TOWN OF TEWKSBURY

HAZARD MITIGATION PLAN (HMP) AND 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. Within the communities of Middlesex County, hazard mitigation planning tends to focus on flooding, which is the most likely natural hazard to impact these communities. The Federal Disaster Mitigation Act of 2000 requires all municipalities to adopt a local multi-hazard mitigation plan (HMP) and update their plan every five years in order to be eligible for FEMA funding for hazard mitigation grants.

The Massachusetts Executive Office of Energy and Environmental Affairs' Municipal Vulnerability Preparedness (MVP) grant program helps communities plan and take action towards becoming more resilient to the impacts of climate change. The program provides MVP Planning Grants to assist municipalities in preparing for the impacts of climate change through participation in a Community Resilience Building (CRB) Workshop and development of a climate change action plan. MVP Action Grants are available to communities that complete the planning process to fund the implementation of priority climate change adaptation actions identified in their final report.

The Town of Tewksbury completed a planning process to fulfill the requirement for both a hazard mitigation plan as well as an MVP planning grant. This approach recognizes that climate change will exacerbate the vulnerabilities and risks associated with natural hazards and provides a robust assessment and implementation plan to build the Town's resilience.

Planning Process

Planning for the Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) was led by Tewksbury's Municipal Vulnerability Preparedness/Hazard Mitigation Core Team ("Core Team"). This Core Team was composed of staff from a number of different Town Departments. The Core Team met on November 4, 2019 and February 19, 2020. Additionally, a Project Kickoff Meeting was held on October 21, 2019 and the CRB Workshop was held on January 22, 2020. During these meetings, the group planned for the CRB Workshop, reviewed public comments, discussed where the impacts of natural hazards most affect the Town, endorsed goals for addressing these impacts, developed the mitigation plan, and transitioned towards implementation of the plan's mitigation strategies.

The Town conducted a virtual webinar in place of an in-person public Listening Session. Additionally, the draft plan was posted on the Town's website for public review between the dates of April 7th and April 24th. Key Town stakeholders, public residents, and neighboring communities were notified of the video and invited to submit comments on the draft plan via an online survey.

Risk Assessment

The Tewksbury HMP-MVP Plan assesses the potential impacts to the Town from a variety of natural disasters.

- Heavy precipitation and flooding
- Snowstorm, ice storm, extreme cold
- Extreme heat, drought, wildfire
- Severe wind, Nor'easters, tornados

Tewksbury's Core Team identified 209 critical facilities. These facilities are shown in the Appendix B map series and listed in Table 4-5, which identifies facilities located within the FEMA flood zone.

Hazard Mitigation Goals

The 2015 update of the Hazard Mitigation Plan for the Northern Middlesex Region included sixteen regional mitigation goals. This list provided a starting point for Tewksbury's more focused and localized set of seven hazard mitigation goals, which are included in more detail below.

1. Coordination: increase coordination between Tewksbury and Federal, State, regional and local partners.
2. Policy: leverage requirements, incentives, and regulatory tools to:
    - Incorporate climate adaptation strategies and climate change projects as an integral factor in all Town departments, committees, and boards
    - Incorporate climate adaptation and hazard mitigation measures into local plans, bylaws, regulations, and other planning tools to protect critical infrastructure and property, and to encourage resilient development
    - Improve the Town's National Flood Insurance Program (NFIP) Community Rating System (CRS) score by exceeding minimum floodplain management standards
3. Protection: develop programs and strategies to protect the following features from natural hazards and the projected impacts of climate change:
    - Irreplaceable cultural and historic resources
    - Critical infrastructure, facilities, and services
    - Residences, businesses, and municipal buildings
    - Open space, wetlands, waterbodies, and other natural features
    - Public utilities including electric, water, and wastewater
4. Vulnerable Residents: implement mitigation measures that protect the Town's vulnerable populations, including residents who are elderly, young, living in poverty, with a disability, and those with limited English proficiency.
5. Public Outreach: increase awareness of climate hazards and personal resilience through public outreach, education, and by sharing resources.
6. Capacity: increase the Town's capacity for responding to a natural hazard event and anticipated climate impact through supplies, staff, training, and emergency plans.
7. Finance: identify and seek funding to support the implementation of climate adaptation strategies.

Hazard Mitigation Strategy

The Core Team identified and discussed several mitigation measures that would serve to reduce the Town's vulnerability to natural hazard events. Overall, the hazard mitigation strategy recognizes that mitigating hazards for Tewksbury will be an ongoing process as our understanding of natural hazards and the steps that can be taken to mitigate their damages change over time. Climate change and a variety of other factors impact the Town's vulnerability. In the future, local officials will need to work together across municipal lines, and with state and federal agencies, to understand and address these changes. The hazard mitigation strategy will be incorporated into the Town's other related plans and policies. This will ensure that all areas of planning and development within the Town will recognize and incorporate hazard mitigation measures.

1.0 INTRODUCTION

The Town of Tewksbury prepared a joint Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) to create an action plan to reduce the impacts of natural hazards and climate change within the community and the region. The Tewksbury HMP-MVP Plan was adopted by the Board of Selectmen on December 1, 2020 to update and replace the Hazard Mitigation Plan (HMP) for the Northern Middlesex Region 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, and
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 below.

[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. The first grant phase is the planning grant, which funds a planning process to identify priorities 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 Workshop following a guidebook developed by the Nature Conservancy, and engaging the public. Communities that complete the planning grant program and prepare an MVP Plan become eligible for the second phase of MVP grant funding, the action grants, and receive increased standing in other state grant programs. MVP action grants fund the implementation of priority climate adaptation actions described in the MVP Plan.[9]

1.3 Hazard Mitigation and Municipal Vulnerability Preparedness Planning in Tewksbury

The Town of Tewksbury received an MVP Planning Grant to simultaneously prepare an MVP plan and an HMP. Many of the required steps of the MVP process also satisfy requirements for updating an HMP. As a result, the Town 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) requirements to follow the Community Resilience Building (CRB) Workshop Guidance, developed by The Nature Conservancy. This enabled Tewksbury

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

to consider the impacts of climate change in its hazard mitigation planning, following the lead established by the Commonwealth when it adopted the first-ever Massachusetts State Hazard Mitigation and Climate Adaptation Plan (2018).

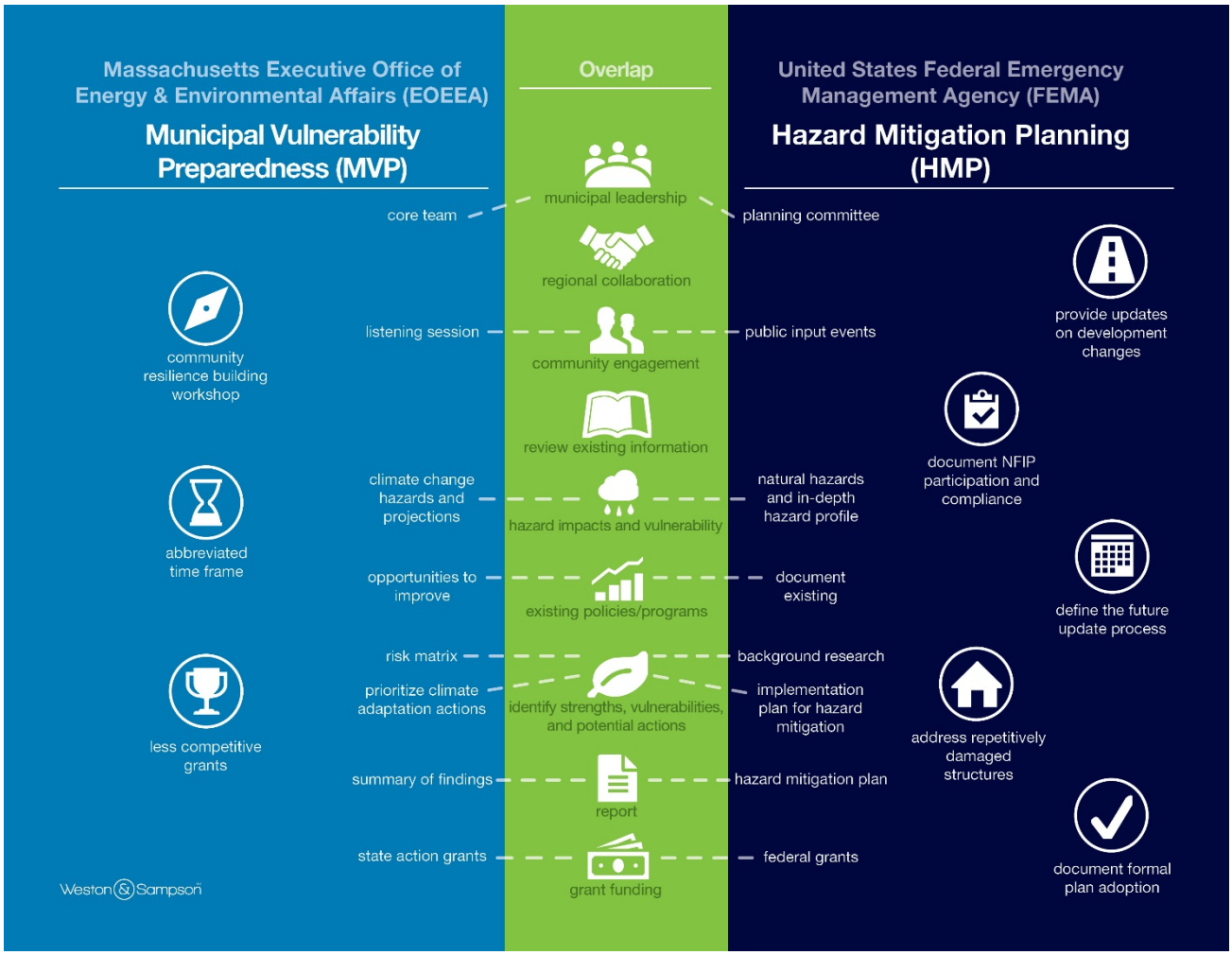


Figure 1-1: Commonalities and Difference between the MVP and HMP Processes

The joint HMP- MVP Plan convened a Core Team of municipal leaders to lead the process and provide local expertise. The Core team met three times and corresponded via email and contributed through interviews. Stakeholder engagement was conducted through the CRB Workshops, an online webinar, and an online survey. Chapter 3 provides more information about the overall process and outcomes.

1.4 Planning Process Summary

To prepare for the development of this MVP-HMP Plan, the Town of Tewksbury followed the process described in the Community Resilience Building Workshop Guidebook, which was developed by The Nature Conservancy.[10] 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

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

community. Developing a plan that reflects the Town of Tewksbury'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.[11] 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:

1. The Core Team, with representation from municipal leadership at the Town of Tewksbury
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 Tewksbury convened the Core Team to act as a steering committee for the development of the HMP-MVP Plan. The Core Team met on October 21, 2019; November 4, 2019; and February 19, 2020 to plan for the Workshop, review public comments, develop the mitigation plan, and transition to implementation of the plan's mitigation strategies. More information on these meetings is included in Appendix A.

The Core Team provided information on hazards affecting the Town, identified critical infrastructure, identified key stakeholders, reviewed the status of existing mitigation measures, and developed proposed mitigation measures for this plan. Members of the Core Team are listed in Table 1-2.

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

Table 1-2. Tewksbury's Core Team

Name	Title
Steve Sadwick	Assistant Town Manager
Anna McGinty	Town Planner
Brian Gilbert	DPW Director
Kevin Hardiman	Town Engineer
Stefania Gallo	Conservation Agent
Vinnie Bomal	Facilities Manager
Melissa Maniscalco	Housing Authority Executive Director
Lt. Scott Gaynor	Police Department Lieutenant
Chester Cheng	GIS Project Manager
Al Vasas	Fire Department Deputy
Eva Durkin	Open Space & Recreation Plan Committee Chair

The Core Team developed the invitation list for the Community Resilience Building 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 Tewksbury. These suggested resources included:

- Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update (NMCOG2015)
- Massachusetts Climate Change Projections (NECSC, 2018)
- Massachusetts Climate Change Adaptation Report (EEA, 2011)
- Massachusetts State Hazard Mitigation and Climate Change Adaptation (EEA and EOPSS 2018)
- Local Mitigation Plan Review Guide, October 2011 (FEMA, 2011)
- National Flood Insurance Program (NFIP) Flood Insurance Rate Map (FIRM) for Tewksbury, Middlesex County, Massachusetts (FEMA, 2016)
- National Center for Environmental Information (NOAA)
- National Water Information System (USGS)
- US Census, 2019 and American Community Survey, 2013-2017 Estimates
- Complete Streets Funding Program Project Prioritization Plan: Tewksbury (MassDOT, 2018)
- Draft 2019 Open Space and Recreation Plan (Town of Tewksbury, Open Space and Recreation Committee, NMCOG, 2019)
- Tewksbury Master Plan 2016 (Tewksbury Planning Board, Tewksbury Department of Community Development, 2016)
- Envisioning Tewksbury 2037 (Town of Tewksbury, Tewksbury Community Vision Committee, 2017)

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 22nd. 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.

Figure 1-2: Images of Local Features. Photos from the Town of Tewksbury and the Tewksbury Public Library.

During the second part of the Workshop, participants identified and prioritized key actions that would improve the Town's resilience to natural and climate-related hazards. Community representatives who were invited via email by Anna McGinty, Town Planner, and those who participated in the process are presented in Table 3-2 in Appendix C and organized by category. Additional materials from the Workshop are also included in Appendix C.

This broad representation of local and regional entities ensures 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 Workshop is included below:

- Staff members of the Town Planning Department, Engineering Department, Police Department, Fire Department, and Department of Public Works, along with many other municipal officials
- Representatives from the Council on Aging, Health Department, Tewksbury State Hospital, and Board of Health
- The Conservation Agent and representatives from the Green Committee, Beautification Committee, and Tewksbury Friends of Open Space
- Regional representatives, including members of the Merrimack River Watershed Council, the Northern Middlesex Council of Governments, National Grid, the Massachusetts Emergency Management Agency (MEMA), and the MVP Regional Coordinator
- Leadership from neighboring communities of Andover, Lowell, Billerica, Wilmington, Chelmsford, and Dracut were invited to participate in the Workshop but were unable to attend

Figure 1-3: Photos from the CRB Workshop (Weston & Sampson)

1.4.3 Listening Session

Due to the public health crisis surrounding COVID-19, the public listening session could not be conducted in person. As a solution, and to gather information from the general public and educate the public on hazard mitigation and climate change, the Town hosted a virtual listening session that included an online video and survey. The video presented information related to the MVP program, climate change in Tewksbury, local strengths and vulnerabilities, existing mitigation measures, and priority action items for future climate adaptation. The online survey collected public feedback on the video, the planning process to-date, and the draft HMP-MVP report.

The draft report was posted on the Town's website, along with the video and a link to the online survey. A link to the online survey was also shared in a promotional flyer emailed to the stakeholder list, on the Town's YouTube page, and in an article in the Tewksbury Patch local newspaper published on April 8th. The Town received 56 survey responses between April 7th and April 24th. More information about the virtual listening session, including a summary of survey responses, is available in Appendix D.

1.5 Planning Timeline

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

Information related to meetings associated with this timeline is included in more detail below:

1. Local Hazard Mitigation Planning Team / Municipal Vulnerability Preparedness Core Team
   Meeting 1: October 21, 2019 – Project Kickoff
   Meeting 2: November 4, 2019 - Plan for MVP Workshop/HMP Community Meeting
   Meeting 3: February 19, 2020 - Review MVP Priority Actions/HMP Mitigation Strategies

2. HMP Stakeholder Meeting / MVP Community Resilience Building Workshop
   8-Hour Meeting: January 22, 2020

3. Virtual Public Listening Session
   Online Video, Survey, and Public Comment Period: April 7 - April 24, 2020

2.0 HAZARD MITIGATION AND CLIMATE ADAPTATION GOALS

The 2015 update of the Hazard Mitigation Plan for the Northern Middlesex Region included sixteen regional mitigation goals. This list provided a starting point for Tewksbury's more focused and localized set of seven hazard mitigation goals. These goals were informed by feedback shared by the Core Team, CRB Workshop participants, and other stakeholders, and are included in more detail below.

1. Coordination - increase coordination between Tewksbury and Federal, State, regional and local partners.
2. Policy - leverage requirements, incentives, and regulatory tools to:
    - Incorporate climate adaptation strategies and climate change projects as an integral factor in all Town departments, committees, and boards
    - Incorporate climate adaptation and hazard mitigation measures into local plans, bylaws, regulations, and other planning tools to protect critical infrastructure and property, and to encourage resilient development
    - Improve the Town's National Flood Insurance Program (NFIP) Community Rating System (CRS) score by exceeding minimum floodplain management standards
3. Protection - develop programs and strategies to protect the following features from natural hazards and the projected impacts of climate change:
    - Irreplaceable cultural and historic resources
    - Critical infrastructure, facilities, and services
    - Residences, businesses, and municipal buildings
    - Open space, wetlands, waterbodies, and other natural features
    - Public utilities including electric, water, and wastewater
4. Vulnerable Residents - implement mitigation measures that protect the Town's vulnerable populations, including residents who are elderly, young, living in poverty, with a disability, and those with limited English proficiency.
5. Public Outreach - increase awareness of climate hazards and personal resilience through public outreach, education, and by sharing resources.
6. Capacity - increase the Town's capacity for responding to a natural hazard event and anticipated climate impact through supplies, staff, training, and emergency plans.
7. Finance - identify and seek funding to support the implementation of climate adaptation strategies.

3.0 COMMUNITY PROFILE, LAND USE, AND DEVELOPMENT TRENDS

3.1 Community Profile

Residents cite the sense of community, dedication of Town staff, natural features, and engaged residents as among their favorite aspects of Tewksbury. Indeed, the Town has many unique features that offer a sense of place. Tewksbury was settled by farmers in the 1700s. Flowers, leather, and lumber were among the Town's largest exports until the early 1900s.[12] This legacy gave Tewksbury the nickname, "Carnation Capital of America."[13] Today, Tewksbury is strategically located near Interstate Highways 93 and 495, is a hub for IT-related manufacturing, and is home to major businesses, including Raytheon and Thermo Fisher.[14]

Tewksbury has active community spaces and events, including the public library and annual celebrations like the Memorial Day Parade and Harvest Festival. As part of its visioning process, the Town seeks to increase housing options and is planning for improved access to natural spaces and other public resources, including parks, playgrounds, and recreational fields. Tewksbury is also working towards becoming a destination through community branding and encouraging the development of stores, shopping and dining options along Main Street (MA Route 38).[15] Tewksbury is experiencing population growth: from 2010 to 2018, its population increased from 28,961 to 31,388 residents. This represents an almost 8% change, higher than the state's overall population increase of 5.4% during the same time period.[16]

Part of Middlesex County, Tewksbury is less than 20 miles from Boston. It is neighbored by Chelmsford, Billerica, Wilmington, Andover, Dracut, and Lowell. Major transportation networks include I-93, I-495 and Route 38. The Town is also home to iconic waterbodies including the Merrimack River and the Shawsheen River.[17] Tewksbury is governed by a Town Manager and a Board of Selectmen and operates under the open Town Meeting system. The Town maintains a website at https://www.tewksbury-ma.gov/.

3.2 Societal Features

A recent visioning process challenged Tewksbury residents to describe their community in one-word. Responses included, "inclusive," "caring," and "generous." Indeed, the Town has an engaged population with access to social services including a Senior Center, Public Library, and Tewksbury Hospital. These facilities are strengths that can be leveraged in the event of an extreme event and may be particularly useful in reaching and assisting vulnerability populations. Vulnerable populations are residents whose everyday stressors make it harder to adapt and recover when shocks or hazards occur. In Tewksbury, children, the elderly, disabled residents, low income residents are considered vulnerable. Children are a significant subpopulation in Tewksbury, making up almost 20% of residents, but this percentage is comparable to data for the State of Massachusetts. Please refer to Table 3-1 for more information.

[12] The Editors of Encyclopaedia Britannica, "Tewksbury, Massachusetts, United States."
[13] Tewksbury Planning Board et al., "Tewksbury Master Plan 2016."
[14] The Editors of Encyclopaedia Britannica, "Tewksbury, Massachusetts, United States."
[15] Town of Tewksbury et al., "Envisioning Tewksbury 2037."
[16] United States Census Bureau, "QuickFacts: Tewksbury Town, Middlesex County, Massachusetts."
[17] Tewksbury Planning Board et al., "Tewksbury Master Plan 2016."

Table 3-1. Tewksbury Demographic Characteristics[18]

Population	Tewksbury	Massachusetts
2018	31,388	6,892,503
2010	28,961	6,547,629
Age		
Under Age 18	19.4%	19.8%
Over Age 65	17.6%	16.5%
Households		
Owner-occupied housing unit rate, 2014-2018	85.7%	62.3%
Language other than English spoken at home	8.6%	23.6%
Median household income	$97,584	$77,378
Population Burdened by Housing Costs (housing with a mortgage)[19]	23.6%	23.6%
Population Burdened by Housing Costs (housing without a mortgage)[20]	24.4%	15.8%
Additional Information		
Persons in Poverty	5.9%	10.0%
Bachelor's degree or higher	35.5%	42.9%
With a Disability	6.6%	7.9%

Note: population burdened by housing costs is defined as housing costs above 35% of income

Societal Features, Strengths, and Vulnerabilities

Tewksbury's growing population, including its growing elderly population, may also be considered a vulnerability. Emergency services capacity will need to grow similarly to meet these increasing demands. Conversely, a growing population could provide more opportunities for volunteers and increased resident engagement, which could provide a strength. Participants at the CRB Workshop discussed these distinctions while identifying key societal aspects of Tewksbury that are most vulnerable to, or provide protection against, natural hazards and climate change impacts. Please refer to Table 3-2 for more information.

[18] United States Census Bureau, "QuickFacts: Tewksbury Town, Middlesex County, Massachusetts."
[19] United States Census Bureau, "Tewksbury Town, Middlesex County, Massachusetts."
[20] United States Census Bureau.

Table 3-2. Societal Features in Tewksbury

Both Vulnerability and Strength	Strengths	Vulnerabilities
• Elderly residents • Commuters • Communication and regional coordination • Senior Center • Library • Schools and students • Local businesses and services • Transportation and roadways • Shelters	• Food and supplies • Cooling and warming stations	• Children • Nursing homes, assisted living facilities, group homes • Multi-lingual populations • Public housing and rentals • Disabled residents • Homeless populations • Residents with mental health challenges

3.3 Economic Features

In 2018, Tewksbury's unemployment rate was 3.0%. This represented a significant decrease from the Town's 8% unemployment rate only eight years previously. Like many communities in Massachusetts, Tewksbury was impacted by the country's 2008 financial crisis. While some residents commute to cities including Boston, Billerica, and Burlington; most Tewksbury residents (14% of the employed labor force) work in town. Major employers in Tewksbury include the Tewksbury Hospital, Market Basket, Raytheon, and ThermoFisher.[21] Management, business, science, and the arts are among the largest local occupations. The largest local industries include educational services, health care, and social assistance.[22] Please refer to Table 3-3 for more information. 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.

Table 3-3 Tewksbury Labor Data (2017)[23]

	Tewksbury	Massachusetts
Labor Force	17,795 residents	3,755,481
Unemployment Rate	4.7%	6.0%
Commuters who drove to work	85.7%	70.7%
Residents with income below the poverty level	5.4%	11.1%

[21] Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG), "2019 Open Space and Recreation Plan."
[22] United States Census Bureau, "Tewksbury Town, Middlesex County, Massachusetts."
[23] United States Census Bureau.

