incorporate engagement into the implementation of the priority action items. All updates to the plan, including implementation

progress, will be placed on the Town's website. All public meetings related to the HMP-MVP Plan will be publicly noticed in accordance with Town and State open meeting laws.

8.3.3 Integration of the Plans with Other Planning Initiatives

Upon approval of the Town of Groton 2020 HMP-MVP Plan by FEMA, the Core Team will make the plan available to all interested parties and all departments with an implementation responsibility. The group will initiate a discussion with those various departments regarding how the plan can be integrated into their ongoing work. At a minimum, the plan will be reviewed and discussed with the following departments:

- Conservation Commission
- Fire Department
- Police Department
- Department of Public Works
- Earth Removal Stormwater Advisory Committee
- Planning Board
- Groton Electric Light

Appropriate sections of the HMP-MVP Plan will be integrated into other plans, policies, and documents as those are updated and renewed, including the writing of, or updates to, the Town's Master Plan, Open Space and Recreation Plan, and Comprehensive Emergency Management Plan. Coordination with the Montachusett Regional Planning Commission, local organizations, businesses, watershed groups, and state agencies will be required for successful implementation and continued updating.

8.4 Process of Updating

By maintaining the Town of Groton 2020 HMP-MVP Plan, the Town will have a competitive application when applying to FEMA for funding to update the plan. Once the resources have been secured to update the plan, the Core Team will need to determine whether to undertake the update itself or hire a consultant. If the Core Team decides to update the plan itself, the group will need to review the current FEMA hazard mitigation plan guidelines for any change in the requirements. The update to the Town of Groton 2020 HMP-MVP Plan will be forwarded to MEMA for review and to FEMA for ultimate approval. The Core Team will begin drafting the full update of the plan in four years. This will help the Town avoid a lapse in its approved plan status and grant eligibility when the current plan expires at the end of year five.

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