3.4 Infrastructure Features

Significant transportation infrastructure in Tewksbury includes I-93, I-495 and Route 38. Local roads have been impacted by snow, ice, downed trees, and flooding. The Town also has forty-seven pump stations, three dams, and a National Grid power station. The Town takes water from the Merrimack River. Only 2% of the town relies on private wells.[24] During the 2016 drought, Tewksbury was except from water restrictions implemented by the Department of Environmental Protection (DEP) because the Town's water comes almost entirely from the River. Tewksbury's sewer system stretches for about 166 miles, provides access to almost every residential and commercial building, and transports sewage for treatment at the Greater Lowell Wastewater utility.[25] Septic systems can be vulnerable to rising groundwater. Backup power of all critical facilities providing water and sewer is essential. See Section 3.5 for more information on critical facilities in Tewksbury.

Discussion of Existing Infrastructure

Participants at the CRB Workshop identified key infrastructure features in Tewksbury that are vulnerable to, or provide protection against, natural hazards and climate change impacts. As shown in Table 3-3 below, most of the infrastructure features were determined to be both a vulnerability and a strength.

Table 3-4. Infrastructure Features in Tewksbury

Both Vulnerability and Strength	Strengths	Vulnerabilities
• Pump Stations • Stormwater system • Public Safety, Emergency Facilities, Regional Emergency Communications Center (RECC) • Department of Public Works Building • Water Treatment Plant, Water Supply, and Water Storage • Roads and Bridges • Sewer • Electric Grid • Communications • Emergency Shelters • Hospital	• Town facilities and operations	• Dams, including Ames Dam • Drainage • Police Station • Culverts

[24] Tewksbury Planning Board et al., "Tewksbury Master Plan 2016."
[25] Tewksbury Planning Board et al.

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, 209 critical facilities were identified in Tewksbury. These facilities include emergency management buildings, Town facilities, shelters, hospitals, evacuation routes, critical intersections, water and sewer infrastructure, natural resources, religious centers, dams, schools, grocery and supplies stores, nursing homes, and other facilities. The full list of these structures is included in a table in Appendix C, shown in the map below, and included in the map series in Appendix B.

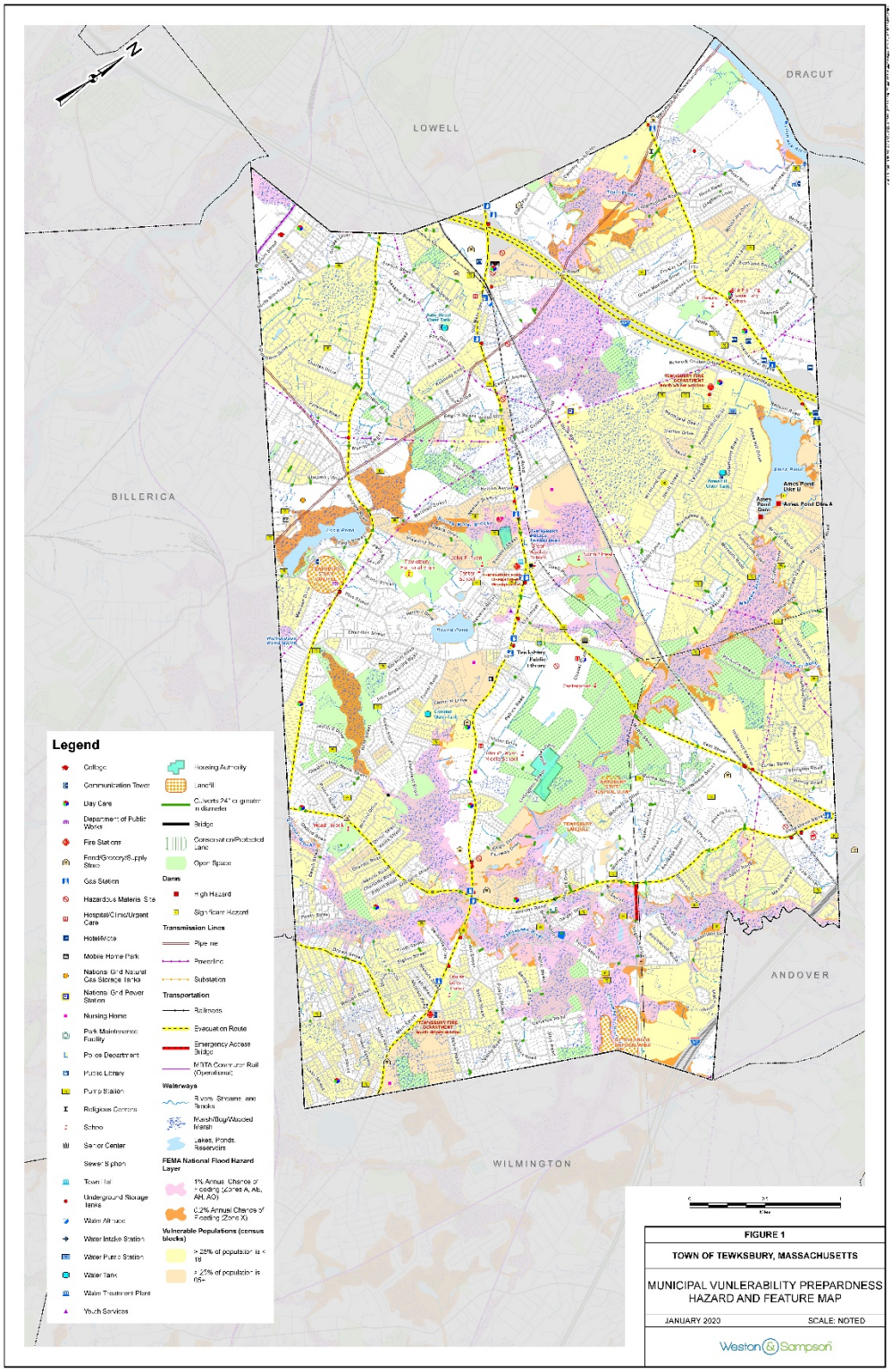


Figure 3-1: Tewksbury's Hazard Map, which includes the location of critical facilities

3.6 Land Use and Environmental Features

The Town of Tewksbury is just over 21 square miles. Although Tewksbury has transformed over time from agricultural land to suburban neighborhoods, the Town includes 1,866 acres (approximately 2.9 square miles) of protected open space. The Town and the State own most of this land, although a small amount is privately owned. Waterbodies provide significant space and recreational opportunities in Town and make up almost a quarter of Tewksbury's total area. These waterbodies include:

- Rivers: Merrimack, Concord, Shawsheen
- Watersheds: Merrimack, Concord, Shawsheen
- Watershed basins: Merrimack, Concord, Shawsheen, Ipswich
- Major streams: Heath Brook, Sutton Brook, Strongwater Brook, Trull Brook
- Great Ponds: Long Pond, Round Pond
- Contiguous wetland: the Great Swamp

The graphic below illustrates a comparative breakout of land use in Tewksbury.[26]

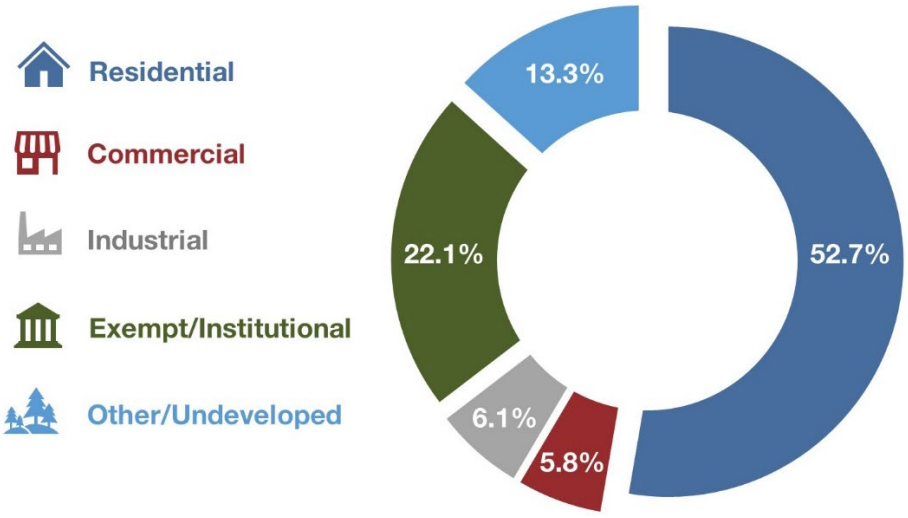


Figure 3-2: Land use in Tewksbury

Discussion of Environmental Features

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

Table 3-5. Environmental Features in Tewksbury

Both Vulnerability and Strength	Strengths	Vulnerabilities
• Watersheds • Drinking Water (Merrimack River)	• Parks and open space • Agricultural lands	• Wetlands and wildlife • Recreational fields • Landfill

[26] Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG), "2019 Open Space and Recreation Plan."

Table 3-5. Environmental Features in Tewksbury

Both Vulnerability and Strength	Strengths	Vulnerabilities
• Rivers, streams, ponds, • Wetlands and swamps • Flora and fauna • Trails • Tree canopy • Air quality and water quality		• Invasive species • Vector-borne illness

3.7 Recent and Potential Development

Development data was identified using input from the Tewksbury 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 16 residential developments, 14 commercial developments, 1 educational building, 1 municipal building, and 12 mixed use development in Tewksbury. Additionally, developments in Tewksbury include a total of 669 residential units, 163 single-family homes, and 884,547 square feet of documented commercial, residential, municipal, industrial/manufacturing, and mixed-use space. Please refer to Table 3-6 and Table 3-7 below for more information.

Table 3-6: Current and Future Development in Tewksbury[27]

Name	Address	Construction Type	Square Feet	PB Approved Date	Year Completed
Katie Estates	27 Jills Way	Residential	-	-	2011
Ocean State Job Lot	553 Main St	Commercial	40,000	-	2011
Tewksbury Memorial High School	320 Pleasant Street	Educational	218,781	-	2012
Walmart expansion	345 Main St	Commercial	141,066	-	2013
Merrimack Valley Pavilion: Family Entertainment Center	2087 Main Street	Commercial	8,800	-	2013
Thermo-Fisher Scientific Relocation 2012	2 Radcliff Rd	Industrial	-	-	2013
-	10-80 Wells Drive	Residential	-	-	2013
-	Crystal Circle	Residential	-	-	2014
Wamesit Lanes	Old L+L Rail Bed	Commercial	40,000	-	2015
Heatherwood	1624 Main Street	Residential	-	-	2015
Cumberland Farms Convenience/Gas Station	270 Main Street	Commercial	-	-	2016
Sarina Way	15-100 Sarina Way	Mixed Use	8,500	-	2016
Winterberry Lane	10-65 Winterberry Ln	Residential	-	-	2017
Balsam Place	70 Victor Drive	Residential	-	-	2017
-	April's Way	Residential	-	-	2017

[27] Metropolitan Area Planning Council (MAPC), "MassBuilds: Tewksbury."

The Residence at Joan's Farm	20 Donny Martel Way	Residential	-	-	2017
Bella Woods	746-774 East St	Residential	-	-	2018
Catamount Road and Scenic Drive	127 Catamount Road	Residential	-	-	2018
Harvest Lane	10-55 Harvest Lane	Residential	-	-	2018
Elaina Estates	140 Elaina Millard Way	Mixed Use	5,400	-	2018
Border Road	255 Salem St	Residential	-	-	In-progress
Poland Ave Open Space Residential Development	20 Robbie Terris Way	Residential	-	-	2019
Circle Health Medical Office	1574 Main Street	Commercial	-	08/2017	2019 - Completed
-	937 Main Street	Mixed Use	21,520	-	2020
Discount Madness	1325 Main Street	Mixed Use	-	03/18	Anticipated 2020
Robertson Estates, Thomas Estates	Fraiser Lane	Residential	-	-	2020
Sarina's Way	1418 Main Street	Mixed Use	-	12/2017	Completed
-	1455 Main Street	Mixed Use	2,200	-	In-progress
-	2230 Main Street	Mixed Use	10,000	2017	-
-	960 Main Street	Mixed Use	2,600	2017	-
-	24 Sunnyslope Ave.	Commercial	7,200	09/2019	-
Hilton Hotel	937 North Street	Commercial	-	-	-
Comfort Dental	307 Old Boston Rd	Commercial	3,740	03/2017	Completed 2019
-	24 Pleasant Street	Commercial	3,500	05/2017	-
-	160 Dascomb Road	Commercial	348,460	01/2018	-
RECC	999 Whipple Road	Municipal	6,500	11/2018	2019 - Completed
-	725 Main Street	Small Mixed Use	-	10/2018	2019-2020 - Completed
-	82 Pleasant Street	Small Mixed Use	1,440	10/2018	-
-	2122 Main Street	Mixed Use	-	08/2016	-
-	2131 Main Street	Mixed Use	-	08/2019	-
Naomi Way	1420 Andover Street	Residential	-	08/2019	-
-	138 Astle Street	Residential	-	03/2019	In-progress
-	105 Lowell Street	Commercial	11,250	03/2016	-
-	1583 Andover Street	Commercial	1,290	09/2019	In-progress
-	1625 Andover Street	Commercial	4,500	09/2019	In-progress

Note: "PB" stands for Planning Board

Descriptions of these developments are included in more detail in Appendix B.

As of March 2020, the Planning Board applications shown in Table 3-7 were pending.

Table 3-7: Current Planning Board Applications - Pending[28]

Name	Address	Construction Type	Residential Units
-	325 Marshall Street	Subdivision/Residential OSRD	Proposed 38 Units
Andover & North	1037 North Street, 1547,1553, 1563 Andover Street	Residential	Proposed 18 Units
Burtt Road Development		Commercial - warehouse	-
Riverview	495 Woburn Street	Commercial - warehouse	-
Fire Station	984 Main Street	-	-
Elementary School	135 Pleasant Street	-	-

Descriptions of these developments are included in more detail in Appendix B.

[28] McGinty, Development Data from Tewksbury Town Planner.

4.0 HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES

Each hazard profile in this chapter contains information related to areas vulnerable to the hazard, documentation of historic events, a risk assessment, and projected climate risk. The hazard profiles were updated using information from the 2013 Massachusetts State Hazard Mitigation Plan, the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), 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 GIS Assessment was conducted to determine the risk in Tewksbury related to future flooding, hurricane, 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. These plans summarize 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 box below gives further definitions of the frequency and severity characterizations. Table 4-1 summarizes the frequency and severity of hazard risk in Tewksbury and the State. These frequency and severity classifications will assist the Town in prioritizing mitigation actions for each hazard.

Definitions used in the Commonwealth of Massachusetts State Hazard Mitigation Plan[1]

Frequency

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

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.

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

Table 4-1. Hazard Risk Summary

Hazard	Frequency		Severity	
	Massachusetts[2]	Tewksbury[3]	Massachusetts[4]	Tewksbury[5]
Inland Flooding	High (1 flood disaster declaration event every 3 years; 43 floods per year of lesser magnitude)	High	Serious to Catastrophic	Serious
Dam failures	Very Low	Low	Extensive to Catastrophic	Minor
Coastal Hazards	High (6 events per year over past 10 years)	N/A	Serious to Extensive	N/A
Tsunami	Very Low (1 event every 39 years on East Coast, 0 in MA)	N/A	Extensive to Catastrophic	N/A
Hurricane/Tropical Storm	High (1 storm every other year)	High	Serious to Catastrophic	Extensive
High Wind (Severe Weather)	High (43.5 events per year)	High	Minor to Extensive	Extensive
Tornadoes (Severe Weather)	High (1.7 events per year)	Low	Serious to Extensive	Minor
Thunderstorms	High (20 to 30 events per year)	High	Minor to Extensive	Extensive
Nor'easter	High (1 to 4 events per year)	High	Minor to Extensive	Extensive

[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"; Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[3] Northern Middlesex Council of Governments (NMCOG), "Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update."
[4] 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"; Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[5] Northern Middlesex Council of Governments (NMCOG), "Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update."

Table 4-1. Hazard Risk Summary

Hazard	Frequency		Severity	
	Massachusetts[2]	Tewksbury[3]	Massachusetts[4]	Tewksbury[5]
Snow and Blizzard (Severe Winter Weather)	High (1 per year)	High	Minor to Extensive	Extensive
Ice Storms (Severe Winter Weather)	High (1.5 per year)	High	Minor to Extensive	Extensive
Earthquake	Very Low (10-15% probability of magnitude 5.0 or greater in New England in 10 years)	High	Minor to Catastrophic	Extensive
Landslide	Low (once every two years in western MA)	Low	Minor to Extensive	Minor
Brush Fires	High (at least 1 per year)	Low	Minor to Extensive	Minor
Extreme Temperatures	High (1.5 cold weather and 2 hot weather events per year)	High	Minor to Serious	Serious
Drought	High (8% chance of "Watch" level drought per month [recent droughts in 2016 and 1960s])	Medium	Minor to Serious	Extensive

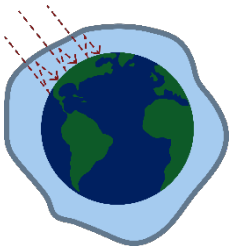
Not all hazards included in the 2018 State Hazard Mitigation and Climate Adaptation Plan, or the 2013 Massachusetts State Hazard Mitigation Plan apply to the Town of Tewksbury. Given Tewksbury's inland location, coastal hazards and tsunamis are unlikely to directly affect the Town. It is assumed that the entire Town of Tewksbury 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 the 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, help planners understand the possible extent and frequency of hazards. Historically, Massachusetts has experienced multiple type of 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 open additional FEMA grant opportunities for regional recovery and mitigation projects. The hazard profiles detailed below contain additional information about federally declared disasters.

4.1.3 Impacts of Climate Change



Many of the hazards that Tewksbury 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, which helps maintain the Earth's annual average temperature. When additional greenhouse gases are released through burning fossil fuels (oil, coal and gas), the Earth's temperature increases. The global temperature increase impacts jet streams and climate patterns. The Massachusetts climate is expected to reflect historic climate patterns of states south of New England depending upon GHG emission scenarios. Climate change is likely to change Massachusetts's typically precipitation cycle, leading to more intense rainfall and storms and more episodic or flash droughts. Temperatures will increase in both summer and winter. Each hazard profiles includes more details on how the frequency and intensity of the hazard will shift with climate change and the anticipated impacts.

4.1.4 Top Hazards as Defined in the CRB Workshop

The Tewksbury Core Team recommended four top hazards/climate change impacts for use during the CRB Workshop. These hazards include:

1. Heavy precipitation and flooding
2. Severe thunderstorms, wind, Nor'easters, and tornado
3. Severe snowstorms, ice storms, and extreme cold
4. Extreme temperatures, drought, and wildfire

The CRB Workshop included small and large group discussions about Town features, environmental hazards, and anticipated climate change impacts. The Merrimack River is the Town's water supply. Sewage is transported to the Greater Lowell Wastewater utility, as part of a 20-year contract with the City of Lowell. There was some concern that, in the future, capacity of this system could be an issue. There may also be a need to relocate sewer pump stations that are in flood-risk areas, including the Regina Street Drive Sewer Pump Station.

Flooding was a common issue discussed during the workshop. Attendees shared stories about areas that flood frequently, including Shawsheen and Main, Pinnacle Street culvert, and the area near the Police Department. Of particular concern was potential flooding Main Street near the James Miceli Bridge, which could cutoff the southeast edge of Town. Participants also discussed recent adaptation actions that had addressed flooding issues, including the elevation of South and Bridge Street after a flood in 2004. Additionally, the Town elevated a portion of Brown Street and installed a new culvert to alleviate flooding.

Figure 4-1: Participants at Tewksbury's CRB Workshop

Workshop attendees also discussed the impact of severe storms and wind events, saying that South Tewksbury experiences more power outages than the rest of Town. Utility lines in the area are vulnerable, although some underground electric utilities are being installed. Participants also discussed the impact of extreme temperatures, and one attendee remarked that their grandchildren will be living in a Massachusetts that feels more like Georgia. The sections below include more information about environmental hazards, climate change projections, and historic and anticipated impacts in Tewksbury.

4.2 Flood-Related Hazards

Flooding was one of the four main hazards discussed by participants during Tewksbury's MVP workshop. Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, and winter storms. While Tewksbury currently experiences these events, the impacts of climate change will likely lead to increasingly severe storms and impacts. Potential impacts of flooding could include injury or mortality, property damage, and traffic disruption. Areas within the FEMA Flood Zones, repetitive flood loss sites, and local areas identified as flood prone are more vulnerable to these impacts.

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 Tewksbury town staff, input collected during expert interviews with local leaders, and accounts of past flood events provided by Tewksbury MVP Workshop participants.

Tewksbury's lowland topography ranges from 85-200 feet above sea level. More than 13% of Tewksbury's land use is classified as "undeveloped" land, and waterbodies also take up a significant amount of space in Town.[6] Waterbodies, topographical variations, and the prevalence of impervious surfaces throughout Tewksbury all contribute to the runoff and flooding that occurs throughout Tewksbury. Additional riverine and stormwater flooding in Tewksbury is due to undersized culverts and insufficient stormwater detention and drainage. The Town is continuously maintaining and upgrading culverts so that they can better accommodate the stormwater volume they are receiving.

[6] Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG), "2019 Open Space and Recreation Plan."

Flood hazards are also linked to erosion, which can compromise receiving water quality, slope stability, and the stability of building foundations. These impacts 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.

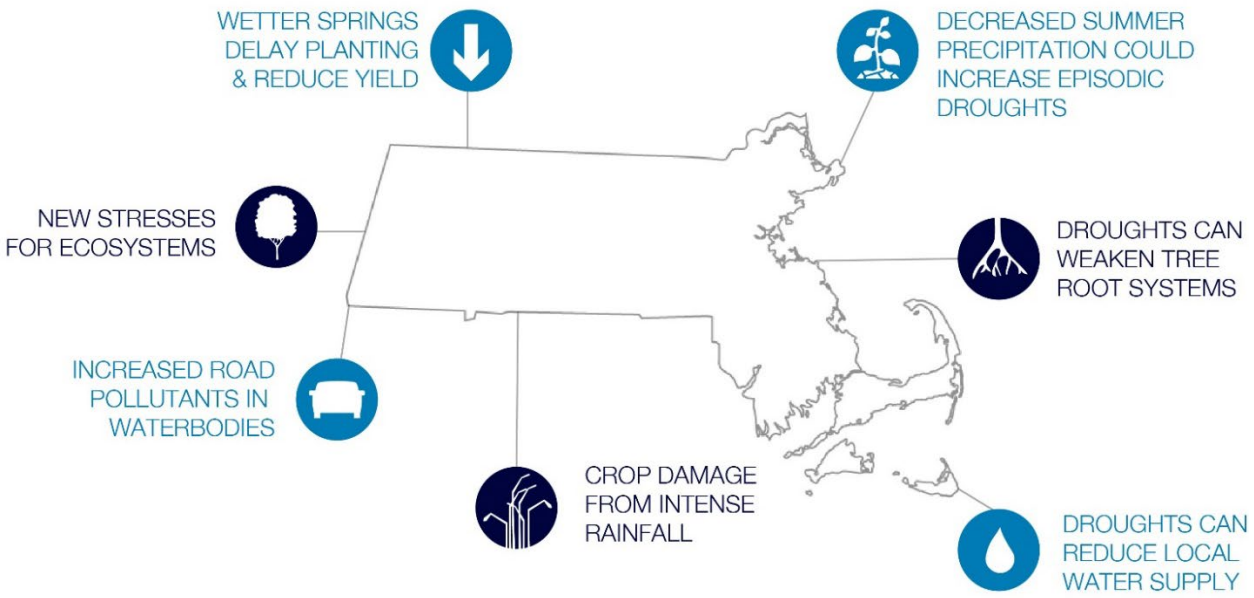


Figure 4-2: Potential Impacts of Increasing Precipitation

A series of expert interviews with representatives from Tewksbury departments and organizations revealed more information about the cascading impacts of flooding on Town operations. For example, if flooding shuts off a section of the Town, emergency response personnel may not be able to access that area. During a previous event, the Shawsheen River flooded Bridge Street and the Fire Department was unable to access South Street. The Town has since addressed that problem by elevating portions of the roadways.

4.2.1 Areas Vulnerable to Flooding

Flooding can include both riverine (topping the banks of streams, rivers, ponds) and stormwater flooding water rainwater that does not properly infiltrate into the ground.

Riverine Flooding

Tewksbury is home to a series of rivers, streams, ponds, and other waterbodies that include:

- Rivers: Merrimack, Concord, Shawsheen
- Major streams: Heath Brook, Sutton Brook, Strongwater Brook, Trull Brook
- Great Ponds: Long Pond, Round Pond
- Contiguous wetland: the Great Swamp[7]

[7] Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG).

FEMA Flood Zones and Repetitive Loss Sites

FEMA-designated flood zones from the NFIP FIRM are included in the Appendix B map series. 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.[8]

Flood Insurance Rate Map Zone Definitions[9]

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.[10] There are eight repetitive flood loss buildings in Tewksbury. All eight properties are residential buildings.[11] Please refer to Section 5.3: Existing Town-Wide Mitigation for Flood Related Hazards, for more information about the NFIP and repetitive flood loss in Tewksbury. It is important to remember that repetitive loss data does not fully represent the damage that Tewksbury 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 Tewksbury have been classified as a high frequency event. As defined by the Massachusetts State Hazard Mitigation and Climate Adaptation Plan this hazard occurs once every three years (33% chance per year).[12]

Stormwater Flooding

Stormwater flooding occurs during a precipitation event where 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

[8] Federal Emergency Management Agency (FEMA), "Flood Insurance Rate Map: Tewksbury, Middlesex County, Massachusetts."
[9] Federal Emergency Management Agency (FEMA), "Flood Zones."
[10] Federal Emergency Management Agency (FEMA), "Definitions: Repetitive Loss Structure."
[11] Federal Emergency Management Agency (FEMA), "Repetitive Property Loss." September 30, 2019.
[12] 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."

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.

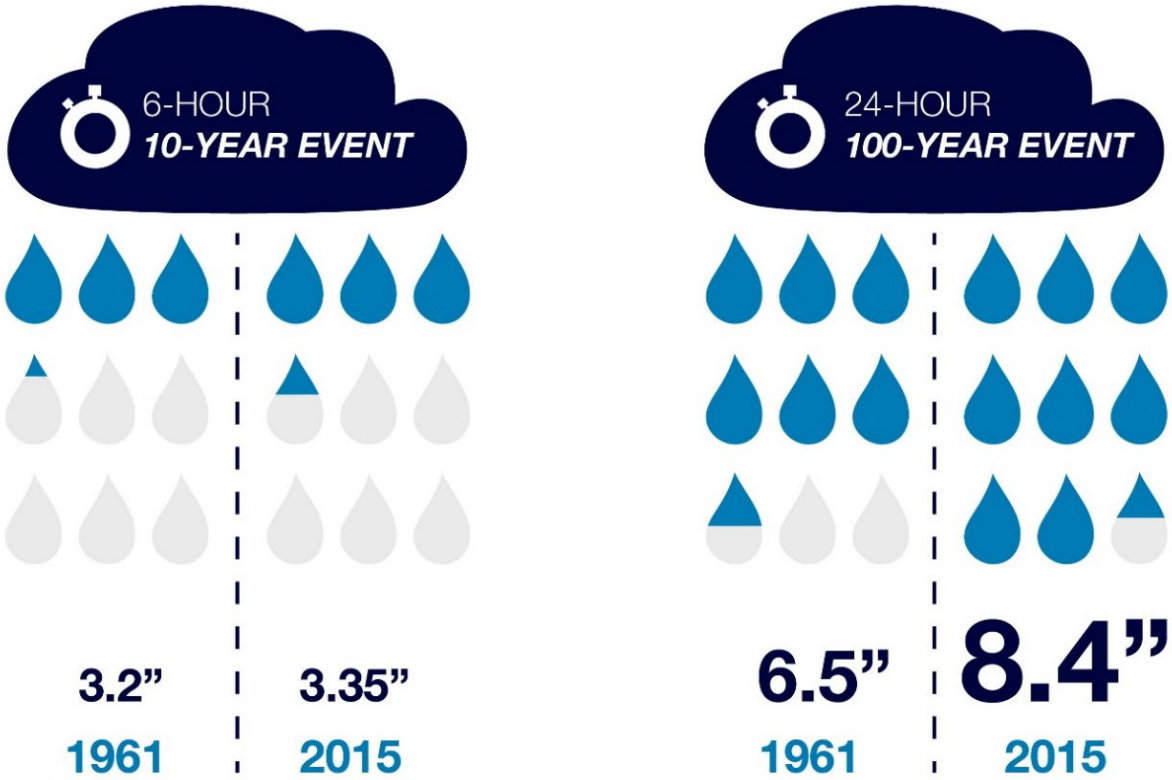


Figure 4-3: Design Storm Standards from 1961 (TP-40) and 2015 (NOAA Atlas 14)

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. For example, the Tewksbury 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. 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
Main Street	Floods at a low point near the Police Station
Shawsheen Street	Near Main Street (Route 38), Mohawk Drive, Algonquin Drive, and the bridge
Brown Street	Near Nichols Road, Whipple Road
Bridge Street	Near South Street
Pinnacle Street	Floods
Pond Street	Floods

Name	Description
Bonnie Lane	Floods
Sutton Street	Floods
Lake Street	Floods
Pupkis Road	Near Heath Street
Starr Ave	Near Mitchell G. Drive
Veranda Street	Floods
Water Street	At Adelaide Road
Greenwood Ave	Near Woburn Street
Vernon Street	Floods
Cayuga Road	Floods
Wolcott Street	At Tewmac Terrace
Van Buren Road	At Marston Street
Dewey Street	At Town Hall Avenue
Whipple Road	At Chandler Street
Claire Street	At Marie Street

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. Tewksbury is included in the Middlesex County data. The storms are categorized by event type, including flood and flash flood events.[13] Flash Flood events are considered by the NOAA's National Centers for Environmental Information 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."[14]

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.[15] Although not all of the flooding documented in the database directly affected Tewksbury, 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 Tewksbury, due to regionally-dependent utilities, supply of goods, transportation networks, and economic impacts, among other considerations.

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

Of the 159 flood events that occurred in Middlesex County between 2000 and 2019, two directly affected Tewksbury. The date and details are listed below:

Table 4-3. Flooding Events in Tewksbury[16]

Date of Flooding Event	Description
May 13, 2006	Heavy rainfall over a 100-hour period caused widespread flooding across Middlesex County, exceeding flooding caused by the 1938 Hurricane and prompting the Governor to declare a State of Emergency.
March 14, 2010	Six to ten inches of rain resulted in major flooding across eastern Massachusetts and Rhode Island. Many streets were closed, and basements flooded in Tewksbury and 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 capabilities of that community. Eight disaster declarations were made in Middlesex County due to flooding between 2000 and 2015, as can be seen in Table 4-4 below.

Table 4-4. Previous Federal and State Disaster Declarations - Flooding[17]

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	Middlesex, Essex, Suffolk

[16] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA).

[17] 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."

Table 4-4. Previous Federal and State Disaster Declarations - Flooding[17]

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
		Program; FEMA Hazard Mitigation Grant Program	
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

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 Tewksbury, which is dated 2016. The FIRM is the official map on which FEMA has delineated both the special flood hazard areas and the risk premium zones applicable to the community under the National Flood Insurance Program (NFIP). This includes high risk areas that have a 1% annual chance of being flooded (often referred to as the "100-year floodplain"), which under the NFIP, is linked to mandatory purchase requirements for federally backed mortgage loans. It also identifies moderate to low risk areas, defined as the area with a 0.2% annual chance of flooding (often referred to as the "500-year floodplain"). For purposes of this exposure analysis, the following special flood hazard areas identified in the Town of Tewksbury'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 Tewksbury that are located within either the 100-year or 500-year FEMA flood zone.

As can be seen in the Table 4-5, 13 critical facilities are located within the 100-year flood zone and 8 critical facilities are 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 flooding or any other hazard that could threaten the facility.

During the workshop, stakeholders discussed concern around the location of vulnerable populations. Some of these community members rely on assistance and it is important that someone is able to access them if needed. It becomes a concern if the vulnerable populations are located within a flood zone or in an area that extreme flooding could isolate them from the rest of the town. A GIS analysis found that 59 census blocks containing vulnerable population are located within the 100-year flood zone. More data related to this analysis is included in Appendix B.

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

Facility	Address	100-Year Flood Zone	500-Year Flood Zone
Ames Pond Dam	N/A		X
Ames Pond Dike B Dam	N/A		X
Gas Station	1992 Main Street		X
Gas Station	1975 Main Street	X	
Housing Authority	Carnation Drive	X	
Pump Station	Decarolis Drive	X	
Pump Station	East Street	X	
Pump Station	Meredith Road	X	
Pump Station	Hill Street		X
Pump Station	Moonlight Drive		X
Pump Station	Munro Circle	X	
Pump Station	Pinnacle Street	X	
Pump Station	Riverdale Avenue	X	
Pump Station	Rockvale Road	X	
Pump Station	Serenity Drive	X	
Sewer Siphon	Bridge Street	X	
Solid Waste Facility	1069 South Street	X	X
Underground Storage Tank	1992 Main Street		X
Water Intake Station	Merrimac Drive		X
Youth Services - Roxbury	1147 Main Street	X	

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 these 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.

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

Land Use Type	Total # of Parcels	Total Area of Parcels (acres)	# 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	7980	6084	723	1048	17	$216,727,400
Commercial	190	756	24	293	39	$28,443,900
Industrial	49	664	7	151	23	$15,155,800
Institutional	63	927	14	439	47	$38,108,500
Agricultural	1	2	1	2	100	$133,700.00
Open Space	4	41	N/A	N/A	N/A	N/A
Total	**8287**	**8475**	**769**	**1933**	**23**	**$298,569,300**

23% of the developed parcels in Tewksbury are located within the 100-year flood zone, and 20% are located within the 500-year flood zone. Some of these locations include areas which were noted as frequent flooding areas during the CRB Workshop. The tables below include more information about the exposure of developed parcels in the Town of Tewksbury.

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

Land Use Type	Total # of Parcels	Total Area of Parcels (acres)	# 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	7980	6084	457	783	13	$168,338,200
Commercial	190	756	21	311	41	$38,533,600
Industrial	49	664	4	137	21	$15,592,700
Institutional	63	927	12	429	46	$29,351,500
Agricultural	1	2	1	2	100	$133,700
Open Space	4	41	N/A	N/A	N/A	N/A
Total	**8287**	**8475**	**495**	**1661**	**20**	**$251,949,700**

Recent developments, or redevelopments, within the past 10 years (2010 – 2020) were then isolated and an additional exposure analysis was done on these parcels. The methodology for this exposure analysis is the same as above. This data was pulled from the MassBuilds database[18] and confirmed by the Town Planner.

[18] Metropolitan Area Planning Council (MAPC), "MassBuilds: Tewksbury."

Table 4-8. Exposure of Recently Developed Parcels to the 100-Year FEMA Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	% of the Parcels in the Flood Zone	Property Value in the Flood Zone
The Residence at Joan's Farm	20 Donny Martel Way	Residential	10	1	15	$12,375,000
Merrimack Valley Pavilion - Family Entertainment Center at 2087 Main Street	2087 Main St	Commercial	3	1	47	$594,800
Total			**13**	**2**	**22**	**$12,969,800**

Table 4-9. Exposure of Recently Developed Parcels to the 500-Year Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	% of the Parcels in the Flood Zone	Property Value in the Flood Zone
Merrimack Valley Pavilion - Family Entertainment Center at 2087 Main Street	2087 Main St	Commercial	3	0.6	21	$594,800
Thermo-Fisher Scientific Relocation 2012	2 Radcliff Rd	Industrial	25	0.6	2	$6,143,100
The Residence at Joan's Farm	20 Donny Martel Way	Residential	10	0.7	7	$12,375,000
Border Road (255 Salem St)	11 Scaltrito Drive	Residential	2	0.2	8	N/A
Total			**40**	**2.1**	**5**	**$19,112,900**

Tewksbury is a growing community and as the population grows, so does the demand for additional facilities in the town. To further resiliency in the Town, a flood exposure analysis was completed on all vacant, developable parcels. The analysis was conducted utilizing MassGIS data, FEMA flood maps, and information from the Town. The result of this analysis will bring light to future flooding that could occur on these 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 FEMA Flood

Zones. While there are 3,176 acres of land in Tewksbury that are vacant and developable, 48% of that land is located within the 100-year flood zone, and 44% is located within the 500-year flood zone.

Table 4-10. Exposure of Developable, Vacant Land to the 100-Year FEMA Flood Zone

Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	# of Parcels in Flood Zone	Total Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	224	409	37	70	17
Commercial	18	73	4	20	28
Industrial	36	201	3	7	4
Institutional	83	511	21	400	78
Agricultural	7	29	1	12	42
Open Space	434	1954	123	1023	52
Total	**470**	**3176**	**189**	**1532**	**48**

Table 4-11. Exposure of Developable, Vacant Land to the 500-Year FEMA Flood Zone

Land Use Category	Total Number of Parcels	Total Area of Parcels (acres)	# of Parcels in Flood Zone	Total Area of Parcels in Flood Zone (acres)	Percentage of Parcels in the Flood Zone
Residential	224	409	21	166	41
Commercial	18	73	5	55	75
Industrial	36	201	6	67	33
Institutional	83	511	14	209	41
Agricultural	7	29	2	24	83
Open Space	434	1954	78	874	45
Total	**802**	**3176**	**126**	**1395**	**44**

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 exposure of potential development within each land use type was documented by the 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, which can be seen in Table 4-12 below.

Table 4-12. Exposure of Locally Identified Areas for Potential Development to the 100-Year FEMA Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	% of the Parcels in the Flood Zone
N/A	2131 Main Street	Commercial	3	0.8	28
Elementary School	135 Pleasant Street	Institutional	26	5	20
N/A	937 Main Street	Open Space	6	5	75
Total			**35**	**10.8**	**31**

Table 4-13. Exposure of Locally Identified Areas for Potential Development to the 500-Year FEMA Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	% of the Parcels in the Flood Zone
Elementary School	135 Pleasant Street	Institutional	26	0.8	3
N/A	325 Marshall Street	Residential	57	19	33
Total			**83**	**19.8**	**24**

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.[19] Dam failures during flood events are of concern in Massachusetts, given the high density of dams constructed in the 19th century.[20]

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 earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage.[21]

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

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 Tewksbury, it can cause property damage, injuries, and potentially fatalities. These impacts can be at least partially mitigated through advance warning to communities impacted by a dam failure. In addition, the breach may result in erosion on the rivers and stream banks that are inundated.

In Tewksbury, dam failure is classified as a low frequency event, which is defined by the 2018 State Hazard Mitigation and Climate Adaptation Plan as occurring less frequently than once every 100 years (less that a 1% chance per year). Although there have been no recorded dam failures in Tewksbury, a dam failure can still present a high level of risk and could result in a catastrophic event with extreme damage to property and loss of life.

According to town officials and the Massachusetts Department of Conservation and Recreation's (DCR) Office of Dam Safety, there are three dams and dikes in Tewksbury. Information related to these dams is summarized in Table 4-14. This summary table includes the hazard classification for each dam, which is defined by DCR as described below:

> *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 4-14. Inventory of Dams in Tewksbury

Dam Name	Impoundment	Dam Owner	Hazard Potential Classification
Ames Pond Dam	Ames Pond	Ames Hill Development, LLC	High Hazard
Ames Pond Dike A	Ames Pond	Unknown	High Hazard
Ames Pond Dike B	Ames Pond	Marc P Ginsburg & Arnold Martel Jr	Significant Hazard

As of February 2017, all dams classified as high hazard potential or significant hazard potential were required to have an Emergency Action Plan (EAP).[22] 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 owned 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.[23] Extreme rain and snow events are becoming increasingly common and severe particularly in the Northeast region of the country (please refer to Figure 4-4 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.[24]

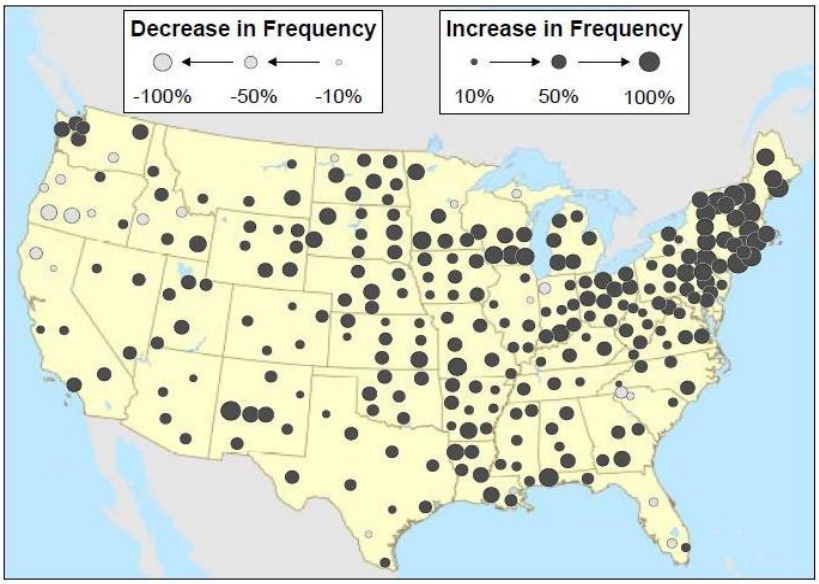


Figure 4-4. Changes in Frequency of Extreme Downpours[25]

4.3 Wind Related Hazard

High winds can occur during hurricanes, tornadoes, nor'easters, and thunderstorms. The entire area of Tewksbury is vulnerable to the impacts of high wind. All current and future buildings including critical facilities and populations are vulnerable during high wind events. Wind may down trees and power lines. High wind and storm events cause property damage and hazardous driving conditions. While Tewksbury's current 100-year wind speed is 96 mph[26], climate change will likely increase events and severity.

[22] Massachusetts Department of Conservation and Recreation (DCR), "Emergency Action Plans."
[23] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Annual Total Precipitation: Middlesex County, MA."
[24] Madsen and Willcox, "When It Rains, It Pours: Global Warming and the Increase in Extreme Precipitation from 1948 to 2011."
[25] Madsen and Willcox.
[26] American Society of Civil Engineers (ASCE), "ASCE 7 Hazard Tool: Tewksbury, Massachusetts."

Extreme winds can take down trees and branches that cause service disruptions. An identified issue during storms in Tewksbury is the damage to power lines from overhanging trees. Similarly, the Fire Department discussed the challenges that can occur when downed trees block roads and prevent or delay access to certain areas. Currently, the Tewksbury Department of Public Works (DPW) Forestry Department has an ongoing, town-wide tree maintenance program, which involves removing diseased and dead trees that pose a risk to public safety and utility lines. A Hazard Tree Study was conducted as part of this effort, and the DPW currently has a grant to continue this work of identifying hazardous trees. Additionally, the National Grid trims trees along the Tewksbury power lines every five years.

Figure 4-5: Downed Tree Blocking a Road. Photo from Tewksbury Twitter

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.

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 2000 and 2020, Massachusetts experienced six hurricanes and tropical storms, including Hurricanes Earl, Sandy, Jose, Florence, and Dorian; and Tropical Storm Irene. Sandy, Irene, and Earl led to a federal emergency and disaster declarations. Hurricanes that have occurred in the region since 1938 are listed in Table 4-15 below.

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

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

Table 4-15. 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 Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011
Hurricane Sandy	October 29-30, 2012
Hurricane Jose	September 20, 2017
Hurricane Florence	September 18, 2018
Hurricane Dorian	September 7, 2019

* Category 3

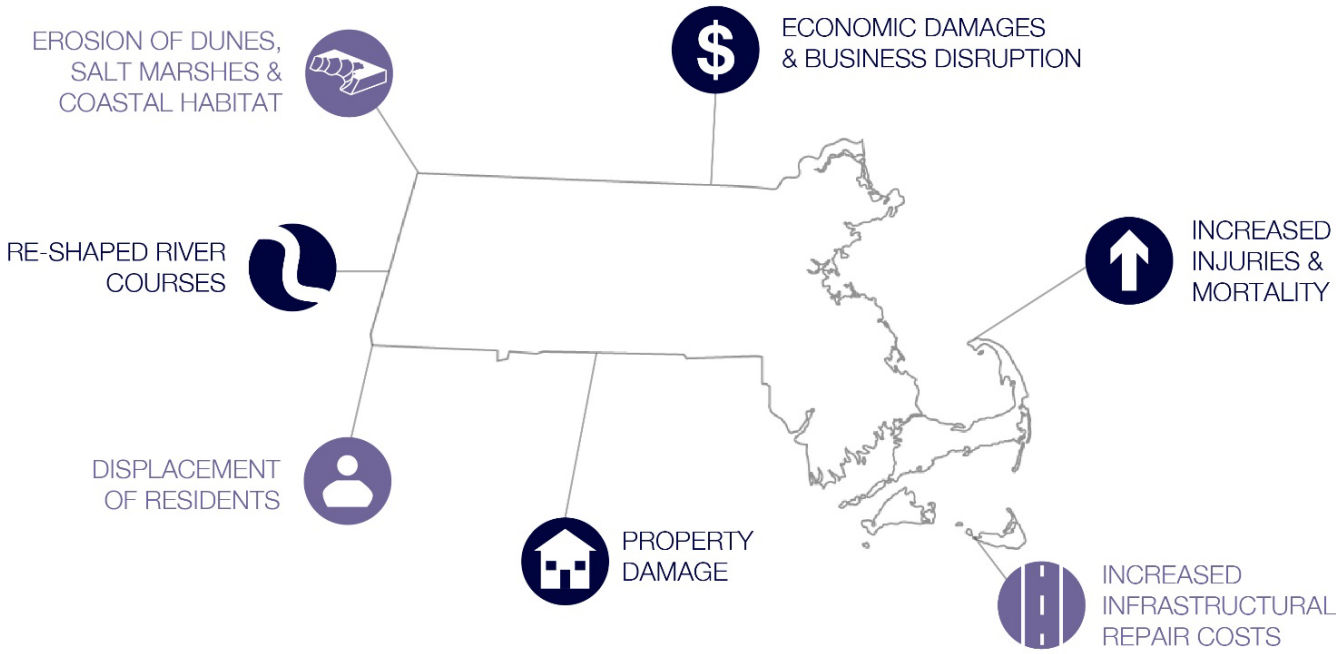


Figure 4-6: Potential Impacts of Extreme Storms, including High Wind Events

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

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 4-16 below:

Table 4-16. 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 Tewksbury 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 witnessed in Massachusetts was a Category 3 hurricane, which occurred in 1954. For the purpose of this analysis, 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 Massachusetts, a

[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).

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 Tewksbury was outlined using Town census tracts. The probabilistic scenario was used for Tewksbury, 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 Tewksbury 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 4-17. Infrastructural Damage from a Category 2 Hurricane on Buildings in Tewksbury

Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[2]
Residential	9558	172	1.8%	$20,905,610
Commercial	621	10	1.6%	$311,920
Industrial	208	3	1.5%	$56,700
Others	92	2	1.5%	$32,000
TOTAL	**10,479**	**187**	**1.8%**	**$21,306,240**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

Table 4-18. Infrastructural Damage from a Category 4 Hurricane on Buildings in Tewksbury

Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[1]
Residential	9,558	1,372	14.4%	$71,944,030
Commercial	621	66	10.6%	$2,703,820
Industrial	208	21	10.0%	$972,820
Others	92	11	11.5%	$340,880
TOTAL	**10,479**	**1,470**	**14.1%**	**$75,961,540**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

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 business interruption loss; monetary wage, capital-related, rental and relocation costs; as well as displaced households and

persons seeking temporary shelter. Additional property damage and business interruption loss were calculated as well, and a full Hazus risk report for each hurricane category can be found in Appendix B.

Hurricanes are a town-wide hazard in Tewksbury and are considered a high frequency event. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, this hazard will occur on average once every other 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.[32] Effects of a tornado include very strong winds in the middle and upper level of the atmosphere which turn clockwise. 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 Great Barrington, Massachusetts tornado in 1995 occurred in May; and the Windsor Locks, Connecticut tornado in 1979 occurred 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 4-19 provides more detailed information on the EF Scale.

Table 4-19. Enhanced Fujita Scale[34]

Fujita Scale			Derived		Operational EF Scale	
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

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

[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."
[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."

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.[37] Table 4-20 below provides additional information.

Table 4-20. Tornado Records for Middlesex County, 1955 to 2020[38]

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 Tewksbury, the National Oceanic and Atmospheric Administration (NOAA) only includes documentation of one tornado track that crossed through Town. On September 29, 1974, a 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.[39]

If another tornado were to occur in Tewksbury, damages would depend on the track of the tornado and would be most likely be high due to the prevalence of older construction and the density of development. 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

[36] Morrison, "Tornadoes of Massachusetts Past"; Epstein, "This Morning's Tornado in Concord, Explained."
[37] Lietz, "Tornado History Project: Middlesex County, Massachusetts."
[38] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database: Middlesex County."
[39] National Centers for Environmental Information (NCEI) and National Oceanic and Atmospheric Administration (NOAA), "Storm Events Database - Event Details - Tornado September 29, 1974."

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 Tewksbury are a low frequency event. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Massachusetts experiences an average of 1.7 tornados per year. Tornados are difficult to simulate well in climate models because of their small size. However, it is predicted that an increase in frequency and intensity of severe thunderstorms may increase the risk of tornadoes.

4.3.3 Nor'easters

A nor'easter is characterized by large counter-clockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, waves, and rain along the East Coast of North America. 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 beach erosion, flooding, and structural damage.[40]

Nor'easters generally occur on at least an annual basis, typically in late fall and early winter. Some years bringing 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. Nor'easters are commonly accompanied by a storm surge equal to or greater than two feet. High surge and winds during a hurricane can last from 6 to 12 hours, while these conditions during a nor'easter can last from 12 hours to three days.[41] Previous nor'easters events are listed in Table 4-21. Notably, the severe Coastal Storm in 1991 led to a federal disaster declaration.

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 a notable storm, and Tewksbury Police Department personnel remember how this event closed down the entire state and made access to certain areas impossible. Now, Tewksbury police cars have all-wheel drive and the Police Department has its own snowplow. However, long events similar to the Blizzard of '78 wear out personnel.

More recently, the blizzard of 2013 left nearly 400,000 Massachusetts residents without power.[42] A series of winter storms in March 2018 also caused significant snowfall amounts (including Winter Storm Riley on March 2, Winter Storm Quinn on March 8, and Winter Storm Skylar on March 13). A FEMA Major Disaster Declaration was issued to provide recovery assistance to Massachusetts counties including Middlesex.[43]

[40] 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."
[41] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA).
[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."

Table 4-21. Nor'easter Events for Massachusetts, 1978 to 2020[44]

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

The Town of Tewksbury 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, Tewksbury is not subject to the coastal hazards often associated with nor'easters.

Nor'easters in Tewksbury are high frequency events. As noted by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Nor'easters are currently the most frequently occurring natural hazards in the state.

4.3.4 Severe 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.[45]

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 Tewksbury. 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.

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

[45] 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."

Table 4-22. Previous Federal and State Disaster Declarations - Thunderstorms[46]

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
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 Tewksbury. Between 2009 and 2019, 248 thunderstorm events caused $3,014,000 in property damages. Two injuries and no deaths were reported.

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 Tewksbury. According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Massachusetts experiences 20-30 thunderstorm days per year.

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

4.3.5 Climate Change Impacts: High Winds

While Tewksbury's current 100-year wind speed is 96 mph,[47] 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.[48] The anticipated increase in frequency and intensity of severe thunderstorms may also increase the risk of tornadoes.[49]

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 can become difficult to pass. This issue may be especially difficult for vulnerable populations such as elderly people 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 4-7: Snow in Tewksbury. Photos from Tewksbury Twitter

Winter storms are a potential town-wide hazard in Tewksbury. 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 4-23 below.

[47] American Society of Civil Engineers (ASCE), "ASCE 7 Hazard Tool: Tewksbury, Massachusetts."
[48] Walsh and Wuebbles, "National Climate Assessment - Chapter 2: Our Changing Climate."
[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."

Table 4-23. Previous Federal and State Disaster Declarations[50]

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
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.[51]

[50] Federal Emergency Management Agency (FEMA), "Disasters: Total Number of Declared Disasters."
[51] 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."

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.[52] 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[53] 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 4-24. 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 large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events.[54]

Table 4-24. NESIS Categories[55]

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.[56] NOAA data demonstrates that the 30-year average snowfall for the City of Boston (based on data from 1981-2010) is 32.8 inches.[57] 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

[52] National Oceanic and Atmospheric Administration (NOAA) and National Weather Service, "Glossary: Heavy Snow."
[53] Kocin and Uccellini, "The Northeast Snowfall Impact Scale (NESIS)."
[54] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[55] 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."
[56] National Oceanic and Atmospheric Administration (NOAA) and National Weather Service, "Boston Breaks Record Seasonal Snowfall."
[57] National Oceanic and Atmospheric Administration (NOAA) and National Centers for Environmental Information (NCEI), "National Climate Report - February 201 9- Winter Snowfall Departure from Average."

damage. The greatest damage was during this time frame was a storm in 2011 causing $926,000 of damage.

The town 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 Tewksbury'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 Tewksbury. 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 Tewksbury. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, this hazard can occur 1.5 times per year.

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.[58]

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.[59]

Climate projections indicate that climate change will result in more precipitation during the winter in the Northeast.[60] This trend may result in more frequent and/or more severe winter storms.

[58] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[59] 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."
[60] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MA Climate Change Clearinghouse."

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 Tewksbury, and areas surrounding the Tewksbury State Hospital and the Great Swamp are at a higher degree of risk than the rest of Town, it is not a large occurrence. The Town is not overly concerned about the potential for brushfires.

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 4-25 summarizes Richter scale magnitudes and corresponding earthquake effects.[61]

Table 4-25. Richter Scale and Effects[62]

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally, not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage
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.[63] A summary of historic earthquakes in the Boston area is included in Table 4-26 below:

[61] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[62] Louie, "What Is Richter Magnitude?"
[63] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Table 4-26. Historical Earthquakes in Massachusetts and Surrounding Area, 1727-2020[64]

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
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
VA - Mineral	8/23/2011	5.8
MA - Nantucket	4/12/2012	4.5
ME - Hollis	10/17/2012	4.0
MA – Newburyport	2/20/2013	2.3
NH – Contoocook	10/11/2013	2.6
MA – Freetown	1/9/2014	2.0
MA – Bliss Corner	2/11/2014	2.2
MA – off Northshore	8/18/2014	2.0
CT - Deep River Center	8/14/2014	2.7
CT – Wauregan	1/12/2015	3.3
CT – Wauregan	1/13/2015	2.6

[64] United States Geological Survey (USGS), "Earthquake Hazards Program."

Table 4-26. Historical Earthquakes in Massachusetts and Surrounding Area, 1727-2020[64]

Location	Date	Magnitude
RI – Newport	2/3/2015	2.0
NH – Epsom	8/2/2015	2.2
NH – Contoocook	3/21/2016	2.8
MA – Rockport Coast	6/1/2016	2.2
NH – Bedford	2/11/2017	2.2
NH – East Kingston	2/15/2018	2.7
ME – Cape Neddick	7/16/2018	2.1
MA – Nantucket	8/18/2018	2.4
MA – Templeton	12/21/2018	2.1
MA – Gardner	12/23/2018	2.2
RI – Charlestown	3/1/2019	2.3
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 provides additional information.

Tewksbury is located in an area with a PGA of 16 %g with a 2% probability of exceedance in 50 years (please refer to Figure 4-8). Compared to the rest of the United States, Massachusetts overall has a low risk of earthquakes.

No earthquake epicenters have been recorded within Tewksbury. 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. Earthquakes often trigger fires. The water distribution system may be disrupted, thus posing a risk for public health and safety.

While there is no established correlation between earthquakes and climate change, an earthquake can still have catastrophic impacts on a community. A serious earthquake in Massachusetts is possible. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations.

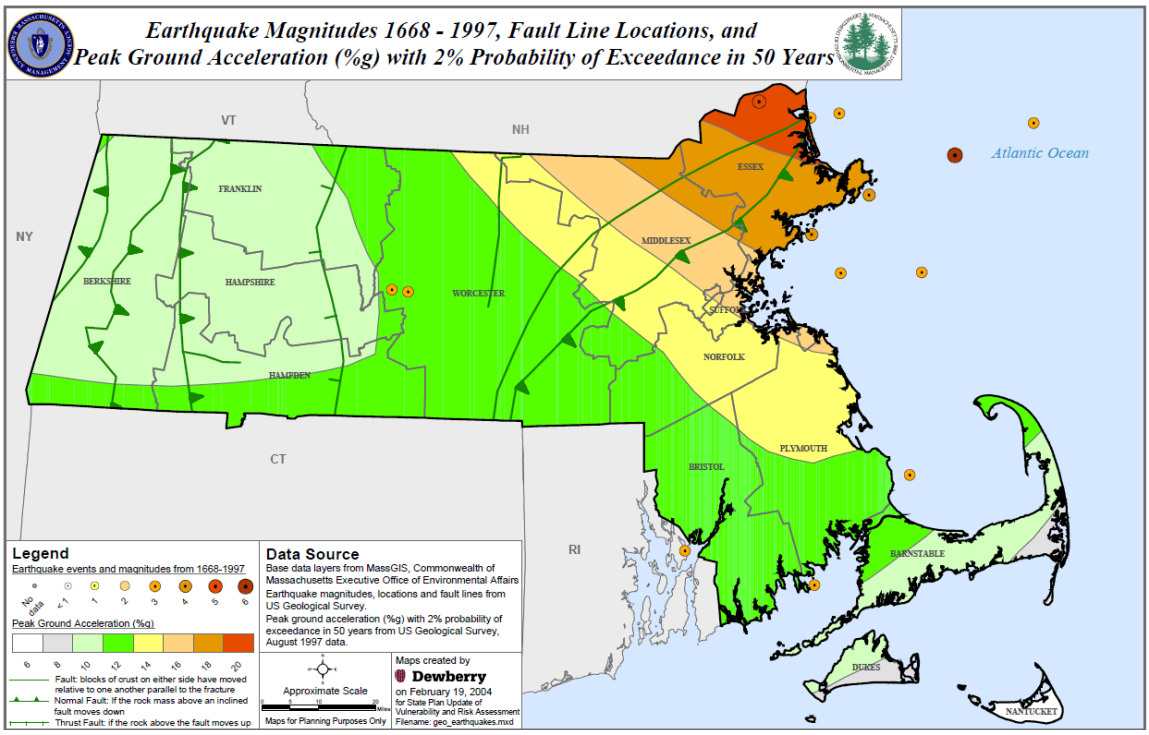


Figure 4-8. State of Massachusetts Earthquake Probability Map
Source: Massachusetts State Hazard Mitigation Plan

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. 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 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 Tewksbury. Hazus Multi-Hazard (Hazus) is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. 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 Tewksbury was outlined using Town census tracts. The arbitrary event scenario was used for Tewksbury,

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 Tewksbury 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. The tables below show the estimated damage from both a magnitude 5.0 and a magnitude 7.0 earthquake in the municipality.

Table 4-27. Infrastructural Damage from a Magnitude 5.0 Earthquake on Buildings in Tewksbury

Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[1]
Residential	9,558	4,555	47.7%	$311,923,400
Commercial	621	481	77.5%	$133,336,300
Industrial	208	164	78.8%	$38,789,700
Others	92	68	73.2%	$14,859,700
TOTAL	**10,479**	**5,268**	**50.3%**	**498,909,100**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

Table 4-28. Infrastructural Damage from a Magnitude 7.0 Earthquake on Buildings in Tewksbury

Land Use Type	Total Number of Buildings	Total Number of Buildings Damaged[1]	Percent of Buildings Damaged[1]	Total Value of Building Damage[1]
Residential	9,558	9,532	99.7%	$2,665,642,000
Commercial	621	621	99.9%	$832,164,300
Industrial	208	208	99.9%	$236,699,100
Others	92	92	99.9%	$94,114,200
TOTAL	**10,479**	**10,453**	**99.8%**	**$3,828,619,600**

[1]Includes Slight, Moderate, Extensive, and Complete Damage
[2]Includes Building, Content and Inventory

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 business interruption loss; monetary wage, capital-related, rental and relocation costs; as well as displaced households and persons seeking temporary shelter. Additional property damage and business interruption loss were calculated as well, and a full HAZUS risk response report for each earthquake category can be found in Appendix B.

Earthquakes are classified as a high frequency event in Tewksbury. As defined by 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.[65]

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, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards.[66] 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 4-29 below.

Table 4-29. Landslide Volume and Velocity[67]

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

Tewksbury Town Hall is sited at an elevation of 120 feet above sea level.[68] No significant landslides have been recorded for Tewksbury or Middlesex County (for more information, please refer to Appendix B of the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan).[69] 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 Tewksbury. These events can occur once in 50 to 100 years (a 1% to 2% chance of occurring each 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

[65] United States Geological Survey (USGS), "Landslides 101."
[66] United States Geological Survey (USGS).
[67] Cardinali et al., "A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy."
[68] Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG), "2019 Open Space and Recreation Plan."
[69] 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."

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.[70] The State Hazard Mitigation and Climate Adaptation Plan[71] 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 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."*

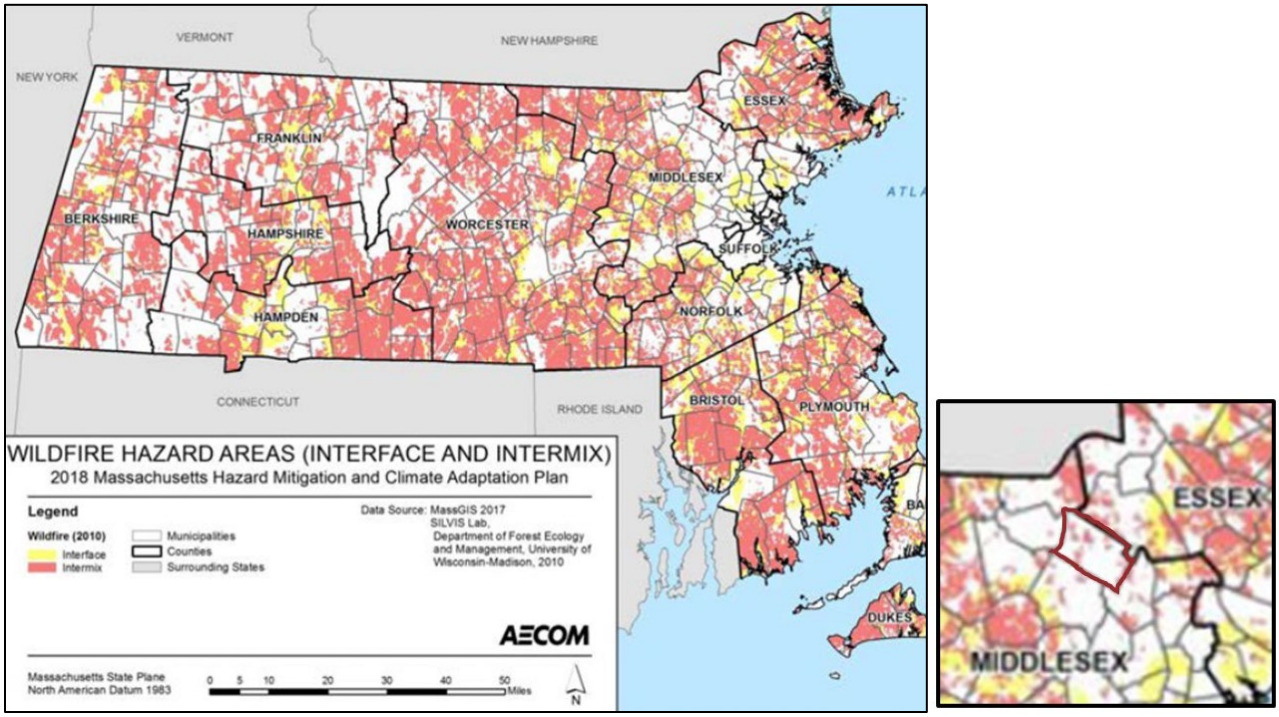


Figure 4-9: Wildfire Hazard Areas Statewide (left) and in Tewksbury (right)

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

[71] 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."

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 Tewksbury. 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 under the age of 5, people with mobility limitations, and people with low socioeconomic status.[72] 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 Tewksbury Fire Department responds to a fair amount of brush fires. In fact, four hundred brush fires were reported in Tewksbury over a three-year period. The areas surrounding the Tewksbury State Hospital and the Great Swamp are at a higher degree of fire risk than other parts of Town. After a dry winter and spring in 2012, a field caught fire near Main Street and spread quickly before being extinguished by the Tewksbury Fire Department.[73] Brush fires are classified as low frequency events in Tewksbury.

4.7 Extreme Temperatures

Extreme temperatures are considered a town-wide hazard in Tewksbury. These events can include both temperatures over and under seasonal averages. These extreme temperature events can range from brief to lengthy.

Middlesex County has four clearly defined seasons. Extreme temperatures fall outside of the ranges typically experienced during these seasons. Middlesex County's most recent observed summer temperature was 71.33°F in 2005. The County's most recent observed winter temperature was 26.97°F in 2005.[74]

[72] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA).
[73] Northern Middlesex Council of Governments (NMCOG), "Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update."
[74] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Average Temperature: Middlesex County, MA."

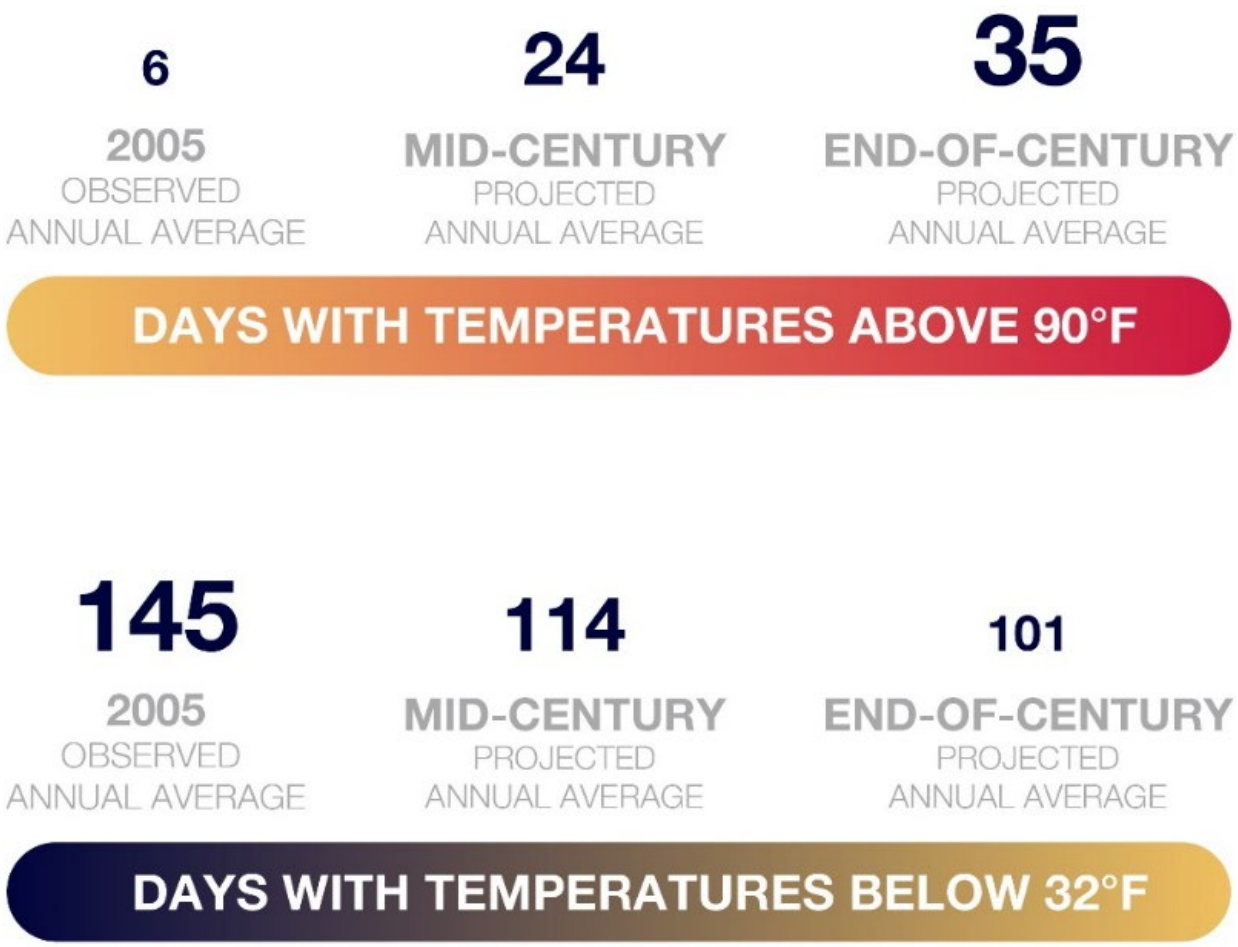


Figure 4-10: Anticipated Temperature Changes in Massachusetts

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 4-11 below provides more information.

Extremely cold temperatures can create dangerous conditions for vulnerable populations. The homeless, the elderly, and people with disabilities are often most vulnerable. In Tewksbury, 17.5% of the population are over 65 years old and 6.2% of the population has a disability.[75] 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.

[75] United States Census Bureau, "QuickFacts: Tewksbury Town, Middlesex County, Massachusetts."

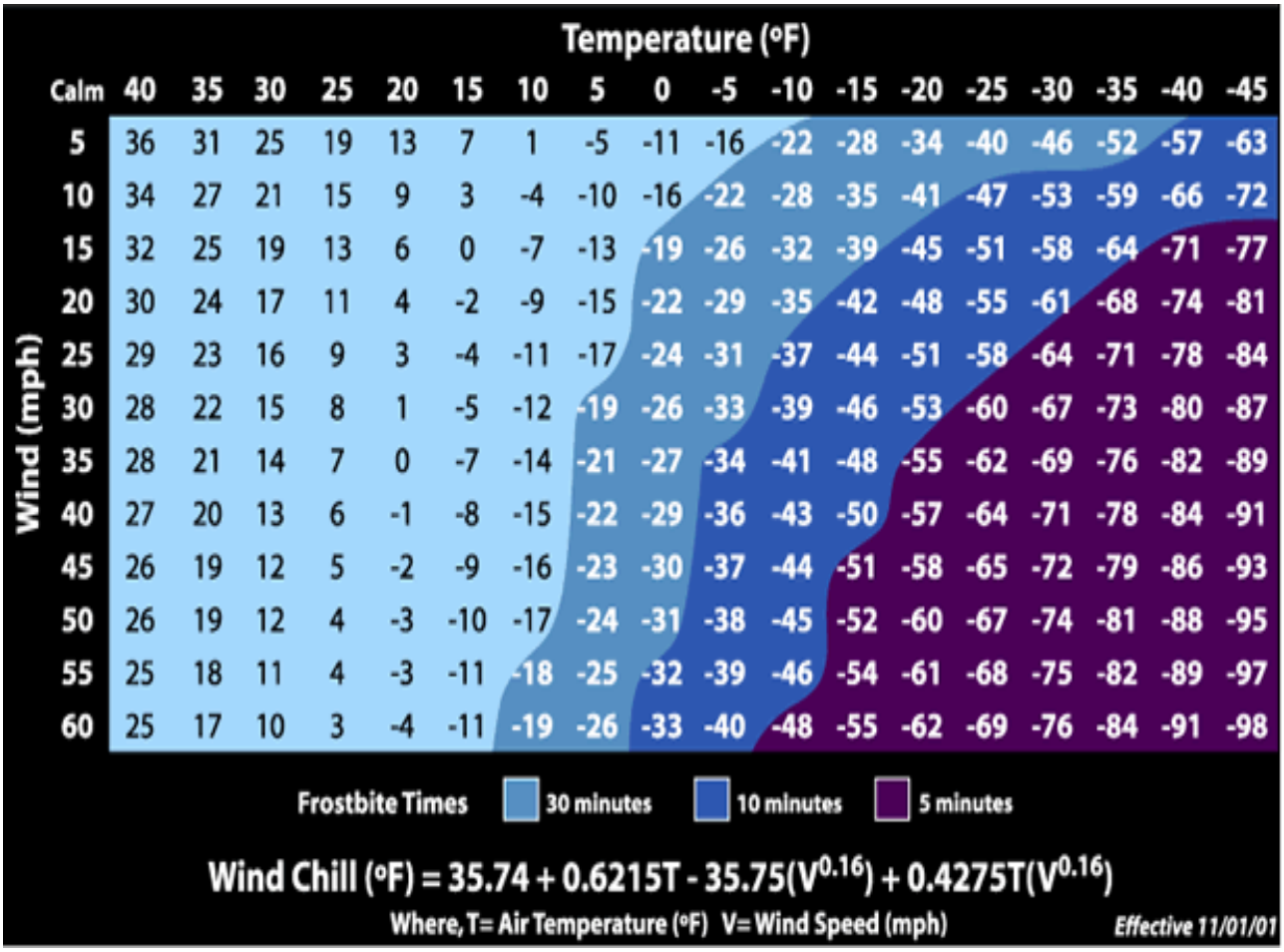


Figure 4-11. Windchill Temperature Index and Frostbite Risk
Source: National Weather Service

NOAA's National Centers for Environmental Information Storm Events Database provides data for extreme cold events. Between 2000 and 2018, Middlesex County experienced three extreme cold and will chill events, which luckily caused no deaths, injuries, or property damage. Table 4-30 provides more information.

Table 4-30. Middlesex County Extreme Cold and Wind Chill Occurrences, 2000-2018[76]

Date	Deaths	Injuries	Damage
2/15/2015	0	0	0
2/16/2015	0	0	0
2/14/2016	0	0	0

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

4.7.2 Extreme Heat

Increased temperatures will impact all locations within Tewksbury. Projected heat days and heat waves can have an increased impact in densely settled urban areas. These can become "heat islands" as dark-colored asphalt and roofs store the heat from the sun. Homeless people are increasingly vulnerable to extreme heat. The capacity of homeless shelters is typically limited. Impacts from heat stress can exacerbate pre-existing respiratory and cardiovascular conditions. According to the Centers for Disease Control and Prevention, additional populations 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,
- Individuals with respiratory conditions,
- The general public who may overexert themselves during extreme heat events.

The NWS issues a Heat Advisory when the Heat Index (Figure 4-13) is forecast to reach 100˚F or higher for at least two days, although the guidance varies depending on location. The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach or exceed 105˚F for at least two days.[77] Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. In Boston, over 50 people die each year due to heat-related illnesses. From 1979-2012, excessive heat exposure caused in excess of 8,000 deaths in the United States.[78] During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

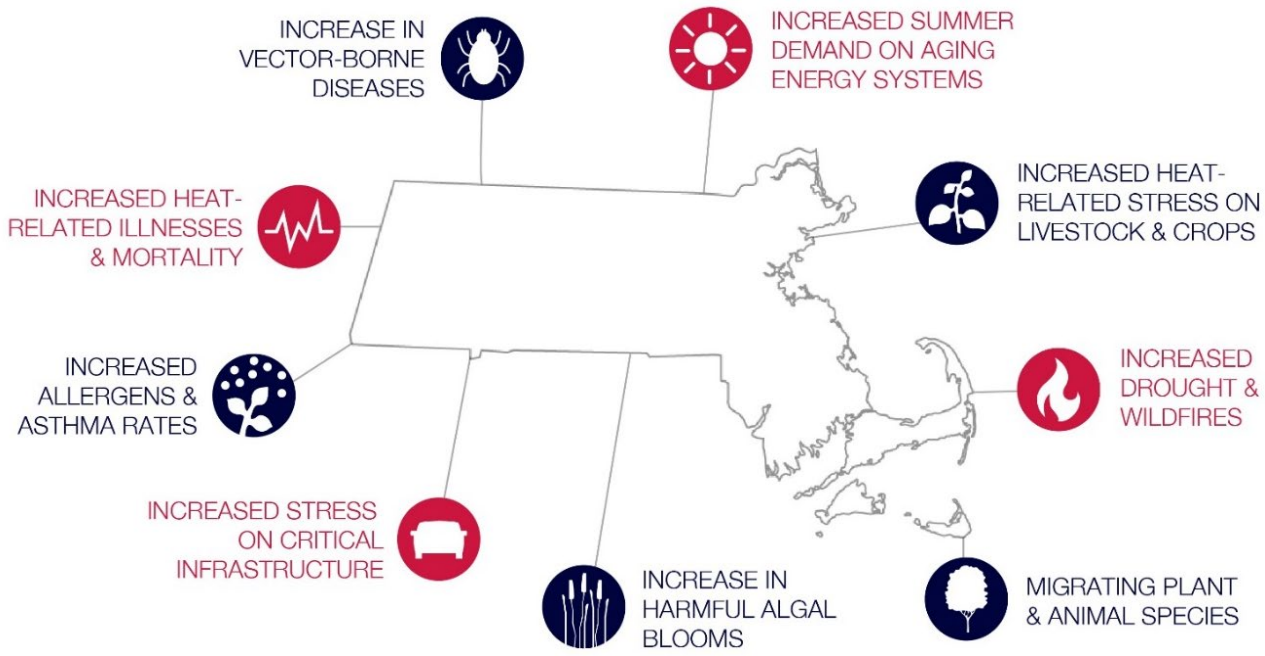


Figure 4-12: Potential Impacts from Increasing Temperatures

[77] National Oceanic and Atmospheric Administration (NOAA), "Heat Watch vs. Warning."
[78] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Relative Humidity (%)	Temperature (°F)																
	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)

On July 6, 2013, a postal worker in MA collapsed and died as the Heat Index reached 100°F.[79] 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 Tewksbury, children under eighteen years old make up 19.7% of the population, and 17.5% are over 65 years old.[80] However, even young and healthy individuals can succumb to heat if they participate in strenuous 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.[81] 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.

The Town of Tewksbury 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 2018, Middlesex County experienced three extreme heat days, which did not result in injury or property damage. One event did result in a single death in 2013. Please refer to Table 4-31 for more information.

[79] 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."

[80] United States Census Bureau, "QuickFacts: Tewksbury Town, Middlesex County, Massachusetts."

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

Table 4-31. 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+)*[82]

Based on Figure 4-14 below, compiled in 2019 by the Massachusetts Department of Public Health Bureau of Environmental Health (BEH), Tewksbury has a population density that ranges from less than 1,270 residents to 5,780 residents per square mile. The total number of population vulnerability measures in each Census Tract (2010) is 2. Population vulnerability measures defined by the BEH include low income, low English proficiency, non-white (Hispanic and non-Hispanic ethnicities), and elderly residents.

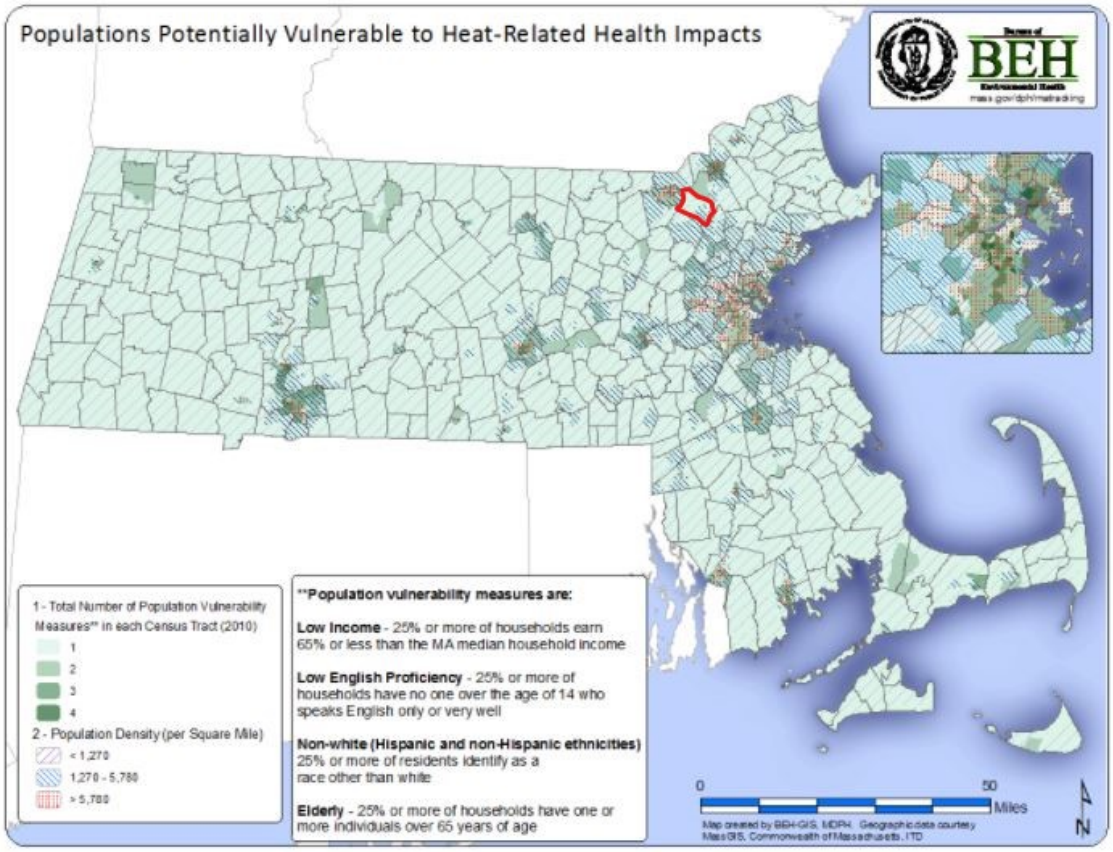


Figure 4-14: Populations Potentially Vulnerable to Heat Related Health Impacts (Tewksbury is outlined in red). Image by the Massachusetts Department of Public Health, Bureau of Environmental Health, 2019

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

Extreme temperatures are classified as medium frequency events. According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, between four and five heat waves (3 or more consecutive days of 90˚F+ temperatures) occur annually in Massachusetts.[83]

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 4-15 below). These changes in temperature would also have a detrimental impact on air quality and public health concerns including asthma and other respiratory conditions.[84]

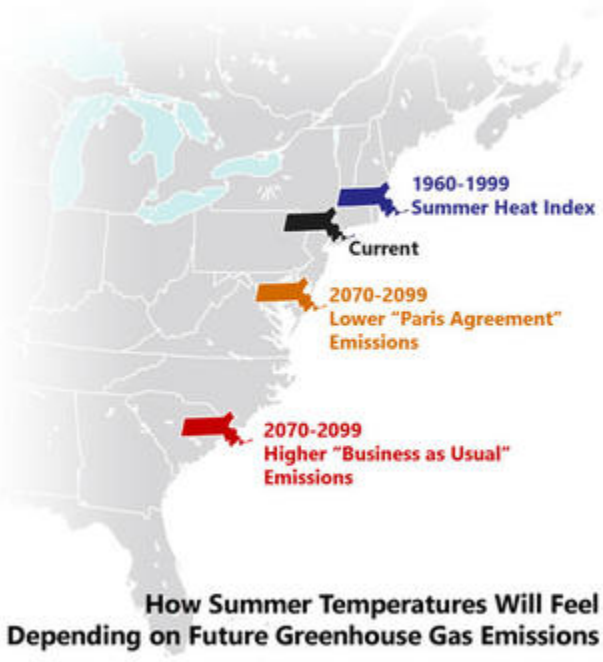


Figure 4-15. How Summer Temperatures Will Feel[85]

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.[86]

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[83] 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."

[84] Frumhoff et al., "Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions."

[85] Mass Audubon, "Effects of Climate Change on Rising Temperatures."

[86] 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."

Middlesex County's observed annual precipitation in 2005 was 56.17 inches.[87] 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, 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 six regions: Western, Central, Connecticut River Valley, Northeast, Southeast, Cape Cod, and Islands Region.[88] Tewksbury 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 (was Warning), and Level 4 - Emergency Drought (was Emergency), respectively, of the draft Drought Management Plan update. 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.[89]

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. (In its draft updated Drought Management Plan, the Drought Management Trask Force has proposed to eliminate the precipitation index that is based on percent of normal precipitation.)

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.[90]

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[87] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "Annual Total Precipitation: Middlesex County, MA."

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

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

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

Figure 4-16 illustrates statewide drought levels in Massachusetts from 1850 to 2012, using the Standardized Precipitation Index (SPI). Table 4-32 below summarizes a history of Massachusetts droughts between 1879 and 2017.[91]

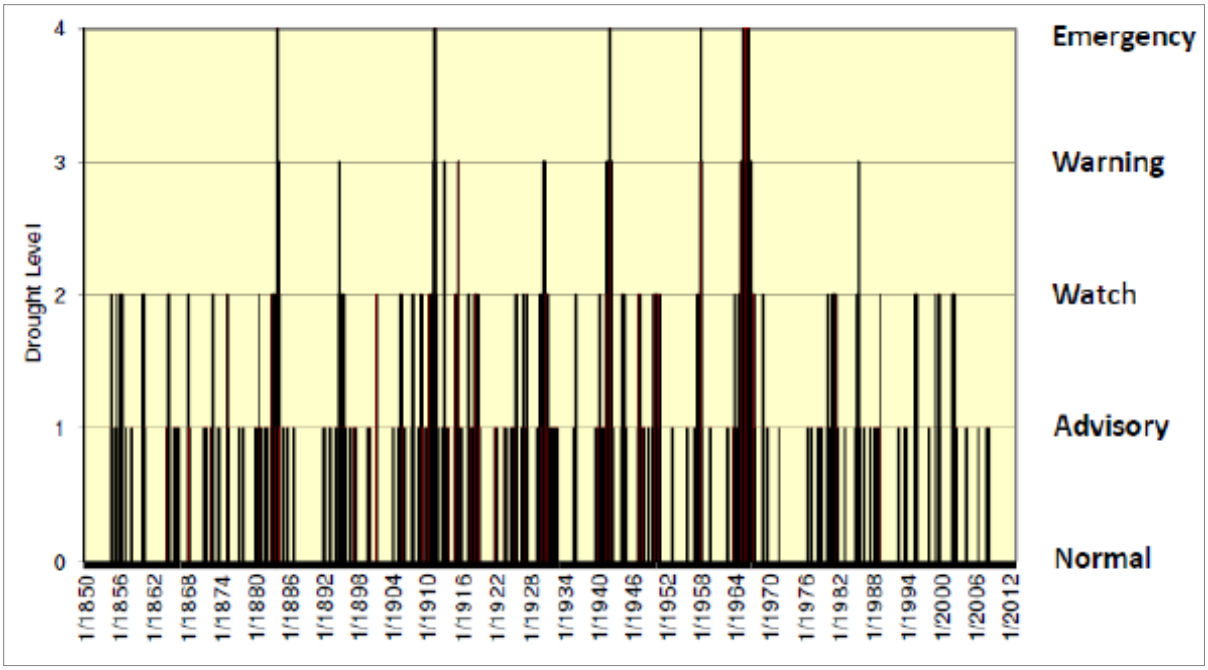


Figure 4-16: Statewide Drought Levels Using SPI Thresholds, 1850 to 2012.

Table 4-32. Droughts in Massachusetts Based on Instrumental Records[92]

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.

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

[92] 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."

Table 4-32. Droughts in Massachusetts Based on Instrumental Records[92]

Date	Area Affected	Recurrence Interval (years)	Remarks
1961 to 1969	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.
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).

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.[93]

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.[94]

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.[95] There were six drought watches in Massachusetts in 2002, five drought watches in 2016, and two drought watches in 2017.[96] Figure 4-17 presents an example of drought conditions in the six drought regions.

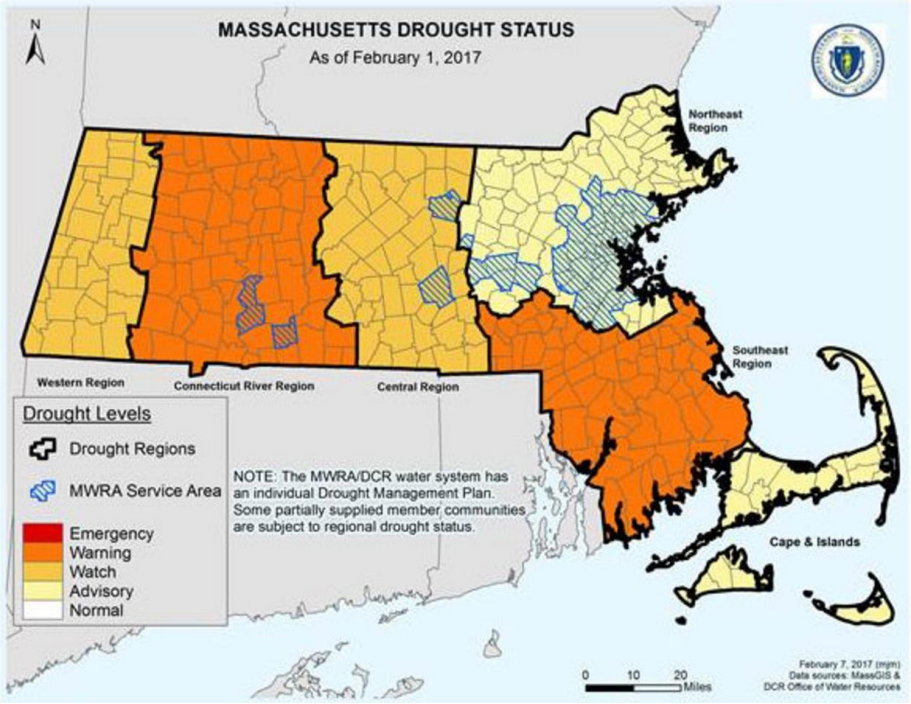


Figure 4-17. Massachusetts Drought Status, February 2017. Image by the Massachusetts Department of Conservation and Recreation

[93] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[94] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR); Massachusetts Department of Conservation and Recreation (DCR), "Recent Drought History."
[95] Massachusetts Emergency Management Agency (MEMA) and Massachusetts Department of Conservation and Recreation (DCR), "Commonwealth of Massachusetts State Hazard Mitigation Plan."
[96] Massachusetts Department of Conservation and Recreation (DCR), "Recent Drought History."

Drought is a potential town-wide hazard in Tewksbury 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 10% for every degree Celsius of warming.[97] During Tewksbury'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 wear and tear on their equipment, expense of apparatus, and requires calling in off-duty staff. The last Town water ban that stakeholders could remember was 15 years ago.

A long-term drought could lead to impacts to Tewksbury's wetlands and streams, and to the Merrimack River. Tewksbury relies on the Merrimack River for its drinking water source, and water supply has not been a significant issue to-date, but conditions could change significantly with future climate change. Droughts are classified as a medium frequency natural hazard event in Tewksbury.

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.[98]

[97] 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."

[98] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), "MA Climate Change Clearinghouse."

5.0 EXISTING MITIGATION MEASURES

FEMA categorizes hazard mitigation measures into four types as displayed in Table 5-1. The existing protective measures already being implemented in the Town of Tewskbury including zoning and regulations, community outreach and engagement, and infrastructural projects and maintenance. Infrastructure maintenance generally addresses localized drainage problems, while large scale capacity problems may require pipe replacement or invert elevation modifications. These more expensive projects are subject to the capital budget process. The Town's existing mitigation measures are described by hazard type here and are summarized in Table 5-2 below. Many upgrades to existing measures are noted in the following sections.

Table 5-1. FEMA Mitigation Action Types[1]

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 ordinances • 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 also preserve or restore the functions of natural systems.	• Sediment and erosion control • Stream corridor restoration • Forest management • Conservation easements • Wetland restoration and preservation

[1] Federal Emergency Management Agency (FEMA), "Local Mitigation Planning Handbook. Table 6.1: Types of Mitigation Actions."

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 • Presentations to school groups or neighborhood organizations • Mailings to residents in hazard-prone areas. • StormReady • Firewise Communities

5.1 Summary of Existing Mitigation Measures

There are numerous existing natural hazard mitigation measures already in place in Tewksbury. These were identified through feedback from the Core Team, CRB Workshop participants, and other stakeholders, and are summarized in Table 5-2 below.

Table 5-2: Summary of Existing Mitigation Measures

Entity	Type of Existing Protection	Area Covered	Effectiveness or Enforcement	Improvements or Changes Needed
Multi-Hazard				
Planning	Green Community Designation	Town-wide	Effective	None. Ongoing program.
Open Space & Recreation Committee	Open Space and Recreation Plan addresses Natural Disaster Mitigation	Key parcels town-wide	Effective	None
Water Department and DPW, Planning	Capital Improvement Program	Town-Wide	Effective	None
Housing Authority, Police Department	Emergency generators	Town wide	In-progress	Housing Authority properties do not currently have generators. Generators will be added to schools as they are renovated. The Town is working on installing generators for

				sewer pump stations.
Emergency Management	Reverse 911	Town wide	Effective	None
Police Department	All-Hazard Plan	Town wide	Effective	None
Emergency Management	Shelter	Senior Center	Effective	None
Housing Authority	Energy Efficiency	Housing Authority properties	Effective	None
Police Department	Traffic support and escort	Police Department	Effective	None
Facilities	Electric Vehicle Charging Stations	Town Hall, Library	Effective	None
Flood-Related Hazards				
Planning	The Town participates in the National Flood Insurance Program	Town-wide	Effective	None
Planning	Tewksbury participates in the Community Rating System (CRS)	Town-wide	Effective	None
Planning	Floodplain overlay district zoning bylaw	Town-wide	Effective	None
DPW	Discharges to municipal storm sewers by-law has been adopted	Town wide	Effective	None
Conservation Commission	Local Wetlands Protection Bylaw	Town-wide	Effective	None
Planning, DPW	Subdivision regulations address drainage, erosion and sediment control, and have additional standards for the floodplain district	Town-wide	Effective	None
DPW	Street Sweeping Program, Cleaning	Town-wide	Effective	None

	Catch Basins and Culverts			
Planning, State Hospital	Groundwater Protection Overlay District	Wellhead area for the Tewksbury State Hospital water supply.	Effective	None
Planning	FMA and HMGP Grants	Two repetitive flood loss properties, and East Street/Strong water Brook crossing	Effective	None
Planning	Stormwater Management and erosion control bylaw	Town wide	Effective	There is interest in improved stormwater management regulations.
Housing Authority	Manhole Maintenance	All Housing Authority properties	Effective	None
Planning	Drainage improvement program	Town wide	Effective	None
DPW	Stormwater Management	Whipple Road	Effective	None
Police Department	Sump Pumps	Police Department	Ongoing	Assess flood risk and options for elevation or relocation
Dam Mitigation Measures				
DPW	Repair of the Ames Pond Dam and Dikes (privately owned)	Ames Pond Dam and Dikes A and B	Effective	Future maintenance responsibilities for these facilities need to be addressed.
Wind-Related Hazards				
DPW	DPW Forestry Department Tree Maintenance Program	Town-wide	Effective	None

Winter-Related Hazards				
DPW, Parks and Facilities, Housing Authority	Snow removal	Town wide	Effective	None
Fire-Related Hazards				
Fire Department, Building Facilities	Measures to address wildfire risk	Town-wide	Effective	None
Facilities, Fire Department	Backup generators	Fire Department truck	Effective	The Fire Department does not have portable generators that they could lend out
Fire Department	Road maintenance	Town wide	Effective	None
Fire Department	Open burning permits	Town wide	Effective	None
Fire Department	Fire Department review of proposed development	Town wide	Effective	None
Fire Department, DPW	Public education	Town wide	Effective	None
Fire Department	Statewide Fire Mobilization Plan	Statewide effort	Effective	None
Fire Department	Regional Emegency Planning Committee			
Fire Department	GPS Units	Town wide	Effective	None
Extreme Temperature-Related Hazards				
Housing Authority	Housing Authority water use	All Housing Authority properties	Effective	None
DPW, Parks and Facilities	Tree planting	Town wide	Effective	None
DPW	Backup water supply	Town wide	Effective	None

Police Department	Cold Weather Alerts	Town wide	Effective	None
Geologic				
Planning, Facilities	Enforce the Massachusetts State Building Code section on designing for earthquake loads (780 CMR 1612.0)	Town wide	Effective	None

These existing mitigation measures are organized by climate hazard and described in more detail below.

5.2 Existing Multi-Hazard Mitigation Measures

Green Community Designation: The Town has been designated by the Department of Energy Resources as a Green Community. Hence, the Town conducts projects annually that improve energy efficiency and reduce greenhouse gas emissions. This is an ongoing program that the Town is actively participating in.

Capital Improvement Program: The town has a capital improvement program that includes projects that will benefit natural hazard mitigation, such as the implementation of stormwater management improvements. The program is updated annually and is currently recieving input. It will be effective in July 2020.

Regional Emegency Planning Committee: The Tewksbury Fire Chief attends monthly meetings.

Emergency generators: The Housing Authority is assessing acquisition of generators for each of their developments, including the cost of maintenance. The Senior Center has a generator and the Police Station has a 20-year old generator. Additionally, generators are being installed at the following pump stations through the Hazard Mitigation Grant Program:

Wamesit P.S
New Jersey Road P.S.
Joanne Drive P.S.
Westland Drive P.S.
Germano Drive P.S.
Eastgate Road P.S.
Riverdale P.S.
Louis Road P.S.
Grasshopper Lane P.S.

Reverse 911: Tewksbury has had a Reverse 911 system for many years.

All-Hazard Plan: Police departments that are accredited and certified in Massachusetts, including the Tewksbury Police Department, must review and sign off on the All-Hazards Plan each year. The plan typically identifies existing shelters and needs, among other items.

Emergency Shelters: The Town's emergency shelters include the following locations:

> ***Senior Center:*** Built with a kitchen and generator for sheltering capability. Includes emergency storage for cots, blankets, pillows, and other supplies. Most recently, the Senior Center was used as a daytime warming station. The Housing Authority directs their residents to use the Senior Center when shelters are needed.
>
> ***Tewksbury Memorial High School:*** The high school would be used as an emergency area in the case of a virus or outbreak. Town staff would meet at the high school and emergency supplies would be moved from the Senior Center to the high school gym. The high school would also be used in the event of a tornado warning.
>
> ***Tewksbury Congregational Church***: This large, standalone facility has been used as a warming station in the past.
>
> ***Billerica Shelter:*** The Town of Tewksbury has been invited to participate with Billerica's shelter, which has been used during power outages after ice storms.

Energy Efficiency at Housing Authority Properties: The State requires an energy assessment of Housing Authority properties every 5 years. The Authority has switched lighting to LED, installed air source heat pumps in many units, changed out refrigerators and air conditioning in many units, and completed weatherization including caulking, changing weather stripping on main doors, and adding blown-in/foam insulation. The Housing Authority also uses solar energy. The building on Corrine Way is a designated Green Building.

Traffic Support and Escort: The Police Department provides traffic support and escort for buses if evacuating nursing homes to the senior center.

Comprehensive Emergency Management Plan (CEMP): Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. These plans address mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. These plans contain important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to all the hazards discussed in this plan.

Regional Emergency Planning Committee (REPC): Under the Emergency Planning and Community Right to Know Act of 1986, communities are required to establish Local Emergency Planning Committees (LEPC) or Regional Emergency Planning Committees (REPC) to develop a response plan for chemical emergencies. In accordance with this legislation, the Town of Tewksbury is working with the Greater Lowell REPC (which includes Billerica, Chelmsford, Dracut, Lowell, Tyngsboro, and Wilmington) to identify locations where hazardous materials are stored, used, and transported.[2]

Public Education: Emergency Preparedness public education is available on the Town's website and social media, via the Town's homepage "Emergency Info" tab, the Fire Department, and the Police Department. Additionally, the Tewksbury Health Department's webpage links to information related to mosquito control, virus outbreak information, and other resources. The Town also maintains social media platforms on Facebook and Twitter, which are used to advertise public meetings and share

[2] Massachusetts Emergency Management Agency (MEMA), "Massachusetts Emergency Planning Committees (EPC)."

information. Additionally, the Fire and Police Departments host collaborative public open houses at their stations.

Multi-Department Review of Developments: Multiple Town departments, such as Planning, Zoning, Health, Public Works, Engineering, Fire, Police, Emergency Management and Conservation, thoroughly review all subdivision and site plans prior to approval.

Regional Emergency Communication Center (RECC): The Town has met its goal to establish a regional 911 center. This center will provide state of the art communication for both Tewksbury and Dracut.

Massachusetts State Building Code: The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads.

Medical Reserve Corps (MRC) Volunteers: The Upper Merrimack Valley MRC is a volunteer program that provides ongoing health care and community services and support after a disaster or public health emergency to communities including Tewksbury. The Town of Westford's Health Department leads this initiative.

5.3 Existing Town-Wide Mitigation for Flood Related Hazards

Tewksbury employs a number of practices to help minimize potential flooding, reduce impacts from flooding, and to proactively maintain existing drainage infrastructure. Existing Town-wide mitigation measures include the following:

Participation in the NFIP – Tewksbury 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 offers flood insurance to communities that comply with the minimum standards for floodplain management.[3]

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.[4] Tewksbury first joined the CRS in October 1993,[5] is still participating in the program, and has a Class 10 Designation.[6] FEMA assigns each community a point-based classification (ranging from 1-10) that reflects the level of their floodplain management efforts. Class 1 communities receive a 45% discount on flood insurance premiums. Class 10 communities do not receive a discount.[7]

FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website at fema.gov/policy-claim-statistics-flood-insurance. Additionally, the Massachusetts Department of Conservation and Recreation (DCR) shared the information below for the Town of

[3] Federal Emergency Management Agency (FEMA), "The National Flood Insurance Program."
[4] Federal Emergency Management Agency (FEMA), "National Flood Insurance Program Community Rating System."
[5] Federal Emergency Management Agency (FEMA), "NFIP Flood Insurance Manual Appendix F: Community Rating System."
[6] Massachusetts Department of Conservation and Recreation (DCR), "Community Information System: Repetitive Loss for the Town of Tewksbury."
[7] Federal Emergency Management Agency (FEMA), "National Flood Insurance Program Community Rating System."

Tewksbury, related to flood insurance and repetitive loss. 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]

Table 5-3. National Flood Insurance Program in Tewksbury[9]

Flood Insurance Data		Repetitive Loss (RL) Data	
Flood Insurance Policies in Force	125	RL Buildings	7
Premium	$118,894	RL Losses	21
Insurance in Force	$35,158,700	RL Payments (total)	$153,344.12
Number of Closed Paid Losses	55	RL Payments (building)	$140,945.19
Dollar Amount of Closed Paid Losses	$353,336.68	RL Payments (contents)	$12,398.93

The Town complies with the NFIP by enforcing floodplain regulations, maintaining up-to-date floodplain maps, and providing information to property owners and builders regarding floodplains and building requirements. Tewksbury has also adopted an improved stormwater management program as a result of its participation in the CRS program.

Floodplain Overlay District Bylaw: The Town's floodplain overlay district zoning bylaw was revised in 2002. All development in the district must comply with Chapter 131, Section 40 MGL; 780 CMR (State Building code) for flood resistant construction which addresses floodplain; 310 CMR Section 10.00; and 302 CMR 6.00, as well as DEP Title V regulations for subsurface disposal of sanitary sewage. The town is now using the most up-to-date FEMA Flood Insurance Rate Map (FIRM), which is from 2016.

Discharges to Municipal Storm Sewers Bylaw: Includes enforcement by the DPW on illicit connections to prevent pollutant from entering the system.

Local Wetlands Protection Bylaw: The Town has a local wetlands protection bylaw which states that no person shall alter land within 100 feet of any resource area. Resource areas can include vegetated wetland, meadow, swamp, or bog; or within 100 feet of any river, brook, stream (intermittent or otherwise), pond of lake; any land under water; or within 100 feet of bordering or isolated land subject to flooding or inundation by groundwater or surface water. The local bylaw gives the Commission authority to regular buffers to resource areas.

Stormwater Management and Erosion Control Bylaw: The bylaw was approved by town meeting in October 2010 and Chapter 19 of the Stormwater Bylaws was amended in 2011. Most recently, the stormwater bylaw was updated at the June 2020 Town Meeting and is awaiting approval by the Attorney General.

Subdivision Regulations: Address drainage, erosion and sediment control, and have additional standards for the floodplain district. The peak rate of stormwater runoff shall not exceed the rate prior to construction based on a 2, 10, 25, 50 and 100-year storm design. Street drainage cannot be channeled into a wetland or water body without first going to a vegetated detention basin in

[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 Tewksbury."

accordance with DEP stormwater regulations. Where possible, streets must be laid out so that filling or construction in the flood plain district is not required. DPW and Planning are updating subdivision rules and regulations, including considerations related to stormwater runoff. Aiming for completion in 2020.

Groundwater Protection Overlay District: The Groundwater Overlay District bylaw protects the wellhead for the Tewksbury State Hospital drinking water supply.

Drainage Improvement Program: The Town passed a stormwater utility fee that will be established shortly, and is currently developing a stormwater capital budget.

Massachusetts Stormwater Regulations: These regulations are applied to developments within the jurisdiction of the Conservation Commission.

Wetlands Protection Act: The Tewksbury Conservation Commission administers the state's Wetlands Protection Act (Chapter 131, Section 40 MGL) to protect resource areas in and around wetlands, including land subject to flooding.

Open Space and Recreation Plan: The current Plan was recently approved by the State and includes a chapter on flood hazard areas and related data.

Street Sweeping Program: As part of the Town's program, street sweeping is conducted twice a year.

Cleaning Catch Basins and Culverts: As part of the Town's program, all catch basins are cleaned annually.

FEMA Flood Mitigation Assistance (FMA) and Hazard Mitigation Grant Program (HMGP) Projects: Two repetitive flood loss structures were elevated above base flood elevation, and culverts were installed on East Street to address flooding.

Housing Authority Manhole Maintenance: The Housing Authority contracts with a company to clean all manholes every year to prevent sewer back flow.

Stormwater Management: Built a rain garden drainage system along Whipple Road for the Long Pond Tributaries, to retain runoff before it enters another water supply. This project was completed using a combination of a 319 Grant and CPA funds.

Police Station Sump Pumps: Sump pumps in the basement of the police station run continuously to remove water from the basement even during normal conditions. There is a high water table in this location. The Police Station basement houses boilers and other critical equipment.

Public Education on Stormwater: The Town continues to fulfill the requirements of the EPA's National Pollutant Discharge Elimination System (NPDES) MS4 Stormwater Permit Regulations. The Town shares information on these efforts as part of the Stormwater Management Program webpage on the Town's website. The webpage shares resources including best practices for residents, business owners, and construction sites; brochures; a link to an article; and a video on stormwater. Additionally, plaques were installed along Whipple Road near the DPW to share information on stormwater projects.

5.4 Existing Dam Mitigation Measures

DCR Dam Safety Regulations: 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 communicates with the DCR Office of Dam Safety to confirm regular maintenance is performed to make sure the dams in Tewksbury are stable.

Permits Required for Construction: State law requires a permit for the construction of any dam.

5.5 Existing Town-Wide Mitigation for Wind-Related Hazards

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 measure against tornados given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages would be extremely high.

Tree Maintenance by Energy Utility National Grid: National Grid trims along power lines every five years.

DPW Forestry Department Tree Maintenance Program: The Town DPW has an ongoing program for removing diseased and dead trees which pose a risk to public safety and utility lines. A Hazard Tree Study was conducted since 2015. DPW currently has a grant to identify hazardous trees.

5.6 Existing Town-Wide Mitigation for Winter-Related Hazards

Snow Removal: The Town conducts snow plowing operations and provides standard sanding and salting. The Housing Authority also conducts snow removal operations on their properties.

Public Alerts: The Tewksbury Police Department issues public cold weather alerts.

Emergency Shelters: The Town's emergency shelters include the Senior Center and the Tewksbury Congregational Church, both of which have been used as warming stations in the past. Please refer to Section 5.2: Existing Multi-Hazard Mitigation Measures for more information on Tewksbury's emergency shelters.

5.7 Existing Town-Wide Mitigation for Fire-Related Hazards

Measures to Address Wildfire Risk: The Town requires fireproof roofing shingles. Vegetative fuel under power lines is also removed to reduce fire risk.

Backup Generators: The Fire Department has one generator on the fire truck, which is used for emergency situations.

Road Maintenance: This includes removing road debris that poses a fire risk, assessing bridges and roadways to ascertain their capability to support fire apparatus, and developing alternative routing plans where deficiencies are noted.

Public Education: The Tewksbury Fire Department's Student Awareness of Fire Education (SAFE) Coordinator conducts events at schools. The SAFE Coordinator also works with the Police Educator on community events. For example, the Fire and Police Departments host collaborative public open houses

at their stations. Tewksbury also hosts a "Safe Halloween" event annually. The Fire Department Secretary keeps the Department's Twitter page up to date.

GPS Units for Hydrants: The Fire Department has GPS units for their fire hydrants, which assists responders in finding hydrants if they are covered by snow drifts.

Open Burning Permits Required: The Town allows controlled open burning in accordance with state regulations, but a permit is required from the Fire Department. Open burning is only allowed from January 15th to May 1st. Residents can call the department with questions and complaints.

Fire Department Review of Proposed Development: The Fire Department reviews all subdivision and site plans for compliance with site access, water supply needs, and other applicable regulations within their jurisdiction.

Statewide Fire Mobilization Plan: The State has a fire mobilization plan for brush fires. The Tewksbury Fire Chief participates in this plan.

Fire Prevention Association of Massachusetts: Tewksbury's Fire Prevention officers attends monthly meetings in conjunction with the State Fire Marshall's office.

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

Water Use at Housing Authority Properties: The Housing Authority monitors water consumption at their properties.

Backup Water Supply: A three million gallon water tank was built on Colonial Drive ten years ago, for additional water supply.

5.9 Existing Town-Wide Mitigation for Geologic Hazards

Massachusetts State Building Code: 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 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.

5.10 Mitigation Capabilities and Local Capacity for Implementation

Under the Massachusetts system of "Home Rule," the Town of Tewksbury 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 Ordinance, Stormwater Ordinance, Subdivision

and Site Plan Review Regulations, Wetlands Ordinance, Health Regulations, Public Works regulations, and local enforcement of the State Building Code. Local Ordinances may be amended by the Town Board of Selectmen 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 Tewksbury 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 in the sections above.

6.0 STATUS OF MITIGATION MEASURES FROM THE 2015 HMP

6.1 Implementation Progress on the Previous Plan

During expert interviews and a Tewskbury Core Team meeting, Town staff reviewed the proposed mitigation measures identified in the Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update. The Core Team recognized that it was important to determine which mitigation measures were still relevant and whether each measure had been implemented or deferred. Of those measures that had been deferred, the committee evaluated whether the measure should be deleted or carried forward into this 2020 HMP-MVP Plan. The decision on whether to remove or retain a particular measure was based on the Committee's assessment of the continued relevance or effectiveness of the measure and whether the deferral of action on the measure was due to the inability of the Town to take action on the measure. Table 6-1 summarizes the status of the mitigation measures, along with the priority of these measures.

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

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable)	Include in 2020 Plan? Priority?
Stabilize stream bed at the Bridge Street culvert	On hold. DEP did not approve the permit.	Yes, included in Chapter 7 as a high priority
Elevate Bridge and South Streets to address flooding issues	On hold. The Town has secured funding from the FEMA Hazard Mitigation Grant Program (HMGP), but FEMA also increased the base flood elevation. The road will have to be elevated an additional foot.	Yes, included in Chapter 7 as a high priority
Construct drainage improvements on Main Street (Route 38) at the I-495 ramps	Not applicable. MassDOT owns this location.	No
Purchase emergency generators for schools	In progress. This is a long-term action and will be implemented as schools are renovated.	Yes, included in Chapter 5 under multi-hazard mitigation
Construct culvert improvements on Pinnacle Street	In progress. There are two culverts on Pinnacle Street. The Town is currently replacing one, which started to fail and required road closure. The second culvert will need to be revisited later.	Yes, included in Chapter 7 as a "highest-high" priority
Construct boat ramp to the Merrimack River at the end of Merrimack Drive to respond to emergencies	On hold. There is a launch space that could be improved, but no boat ramp.	Yes, included in Chapter 7 as a low priority

Replace Brown Street bridge and raise approach ramps	On hold. The bridge was replaced but the approach ramps were not raised. The existing abutment remains.	Yes, included in Chapter 7 as a low priority
Purchase large backup pump and generator for East Street pump station	Completed. The backup generator was purchased.	No
Install culvert improvements and stabilize slopes at Trull Brook on River Road	Completed	No
Flood proof Shawsheen Street at Heath Brook Road	Completed	No
Replace Mill Street Bridge	Not applicable. The bridge was reassessed by MassDOT and found to be structurally sufficient.	No
Flood proof sewer manholes and sewer collection system	On hold. the Town did not receive funding from FEMA's Hazard Mitigation Grant Program (HMGP).	Yes, included in Chapter 7 as a medium priority
Install emergency back-up generators for sewer pump stations	In progress. The Town has received FEMA HMGP funding for this action and is waiting for a time extension.	Yes, included in Chapter 5 under multi-hazard mitigation
Incorporate hazard mitigation into the Master Plan process	Completed. The 2016 Master Plan includes mentions of flood areas.	No
Study regional consolidation of 911 dispatch services by establishing an Regional Emergency Communications Center (RECC)	Completed. The RECC building will open April 1, 2020 and will service both Tewksbury and Dracut.	No
Study the establishment of a mutual aid agreement with neighboring communities to administer NFIP following a major storm event	On hold. The Tewksbury Emergency Manager is involved in the Emergency Regional Planning Committee	Yes, included in Chapter 7 as a low priority
Revise subdivision regulations, erosion control regulations, and Board of Health regulations to improve floodplain management as needed	In progress. There is interest in improved stormwater management regulations. New development should be able to manage more of their stormwater on site.	Yes, included in Chapter 5 under flood mitigation

Ensure that administrators of schools, businesses, medical facilities, and the mobile home park have a shelter plan in the event of a tornado warning	In progress. The high school or library would be used as shelters in the event of a tornado warning.	Yes, included in Chapter 5 under multi-hazard mitigation
Address drainage issues on East Street by upgrading and improving infrastructure	Not applicable. East Street does not flood.	No
Purchase GPS Units for DPW vehicles and new messaging board system for emergency management	Not applicable. The Town has four messaging boards and there are no plans for GPS Units for DPW vehicles.	No
Install an emergency generator at the Water Treatment Plant (WTP)	Completed. The WTP generator has been upgraded to a larger unit with protective housing.	No
Install emergency generators for Senior Housing	In progress. None of the Housing Authority properties have generators but they are assessing options and considering the cost of mainteinance.	Yes, included in Chapter 5 under multi-hazard mitigation
Develop dam maintenance plan outlining future responsibilities for inspection, maintenance, and repair of all dams and related structures	Not applicable. The Town does not own any of the dams in Tewksbury.	No
Increase public awareness of the dangers of extreme temperatures and outline locations where vulnerable populations (elderly, homeless and those with health issues) can have access to air conditioning or shelter from the cold	In progress. The Fire Department's Student Awareness of Fire Education (SAFE) Coordinator conducts events at schools and with the elderly. The Fire and Police Departments host collaborative public open houses at their stations.	Yes, included in Chapter 5 under fire mitigation
Distribute educational information to residents and businesses on protecting life and property from severe winter storm events	In progress. The Police Department is involved in public education efforts and currently issues cold weather alerts	Yes, included in Chapter 5 under winter weather mitigation

Inspect public buildings to evaluate the capacity to withstand snow loads and prevent roof collapse. Develop plans to clear roofs of excessive snow accumulations to prevent collapse	In progress. Only the Town Hall Annex and the DPW have flat roofs.	Yes, included in Chapter 7 as a low priority
Identify locations for snow storage farms for utilization in severe winters with heavy snowfall	Completed. The Town piles snow locally along streets or cul-de-sacs. In parking areas, the Town keeps piled snow within the parking area. For example, at Town Hall, snow is piled near the end of the Annex lot where parking is reduced.	No
Evaluate public buildings and critical facilities for the potential to withstand high winds	Not applicable. All buildings in Town have already weathered sustained high wind events.	No
Assess bridges and roadways to ascertain their capability to support fire apparatus and develop alternative routing plans where deficiencies are noted	In progress. The bridges on Pinnacle Street and Bridge Street were recently renovated. Two other bridges on Trull Road and Main Street are in good shape.	Yes, included in Chapter 5 under fire mitigation
Develop an inventory of public buildings that do not currently meet seismic standards	Not applicable. All Town buildings are inspected by the Building Inspector annually and receive a Certificate of Inspection. All Town buildings meet seismic standards in the State Building Code.	No
Provide information to homeowners on how to protect their property from brush fire or wildfire during times of drought	In progress. The Fire Department's SAFE education program provides information to students, their parents, and seniors. Residents can call the Department with questions or concerns.	Yes, included in Chapter 5 under fire mitigation

As indicated in Table 6-1, the Town has completed several mitigation measures since the 2015 regional HMP, including:

- Purchasing a backup generator for the East Street pump station
- Installing culvert improvements and stabilizing slopes at Trull Brook on River Road
- Floodproofing Shawsheen Street at Heath Brook Road
- Incorporating hazard mitigation into the Master Plan process

- Establishing a Regional Emergency Communications Center (RECC)
- Upgrading the Water Treatment Plant generator to a larger unit and installing it with protective housing
- Identifying locations for snow storage along streets, cul-de-sacs, and parking lots

Additionally, several mitigation measures from the 2015 regional HMP were identified as not completed, high or highest-high prioritiy action items in the 2020 HMP-MVP, including:

- Stabilizing the stream bed at the Bridge Street culvert
- Elevating Bridge and South Streets to address flooding issues
- Constructing culvert improvements on Pinnacle Street

As the Town moves forward into the next five-year plan implementation period, identifying and incorporating hazard mitigation into the Town's decision-making process will be a high priority. Limited staffing and financial resources are the biggest challenges the Town faces in implementing the mitigations measure identified in this plan. This plan is intended to assist the Town in prioritizing the proposed measures, which will assist in allocating available grant or funding sources.

7.0 HAZARD MITIGATION 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:

- community profile, including the Town's strengths and vulnerabilities;
- hazard and climate change risk assessment;
- existing measures;
- previously identified action items; and
- input from stakeholders.

Stakeholders were engaged through Core Team meetings, the CRB Workshop, and the public input session. The full list of all the action items from the CRB Workshop are available in Appendix C and were integrated into the final list of action items developed by the Core Team. Table 7-1 below represents the action items from the CRB Workshop, as well as action items carried forward from the 2015 HMP. These action items are organized using five feature categories:

1. Infrastructural
2. Societal
3. Environmental
4. Planning & Regulation
5. Communication & Coordination

Although the recommendations are grouped using this framework, many action items can relate to multiple categories. Similarly, although adaptation strategies often provide protection against more than one climate impact, the main hazard addressed by each action is identified in Table 7-1 using a series of icons described below.

Each mitigation measure is paired with an estimated cost, timeframe, and implementation responsibility. These considerations also informed the prioritization of the mitigation measures. A description of the prioritization categories used in Table 7-1 is included below.

Mitigation Action – A brief description of each mitigation measure that was identified in this plan.

Implementation Responsibility – Most mitigation measures will require a multi-department approach where several Town departments share responsibility. This determination is at the discretion of the governing body of the community. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department.

Time Frame – The time frames represented below are assigned based on the complexity of the measure, the overall priority of the measure and at what stage of design and/or funding has been attained. The identification of time frames is not meant to prevent a community from actively seeking out and taking advantage of funding opportunities as they arise. Time frames used include 1-3 years, 3-5 years, and 5-10 years.

Estimated Cost – Cost estimates are given when cost data was available from the community. All cost data would need to be updated at the time of design and construction and is only provided as an estimate. Costs designated as "High" are estimated to be greater than $100,000. Those designated as "Medium" are estimated to between $10,000 to $100,000. "Low" costs are estimated to be less than $10,000.

Priority – Designation of high, medium, or low priority was based on overall potential benefits, areas affected and estimated project costs. A High Priority action is very likely to have political and public support and necessary maintenance can occur following the project, and the costs seem reasonable considering likely benefits from the measure. A Medium Priority action may have political and public support and necessary maintenance had potential to occur following the project. A Low Priority action may still have support for implementation but is not currently a high priority for the Town.

Table 7-1 Hazard Icon Legend:


All hazards


Severe snow, ice, extreme cold


Heavy precipitation and flooding


Extreme heat, drought, wildfire


Severe thunderstorms, wind, nor'easters, tornado

Table 7-1: Recommended Hazard Mitigation Measures

Hazard	Mitigation Action	Implementation Responsibility	Time Frame	Cost
Infrastructural				
Highest-High Priority				
	1. Assess and upgrade drainage infrastructure. Replace culverts and make drainage improvements along roadways including Bay Berry Lane, Bridge Street, Pinnacle Street, and many others in the 5-year Capital Improvement Plan (CIP).	DPW, Planning	3-5 years	High
	2. Increase flood storage through gray and green infrastructure.	Planning, Facilities, DPW	3-5 years	Medium

Hazard	Mitigation Action	Implementation Responsibility	Time Frame	Cost
	3. Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.	DPW	1-3 years	Low
	4. Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.	DPW	5-10 years	High
	5. Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience.	Police, Facilities	1-3 years	Medium
	6. Study overall water capacity and needs and assess options for recycling gray water or improving water conservation practices.	DPW	1-3 years	Low
	High Priority			
	7. Conduct a feasibility study for solar energy on Town facilities and shelters, including the new elementary school.	Facilities, Planning, Public Schools	1-3 years	Low
	8. Support infrastructure improvements at the Water Treatment Plant.	DPW, Water & Sewer Division, Water Treatment Plant	5-10 years	High
	9. Continue to implement resilient improvements at wastewater pumping stations.	DPW, Water & Sewer Division	5-10 years	High
	10. Construct infrastructure for water detention and underground storage.	DPW	5-10 years	High

Hazard	Mitigation Action	Implementation Responsibility	Time Frame	Cost
	11. Stabilize stream bed at the Bridge Street culvert.	DPW	1-3 years	Medium
	Medium Priority			
	12. Flood proof sewer manholes and sewer collection system.	DPW, Water & Sewer Division	3-5 years	Medium
	13. Study impact of future precipitation levels on existing infrastructure, including pump stations.	DPW, Water & Sewer Division, Planning	1-3 years	Low
	14. Purchase generators or portable plug-ins for water and sewer pump stations. Ensure resilient installation of generators, elevated if needed. Study renewable power alternatives.	DPW, Water & Sewer Division	1-3 years	Medium
	15. Design resilient DPW building and vehicle storage.	DPW	1-3 years	High
	16. Assess all pump stations for risks and options for removal or fortification, including the Regina Street Pump Station.	DPW, Water & Sewer Division	1-3 years	Low
	17. Improve water supply intake flood proofing and assess its vulnerability to future conditions.	DPW, Water & Sewer Division	1-3 years	Medium
	18. Implement the Complete Streets model and plant trees on Main Street.	Building Department, Planning, DPW	3-5 years	Medium
	19. Install pervious pavement at Town Buildings.	Building Department, Planning, DPW	3-5 years	Medium
	20. Assess opportunities for more snow clearing.	DPW, Police, Fire, RECC	1-3 years	Low
	21. Update Senior Center roof and HVAC system and evaluate options for solar energy.	Council on Aging, Building Department, Planning	1-3 years	Medium

Hazard	Mitigation Action	Implementation Responsibility	Time Frame	Cost
	22. Evaluate expanding the Library shelter to provide additional warming and cooling capacity.	Building Department, Planning, RECC	1-3 years	Low
	23. Install a solar canopy in the High School parking lot and evaluate options for green infrastructure.	Building Department, Planning, Public Schools	3-5 years	Medium
	24. Increase resources for sheltering in place at the new elementary school.	Building Department, Planning, Public Schools, RECC	1-3 years	Medium
Low Priority				
	25. Construct boat ramp to the Merrimack River at the end of Merrimack Drive to respond to emergencies.	DPW, Police, Fire, RECC	3-5 years	Medium
	26. Replace Brown Street bridge and raise approach ramps.	DPW	5-10 years	High
	27. Inspect Town Hall Annex and DPW buildings to evaluate the capacity to withstand snow loads and prevent roof collapse. Develop plans to clear roofs of excessive snow accumulations to prevent collapse.	Facilities	1-3 years	Low
Societal				
Highest-High Priority				
	28. Update inventories at shelters. Coordinate with Red Cross to assess shelter capacity and needs. Provide pet-friendly shelters.	Planning, Police, Fire, RECC, Council on Aging, Facilities, Health Department	1-3 years	Low
	29. Create a transportation plan for seniors to assist with evacuations and to provide transportation to shelters.	Planning, RECC, Council on Aging	1-3 years	Low

High Priority				
	30. Assist vulnerable populations with a shelter that can address medical needs, building a database of vulnerable residents, using social media to provide emergency alerts, and providing an online platform for residents to report emergencies.	Police, Fire, RECC, Housing Authority, Planning, Council on Aging; Health Department	1-3 years	Medium
	31. Protect children at schools and daycares by conducting outreach to families and having emergency plans to shelter-in-place or evacuate children.	Police, Fire, RECC, Public Schools	1-3 years	Low
	32. Conduct a public health assessment or inventory with a climate resilience chapter.	Planning, Health Department	1-3 years	Low
	33. Provide community rooms at the Library, Senior Center, Town Hall, and Housing Authority properties that can serve as cooling and heating centers, are ADA accessible, and have transportation connections.	Housing Authority, Planning	1-3 years	Medium
Medium Priority				
	34. Identify homeless shelters and capacity. Partner with nonprofits and the Tewksbury State Hospital to provide mental health and substance abuse counseling at shelters.	Planning, Tewksbury State Hospital, RECC,	1-3 years	Low
	35. Develop climate change curriculum for STEM education.	Public Schools, Planning	1-3 years	Low
	36. Host "coffee with a cop" events to share information on emergency preparedness and existing resources.	Police	1-3 years	Low
	37. Support businesses in developing emergency plans.	RECC, Community Development	1-3 years	Low

	38. Work with grocery stores and other local businesses to develop memoranda of understanding and provide food to emergency shelters.	Health Department, Planning	1-3 years	Low
	Low Priority			
	39. Study the establishment of a mutual aid agreement with neighboring communities to administer NFIP following a major storm event.	Police, Fire, ERPC	1-3 years	Low

Environmental

	Highest-High Priority			
	40. Use town properties for stormwater management, green infrastructure, and low impact development.	Planning; Facilities	3-5 years	High
	High Priority			
	41. Assess Long Pond improvements and septic systems. Treat algae growth in Long Pond.	DPW; Conservation	3-5 years	High
	42. Improve recreational fields through parking, stormwater management, and MS4 work.	Planning, DPW, Open Space & Recreation Plan Committee; Facilities	3-5 years	High
	43. Improve standards on water conservation and water restrictions for agricultural land. Provide guidelines for operations and maintenance.	DPW, Planning	1-3 years	Medium
	44. Address Town-owned detention basins with standing water to minimize mosquito populations.	DPW	1-3 years	Medium
	Medium Priority			
	45. Conduct an assessment to acquire open space for flood storage and wildlife corridors. Evaluate options to provide tax incentives for land acquisition or land donation.	Conservation, Planning	1-3 years	Low

	46. Coordinate to provide Town access to rivers and wetlands to conduct maintenance and remove blockages. Assess options for keeping rivers clear and managing beavers.	Conservation, DPW, Planning	1-3 years	Low
	47. Increase hazardous material disposal days with public/private partnerships.	Planning, DPW	1-3 years	Low
	48. Increase the number of street trees and develop planting plan to reduce heat islands.	DPW Forestry Division, Open Space & Recreation Plan Committee	1-3 years	Low
	49. Develop a tree management program and pruning schedule to reduce wildfire and wind vulnerability. Reduce impact of vegetation on powerlines and provide guidelines on the types of trees to plant near lines.	DPW Forestry Division, Open Space & Recreation Plan Committee	1-3 years	Low
	50. Work with regional watershed groups to address water quality in concert with MS4 updates. Improve pollution controls on impaired waterbodies.	Conservation, DPW, Water & Sewer Division	1-3 years	Low
	51. Treat algae growth in Long Pond.	Conservation	1-3 years	Low
	52. Develop invasive species removal policies and programs and provide public education.	Conservation	1-3 years	Low
Low Priority				
	53. Map the future floodplain and provide public education.	Conservation	1-3 years	Low

Planning & Regulation

Highest-High Priority

	54. Implement the capital improvement plan with a climate resilience lens.	Planning	3-5 years	Low

	55. Update subdivision and development regulations with incentives or requirements. Update bylaws, including the wetland and stormwater bylaw. Develop policies for stormwater detention on-site and the use of gray water.	Planning	1-3 years	Low
	56. Develop design guidelines and require increased climate protection in design standards.	Planning	1-3 years	Low

Communication & Coordination

High Priority

	57. Improve emergency response and communication system with backups and redundancy.	Police, Fire, RECC	1-3 years	Medium
	58. Expand communication with residents about the public health impacts of climate change, including vector-borne diseases.	Planning, Health Department, Open Space & Recreation Plan Committee	1-3 years	Low
	59. Improve public education about wetlands and promote wetlands protection.	Planning, Conservation Commission; Open Space & Recreation Plan Committee	1-3 years	Low
	60. Provide commuters with information on safe routes and emergency shelter capacity. Expend the reverse 911 communication system to reach commuters.	Police, Fire; DPW	1-3 years	Low
	61. Increase communication about resources with vulnerable residents, including seniors and disabled residents. Increase coordination with social service organizations.	Planning, Council on Aging, Senior Center; Health Department	1-3 years	Low

Medium Priority

	62. Provide education for homeowners regarding what can go down sink drains.	DPW	1-3 years	Low

	63. Develop a communication and engagement plan for vulnerable residents, including nursing homes, assisted living facilities, group homes, public housing, rentals, and multi-lingual populations. Develop a "Good Neighbor" program to help with snow removal and conduct home checks.	Council on Aging, Planning, RECC, Housing Authority	1-3 years	Low
	64. Share information on shelters through the Town website, message board, Reverse 911, Town Nurse, Town reports, and at the Senior Center.	Council on Aging, RECC, Health Department, Planning	1-3 years	Low
	65. Conduct a GIS study of existing data to identify vulnerable populations. Coordinate with emergency management to map at-risk residents and buildings.	Engineering Division, Planning, RECC	1-3 years	Low
	66. Distribute a pamphlet with emergency information with the water or tax bill. Host events at the library or setup a kiosk at grocery stores and coffee shops.	Planning, RECC, Fire, Police, DPW	1-3 years	Low
Low Priority				
	67. Public education and outreach with residents downstream of dams. Coordination with dam owners.	DPW	1-3 years	Low

Of these action items, three emerged as immediate priorities to find external funding:

Table 7-2: Priority Projects

Hazard	Mitigation Action	Implementation Responsibility	Time Frame	Cost
	Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.	DPW	1-3 years	High
	Elevate roads at strategic locations, including Route 38, Shawsheen, Bridge, and South Street, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.	DPW	5-10 years	High

	Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience.	Police, Facilities	1-3 years	Medium

Potential Grant Funding Options

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. Specific funding options related to Action Items developed by Tewksbury are listed below.

Table 7-3: Funding Opportunities for Resiliency Projects

Category	Grant	Description	Limitations & Stipulations
Community Development	MassWorks Infrastructure Program	Provides grants to communities to help them prepare for success and contribute to the long-term strength and sustainability of the Commonwealth.	None
Emergency Management and Planning	Flood Mitigation Assistance Grant Program (FMA)	Implement cost-effective measures that reduce or eliminate the long-term risk of flood damage	Building and other structures insured under the National Flood Insurance Program (NFIP).
Emergency Management and Planning	Hazard Mitigation Grant Program	Provides funding after a disaster to significantly reduce or permanently eliminate future risk to lives and property from natural hazards	None
Emergency Management and Planning	Pre-Disaster Mitigation (PDM) Grant Program	Provides funds for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event	None
Energy	DOER	The DOER provides grant funding for clean energy-related programs	None
Energy	Green Communities Designation and Grant Program	Provides a road map along with financial and technical support to municipalities that pledge to cut municipal energy and meet other criteria	None

Energy	MassEVIP Fleet Incentives	Helps eligible public entities acquire electric vehicles and install charging stations	None
Environment	Community Forest Grant Program	Funding to establish community forests	None
Environment	Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value	None
Environment	Dam and Seawall Program	Grants for the repair or removal of dams, seawalls, and levees	None
Environment	Drinking Water Supply Protection Grant Program	Financial assistance to public water systems and municipal water departments for the purchase of land or interests in land	50% reimbursable
Environment	604b Grant Program	Water quality assessment and management planning	None
Environment	Land Use Planning Grants	Support effort to plan, regulate, and act to conserve and develop land consistent with the Massachusetts' Sustainable Development Principles	None
Environment	LAND Grant Program	Helps cities and towns acquire land for conservation and passive recreation	Reimbursement rate: 52-70%
Environment	Federal Land & Water Conservation Fund	Funding for the acquisition, development, and renovation of parks, trails, and conservation areas.	Municipality must have an OSRP
Environment	MassTrails Program	Trail protection, construction, and stewardship projects	None
Environment	Municipal Vulnerability Preparedness (MVP) Program	Provides support implement climate change resiliency priority projects	None
Environment	Natural Resource Damages Program	Funding for restoration projects. Funding comes from settlements, so it is does not follow a set schedule.	None
Environment	MS4 Grant Program	Meeting 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)

Public Safety	Emergency Management Performance Grant (EMPG)	Reimbursable grant program to assist local emergency management departments to build and maintain an all-hazards emergency preparedness system	Reimbursable
Public Safety	Public Assistance Program	The state reimburses governments and other applicants for disaster related costs	75% reimbursable
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 on approved projects	None
Public Works and Transportation	Community Transit Grant Program	Funding to meet the transportation and mobility needs of seniors and people with disabilities	None
Public Works and Transportation	Complete Streets Funding Program	Technical assistance and construction funding	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'

While many of the mitigation actions outlined in Table 7-1 were generated during the MVP Planning process, several items relate to recommendations included in the 2015 HMP. Table 7-3 below provides a comparison of previous action items included in the 2015 HMP and highest-high/high priority action items generated during the 2020 CRB Workshop. Please refer to Chapter 6 for a full list of proposed mitigation actions included in the previous HMP, along with corresponding status updates.

Table 7-4: Comparison of Past and Current Mitigation Actions

Proposed Mitigation Actions from the 2015 Regional HMP	Priority Action Items from the 2020 MVP Planning Process
Infrastructural	
Elevate Bridge and South Streets to address flooding issues	Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the

	Main Street reconstruction and coordinate with MassDOT
Construct culvert improvements on Pinnacle Street. Stabilize stream bed at the Bridge Street culvert.	Assess and upgrade drainage infrastructure. Replace culverts and make drainage improvements along roadways including Bay Berry Lane, Bridge Street, and many others in the 5-year Capital Improvement Plan (CIP)
Flood proof sewer manholes and sewer collection system	Continue to implement improvements at wastewater pumping stations
Planning & Regulation	
Revise subdivision regulations, erosion control regulations, and Board of Health regulations to improve floodplain management as needed	Update subdivision and development regulations with incentives or requirements. Update bylaws, including the wetland and stormwater bylaw. Develop policies for stormwater detention on-site and the use of gray water
Communication & Coordination	
Distribute educational information to residents and businesses on protecting life and property from severe winter storm events	Expand communication with residents about the public health impacts of climate change, including vector-borne diseases

7.2 Regional Partnerships

Mitigating natural hazards is not confined to a local issue. The drainage systems that service communities are often complex systems of storm drains, roadway drainage infrastructure, pump stations, dams, and other facilities owned and operated by a wide variety of agencies including the Massachusetts Department of Transportation (MassDOT) and the Department of Conservation and Recreation (DCR). The planning, construction, operation, and maintenance of these structures are integral to hazard mitigation efforts of communities. These agencies are the town's regional partners in hazard mitigation efforts. Mitigation measures for the following regional issues should be considered as Tewksbury implements its own local plan:

- Assess, prioritize, and upgrade bridges, including the State-owned Bridge Street bridge
- Work regionally with communities and watershed groups to reduce pollution in waterbodies and drinking water, including the Merrimack River, Shawsheen, Health Brook, Strongwater Brook, and Sutton Brook
- Address water quality in concert with MS4 updates
- Coordinate meetings or policy with surrounding towns to increase public education and reduce pollutants in the water supply
- Explore alternative treatment and remediation strategies for vector-borne illness
- Improve regional communication and coordination by forming a district-wide team through the Regional Emergency Communication Center (RECC)

- Add staff and develop volunteer training program for shelters. Coordinate with Red Cross and State Hospital for best practices

These agencies also operate under the same constraints as communities do including budgetary and staffing limitations. And as all communities do, 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.

8.0 PLAN ADOPTION AND MAINTENANCE

8.1 Plan Adoption

The Town of Tewksbury 2020 HMP-MVP Plan was adopted by Board of Selectmen on December 1, 2020. Please refer to Appendix E for related documentation. The plan was approved by FEMA on January 6, 2021 for a five-year period that will expire on January 5, 2026.

8.2 Plan Implementation

The Core Team will use Table 7-1 as a guide for taking action to mitigate hazards and improve the Town's climate resilience. The time frame, implementation responsibility, and funding mechanisms in Table 7-1 layout an implementation plan 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 Anna McGinty, will meet once a quarter during regularly scheduled Tuesday morning project meetings to monitor plan implementation. The Core Team will be amended as needed but will include representatives from the Department of Public Works, Police, Fire, the Building Commissioner, FEMA Coordinator, and others. These meetings will provide an opportunity for regular check-ins, identifying overlaps and capital planning needs related to hazard mitigation, and forward-looking discussions regarding next steps.

2. Surveys: The coordinator of Core Team, Anna McGinty, will also prepare and distribute a survey every year. 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.

8.3.1 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.

8.3.2 Integration of the Plans with Other Planning Initiatives

Upon approval of the Town of Tewksbury 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:

Community Development Department
Department of Public Works
Conservation Commission
Building Department
Housing Authority
Police Department
Fire Department
Open Space & Recreation Plan Committee

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, Envisioning Tewksbury, Open Space and Recreation Plan, Comprehensive Emergency Management Plan, and Capital Investment Program. Coordination with the Northern Middlesex Council of Governments (NMCOG), 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 Tewksbury 2020 HMP-MVP Plan, the Town will have a competitive application when applying to FEMA for funding to update the plan. 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 Tewksbury 2020 HMP-MVP Plan will be forwarded to MEMA for review and to FEMA for ultimate approval. When appropriate, the Core Team will begin drafting the full update of the plan. 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.

9.0 LIST OF REFERENCES

American Society of Civil Engineers (ASCE). 2018. "ASCE 7 Hazard Tool: Tewksbury, Massachusetts." 2018. asce7hazardtool.online/.

"Cardinali et Al. - 2002 - A Geomorphological Approach to the Estimation of l.Pdf." n.d. Accessed May 8, 2020. https://www.nat-hazards-earth-syst-sci.net/2/57/2002/nhess-2-57-2002.pdf.

Cardinali, M., P. Reichenbach, F. Guzzetti, F. Ardizzone, G. Antonini, M. Galli, M. Cacciano, M. Castellani, and P. Salvati. 2002. "A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy." *Natural Hazards and Earth System Science* 2 (1/2): 57–72. https://doi.org/10.5194/nhess-2-57-2002.

Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA). 2018. "Massachusetts State Hazard Mitigation and Climate Adaptation Plan."

Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and National Weather Service. 2018. "Storm Data Preparation." National Weather Service Instruction 10-1605. Operations and Services Performance, NWSPF 10-16. nws.noaa.gov/directives/sym/pd01016005curr.pdf.

Department of Conservation and Recreation (DCR). 2017. "302 CMR 10.00: Dam Safety." mass.gov/files/documents/2017/10/30/302cmr10.pdf.

Epstein, David. 2016. "This Morning's Tornado in Concord, Explained." *Boston Globe Media Partners, LLC*, August 22, 2016. boston.com/weather/weather/2016/08/22/this-mornings-tornado-in-concord-explained.

Federal Emergency Management Agency (FEMA). 2013. "Local Mitigation Planning Handbook. Table 6.1: Types of Mitigation Actions." fema.gov/media-library-data/20130726-1910-25045-9160/fema_local_mitigation_handbook.pdf.

———. 2016. "Flood Insurance Rate Map: Tewksbury, Middlesex County, Massachusetts."

———. 2019a. "Fire Management Assistance Grant Program." Government. March 14, 2019. https://www.fema.gov/fire-management-assistance-grant-program.

———. 2019b. "Flood Zones." March 18, 2019. https://www.fema.gov/flood-zones.

———. 2019c. "NFIP Flood Insurance Manual Appendix F: Community Rating System." fema.gov/media-library-data/1559830308363-e690ed2aea6606fb81826904e4a7bd7f/app-f_crs_508_apr2019.pdf.

———. 2019d. "Public Assistance: Local, State, Tribal and Private Non-Profit." Government. May 20, 2019. https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit.

———. 2019e. "The National Flood Insurance Program." Government. July 26, 2019. fema.gov/national-flood-insurance-program.

———. 2019f. “Hazard Mitigation Assistance.” Government. September 18, 2019. https://www.fema.gov/hazard-mitigation-assistance.

———. 2019g. “Hazard Mitigation Grant Program.” Government. December 17, 2019. https://www.fema.gov/hazard-mitigation-grant-program.

———. 2019h. “Definitions: Repetitive Loss Structure.” December 19, 2019. fema.gov/national-flood-insurance-program/definitions#R.

———. 2019i. “Repetitive Loss Properties.” September 30, 2019.

———. 2020a. “Disasters: Total Number of Declared Disasters.” 2020. fema.gov/disasters?field_dv2_state_territory_tribal_value_selective=MA&field_dv2_incident_type_tid=All&field_dv2_declaration_type_value=All&field_dv2_incident_begin_value%5Bvalue%5D%5Bmonth%5D=&field_dv2_incident_begin_value%5Bvalue%5D%5Byear%5D=&field_dv2_incident_end_value%5Bvalue%5D%5Bmonth%5D=&field_dv2_incident_end_value%5Bvalue%5D%5Byear%5D=.

———. 2020b. “FEMA-DR-4379-MA-March 13-14, 2018 Severe Winter Storm.” Mass.Gov. 2020. mass.gov/info-details/fema-dr-4379-ma-march-13-14-2018-severe-winter-storm.

———. 2020c. “Public Assistance Disaster Declarations.” Mass.Gov. 2020. mass.gov/info-details/fema-public-assistance-local-state-tribal-and-non-profit.

———. 2020d. “National Flood Insurance Program Community Rating System.” Government. January 10, 2020. fema.gov/national-flood-insurance-program-community-rating-system.

———. 2020e. “Hazard Mitigation Planning.” Government. February 26, 2020. https://www.fema.gov/hazard-mitigation-planning.

Federal Emergency Management Agency (FEMA), and Federal Insurance and Mitigation Administration. 2018. “Natural Hazard Mitigation Saves Interim Report.” U.S. Department of Homeland Security. https://www.fema.gov/media-library-data/1528732098546-c3116b4c12a0167c31b46ba09d02edfa/FEMA_MitSaves-Factsheet_508.pdf.

Frumhoff, Peter, James McCarthy, Jerry Melillo, Susanne Moser, and Donald Wuebbles. 2007. “Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions.” Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists.

Interviews with Local Experts on Climate Hazards and Mitigation in Tewksbury. 2020.

Kocin, Paul, and Louis Uccellini. 2004. “The Northeast Snowfall Impact Scale (NESIS).” NOAA National Centers for Environmental Information. 2004. ncdc.noaa.gov/snow-and-ice/rsi/nesis.

Lietz, Joshua. 2020. “Tornado History Project: Middlesex County, Massachusetts.” 2020. tornadohistoryproject.com/tornado/Massachusetts/Middlesex/table.

Louie, John. 1996. “What Is Richter Magnitude?” Nevada Seismological Laboratory.

Madsen, Travis, and Nathan Willcox. 2012. "When It Rains, It Pours: Global Warming and the Increase in Extreme Precipitation from 1948 to 2011." Environment America Research & Policy Center. environmentamerica.org/sites/environment/files/reports/When%20It%20Rains,%20It%20Pours%20vUS.pdf.

Mass Audubon. 2020. "Effects of Climate Change on Rising Temperatures." Temperatures. 2020. massaudubon.org/our-conservation-work/climate-change/effects-of-climate-change/on-weather/temperatures.

Massachusetts Department of Conservation and Recreation (DCR). 2019a. "Community Information System: Repetitive Loss for the Town of Tewksbury."

———. 2019b. "Recent Drought History." mass.gov/doc/drought-status-history-0/download.

———. 2020. "Emergency Action Plans." Mass.Gov. 2020. mass.gov/service-details/emergency-action-plans.

Massachusetts Emergency Management Agency (MEMA). 2018. "Massachusetts Emergency Planning Committees (EPC)."

Massachusetts Emergency Management Agency (MEMA), and Massachusetts Department of Conservation and Recreation (DCR). 2013. "Commonwealth of Massachusetts State Hazard Mitigation Plan."

Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA). 2017. "MA Climate Change Clearinghouse." Resilient MA. 2017. resilientma.org/.

———. 2020. "MVP Program Information." Mass.Gov. 2020. https://www.mass.gov/service-details/mvp-program-information.

———. n.d. "Annual Total Precipitation: Middlesex County, MA." Resilient MA Datagrapher. Accessed March 27, 2020a. resilientma.org/datagrapher/?c=Temp/county/pcpn/ANN/25017/.

———. n.d. "Average Temperature: Middlesex County, MA." ResilientMA Datagrapher. Accessed March 27, 2020b. resilientma.org/datagrapher/?c=Temp/county/avgt/DJF/25017/.

Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA), and Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report."

McGinty, Anna. 2020. Development Data from Tewksbury Town Planner.

Metropolitan Area Planning Council (MAPC). 2019. "MassBuilds: Tewksbury." MassBuilds. 2019. massbuilds.com/map?municipal[]=Tewksbury.

Morrison, Sara. 2014. "Tornadoes of Massachusetts Past." *Boston Globe Media Partners, LLC*, July 28, 2014. boston.com/weather/untagged/2014/07/28/tornadoes-of-massachusetts-past.

National Centers for Environmental Information (NCEI), and National Oceanic and Atmospheric Administration (NOAA). 2019. "Storm Events Database: Middlesex County." November 2019. ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=25%2CMASSACHUSETTS.

———. 2020. “Storm Events Database - Event Details - Tornado September 29, 1974.” 2020. ncdc.noaa.gov/stormevents/eventdetails.jsp?id=10041252.

National Oceanic and Atmospheric Administration (NOAA). 2020a. “Observed Weather Reports: Annual Climate Report.” National Weather Service Forecast Office: Boston, MA. January 8, 2020. w2.weather.gov/climate/index.php?wfo=box.

National Oceanic and Atmospheric Administration (NOAA), and National Centers for Environmental Information (NCEI). 2019. “National Climate Report - February 201 9- Winter Snowfall Departure from Average.” February 2019. ncdc.noaa.gov/sotc/national/201902/supplemental/page-2.

National Oceanic and Atmospheric Administration (NOAA), and National Weather Service. 2009. “Glossary: Heavy Snow.” June 25, 2009. w1.weather.gov/glossary/index.php?word=heavy+snow.

———. 2015. “Boston Breaks Record Seasonal Snowfall.” March 15, 2015. web.archive.org/web/20150318050028/http:/www.weather.gov/box/BostonRecordSnow.

National Oceanic and Atmospheric Administration (NOAA), NOAA. 2020b. “Heat Watch vs. Warning.” National Weather Service. 2020. weather.gov/safety/heat-ww.

———. n.d. “Heat.” National Weather Service. Accessed May 8, 2020. https://www.weather.gov/bgm/heat.

Northeast Climate Science Center. 2018. “Massachusetts Climate Change Projections.”

Northern Middlesex Council of Governments (NMCOG). 2015. “Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update.”

Office of Dam Safety. 2019. “Dam Inventory.”

Tewksbury Planning Board, Tewksbury Department of Community Development, RKG Associates, Inc., McMahon Transportation Engineers & Planners, and Northern Middlesex Council of Governments (NMCOG). 2016. “Tewksbury Master Plan 2016.”

The Editors of Encyclopaedia Britannica. 2013. “Tewksbury, Massachusetts, United States.” April 23, 2013. https://www.britannica.com/place/Tewksbury.

The Nature Conservancy. 2019. “Community Resilience Building Workshop Guide.” https://e710de78-1039-4687-962d-33c9ec6dc9c6.filesusr.com/ugd/29a871_ed557c1fca834ca898961d7705dfef03.pdf.

———. 2020. “Community Resilience Building.” Workshop Guide and Materials. 2020. https://www.communityresiliencebuilding.com/crbworkshopguide.

Town of Tewksbury. 2020. “Town of Tewksbury Website.” The Town of Tewksbury, Massachusetts. 2020. tewksbury-ma.gov/.

Town of Tewksbury, Open Space and Recreation Committee, and Northern Middlesex Council of Governments (NMCOG). 2019. "2019 Open Space and Recreation Plan."

Town of Tewksbury, Tewksbury Community Vision Committee, JM Goldson, RKG Associates, Inc., and Favermann Design. 2017. "Envisioning Tewksbury 2037."

Union of Concerned Scientists. 2007. "Massachusetts: Confronting Climate Change in the U.S. Northeast." Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. https://www.cityofboston.gov/images_documents/MA%20confronting%20climate%20change%20in%20US%20Northeast_tcm3-19616.pdf.

United States Census Bureau. 2019. "QuickFacts: Tewksbury Town, Middlesex County, Massachusetts." 2019. census.gov/quickfacts/fact/table/tewksburytownmiddlesexcountymassachusetts/PST045219.

———. n.d. "Tewksbury Town, Middlesex County, Massachusetts." American Fact Finder. Accessed March 5, 2020. factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml.

United States Geological Survey (USGS). 2020a. "Earthquake Hazards Program." 2020. earthquake.usgs.gov/.

———. 2020b. "Landslides 101." Landslide Hazards. 2020. usgs.gov/natural-hazards/landslide-hazards/science/landslides-101?qt-science_center_objects=0#qt-science_center_objects.

Walsh, John, and Donald Wuebbles. 2014. "National Climate Assessment - Chapter 2: Our Changing Climate." National Climate Assessment. 2014. nca2014.globalchange.gov/downloads.

Appendix A

Core Team Materials

Municipal Vulnerability Preparedness Planning Grant

Cor Team Meeting
Nov 4th, 2019 10:00-11:00
Town Hall, Lower Level Conference Room

Introductions	5 minutes
Project Overview and Core Team Role	15 minutes
Community Resilience Building Workshop and Review of Materials	45 minutes
Data Sources	5 minutes
Workshop Participants	15 minutes
Wrap Up and Next Steps	5 minutes

TOWN OF TEWKSBURY

Core Team Meeting

Monday November 4th , 2019

WELCOME CORE TEAM

Anna McGinty
Brian Gilbert
Kevin Hardiman
Melissa Maniscalco
Stefania Gallo
Steve Sadwick
Vinnie Bomal

CORE TEAM

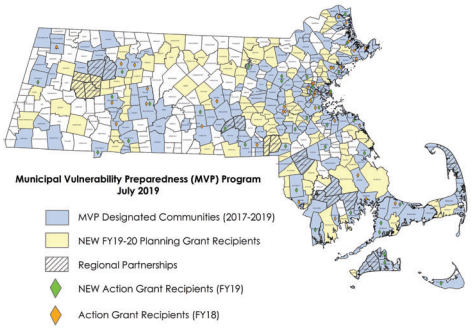
ROLE

- Confirm framework for process
- Provide data and local expertise
- Participate in the stakeholder workshop
- Finalize priority actions for the final report
- Interviews

TODAY'S OBJECTIVES

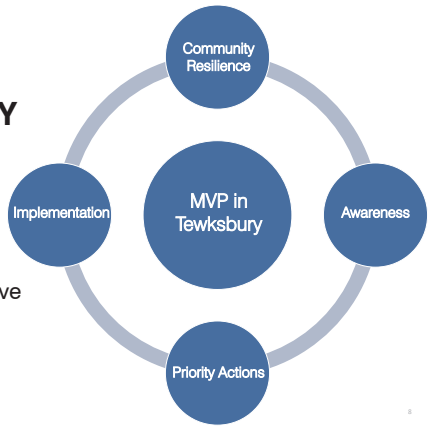
- Review Process
- Set Goals
- Prepare for Stakeholder Meeting

MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM (MVP)



MVP IN TEWKSBURY

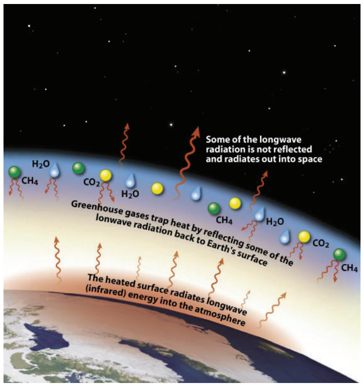
- Increase resilience of community
- Raise awareness of climate threats
- Identify priority actions to move forward
- Create implementation pathways



GREENHOUSE GASES (GHG)

- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

Climate mitigation ensures there is less to adapt to and is a key component of our community's resilience



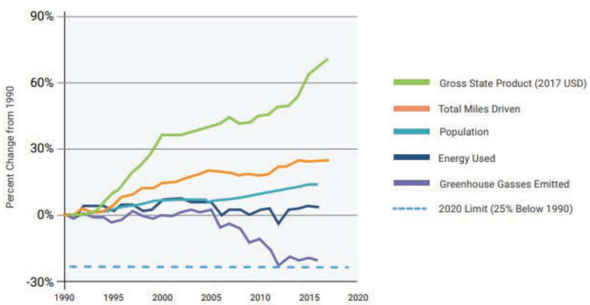
Smithsonian Environmental Research Center. "Too Much of a Good Thing." http://forces.si.edu/atmosphere/02_04_07.html

MA GHG GOALS

- Established by the Global Warming Solutions Act (GWSA) of 2008
- 25% reduction in GHG emissions by 2020
- 80% reduction in GHG emissions by 2050
- 1990 is the baseline year

Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report." 10.

FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report." 10.

HAZARDS IN TEWKSBURY

Extreme Temperatures

Flooding

Severe Thunderstorms, Wind, Hurricanes

Dam Failure

Drought, Wildfire

Severe Snowstorms, Ice Storms, Nor'easters

Erosion, Earthquakes, Landslides

EXTREME TEMPERATURES

WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

EXTREME **TEMPERATURES**
IN MASSACHUSETTS

6	24	35
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE

DAYS WITH TEMPERATURES ABOVE 90°F

145	114	101
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE

DAYS WITH TEMPERATURES BELOW 32°F

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

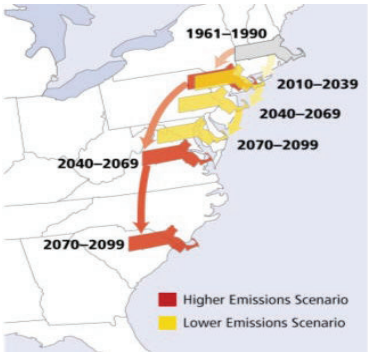


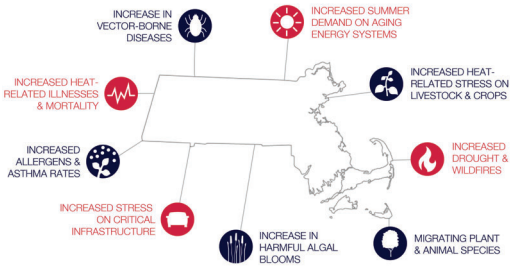
Photo: NECIA/UCS, 2007.

Weston & Sampson

IMPACTS OF **RISING TEMPERATURES**

WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Rising Temperatures." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/rising-temperatures

Rain, Warmth Close Outdoor Rink In Tewksbury

The town said in a notice on its Website that the rink would be closed "until further notice."

By Dave Copeland, Patch Staff
Jan 25, 2019 3:23 pm ET

Source: Patch.com

Tewksbury Health Department Alerts Residents after Mosquitos in Neighboring Communities Test Positive for EEE

Posted On: August 16, 2018 12:45PM

Source: Tewksbury Website, News

CHANGES IN **PRECIPITATION**

MORE **INTENSE & FREQUENT** EXTREME RAIN EVENTS

PRECIPITATION DURING **HEAVY EVENTS** IN THE NORTHEAST

INCREASED BY MORE THAN

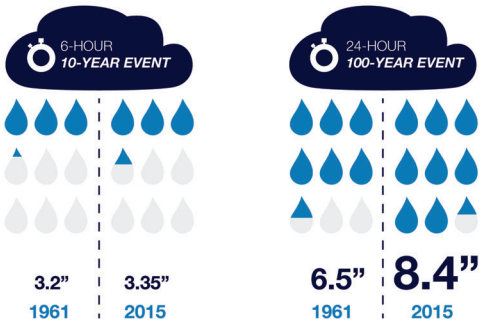
70%

BETWEEN 1958-2010

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. Resilientma.org/changes/changes-in-precipitation

Weston & Sampson

CHANGES IN **PRECIPITATION**



Sources: NOAA TP-40 (1961) and NOAA Atlas Volume 10 (2015)

EXTREME PRECIPITATION

8%

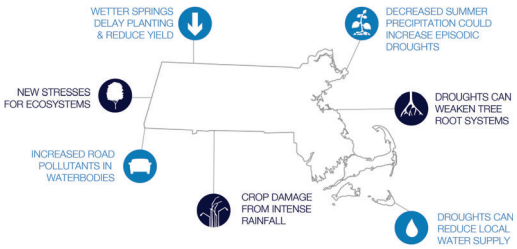
Increase in extreme precipitation events by midcentury

13%

Increase in extreme precipitation events by 2100

IMPACTS OF CHANGING **PRECIPITATION**

HIGHER AVERAGE ANNUAL PRECIPITATION
INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/changes-in-precipitation

FLOODING

ZONE	ANNUAL CHANCE	FLOODPLAIN
A, AE, A1-A30	1% ANNUAL CHANCE	100-YEAR FLOODPLAIN
X	0.2% ANNUAL CHANCE	500-YEAR FLOODPLAIN

"By 2050, Boston could experience the current 100-year riverine flood every two to three years on average"

8
REPETITIVE FLOOD LOSS STRUCTURES

FLOODING

Vulnerable Areas
- Poor drainage
- High amounts of impervious surface
- Undersized culverts

To name a few…
- Lake Street
- Pupkis near Heath
- Starr Ave at Mitchell
- Veranda St
- Water St at Adelaide Rd
- Greenwood Near Woburn St

AREAS PRONE TO FLOODING

Bridge Street and South Street
Shawsheen Street and Mohawk Street
East Street near Strong Water Brook
Pinnacle Street
Shawsheen Street Near
Main Street/Route 38
Brown Street at Whipple Road
Pond Street
Bonnie Lane

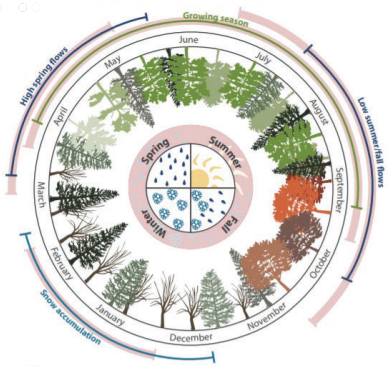
Photo: Pupkis Road Flooding

WINTER STORMS

The blizzard of 2013 left nearly **400,000 Massachusetts residents without power**

"Heavy blizzards are among the **most costly and disruptive** weather events for Massachusetts communities."

Northeast and Midwest seasonal patterns

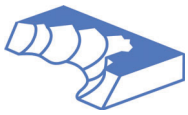


Shifted season projected from increasing temperatures and precipitation changes
Image credit: Northeast Climate Science Center, University of Maryland Center for Environmental Science

The most notable recent drought event was in
2016

The occurrence of droughts **lasting 1 to 3 months** could go up by as much as **75% over existing conditions** by the end of the century, under the high emissions scenario

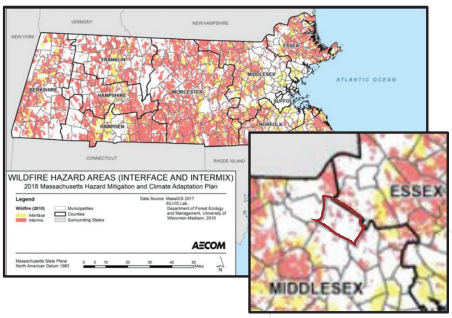
EROSION



- Caused by riverine flow & stormwater[1]
- Increased precipitation, including winter rains, could increase erosion[1]
- Drier soils will reduce resistance to erosion

1. Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 42.

BRUSH FIRE



400 brush fires
in Tewksbury between 2002 and 2010

HURRICANES AND EARTHQUAKES

HURRICANE
Sandy and nor'easters cause downed trees and power lines

Upward trend in North Atlantic hurricane activity since 1970

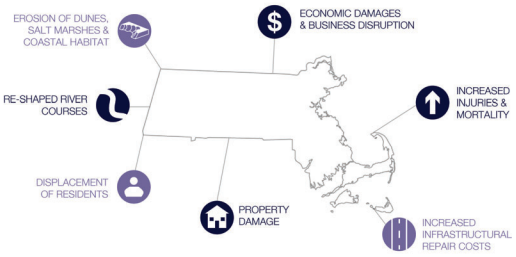
Nor'easters along the Atlantic coast are increasing in frequency and intensity

EARTHQUAKE
30-40
Earthquakes occur in New England each year, although most are not felt.

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)Northern Middlesex Council of Governments. 2015. "Hazard Mitigation Plan for the Northern Middlesex Region," 159-160.

IMPACTS OF EXTREME WEATHER

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Extreme Weather." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/extreme-weather

HAZARD POTENTIAL OF DAMS

Hazard Classification of Tewksbury Dams					
Dam Name	**Impoundment Name**	**Hazard Class**	**Downstream Population**	**Last Inspection Date**	**Next Inspection Due**
Dams in Tewksbury					
Ames Pond Dike A	Ames Pond	High	5,000	10/7/2010	10/7/2012
Ames Pond Dam	Ames Pond	High	5,000	10/7/2010	10/7/2012
Ames Pond Dike B	Ames Pond	Low	5,000	4/30/2003	4/30/2008

As an FYI: Boston Sea Level Rise Projections (ft)

Increased coastal flooding

Permanently inundated low-lying coastal areas

Increased shoreline erosion

Emission Scenario	2030	2050	2070	2100
Intermediate	0.7	1.4	2.3	4.0
Intermediate-High	0.8	1.7	2.9	5.0
High	1.2	2.4	4.2	7.6
Extreme	1.4	3.1	5.4	10.2

(Source: Northeast Climate Adaption Science Center)

RISK MATRIX

Photo: Tewksbury Congregational Church, 2010.

HAZARDS IN TEWKSBURY

CHOOSE 4 FOR THE MVP ACTION PLAN

- Extreme Temperatures
- Heavy Precipitation
- Severe Thunderstorms, Wind, Tornado
- Dam Failure
- Drought, Wildfire
- Severe Snowstorms, Ice Storms, Nor'easters
- Erosion, Earthquakes, Landslides

Weston & Sampson

FEATURES IN TEWKSBURY

Photo: Tewksbury Public Library, Tewksbury Twitter.

INFRASTRUCTURAL FEATURES

Fire Department

Photo by minutemantrucks.com

Wastewater Treatment & Collection

Police Department

Photo by the Northeastern MA Law Enforcement Council

Roadways

Photo by Hazard Mitigation Plan for the Northern Middlesex Region

Water Supply

INFRASTRUCTURAL FEATURES

CRITICAL FACILITIES

Facility Type	Common Name	Street Address	Health Facility Type	Average Daily Patient Capacity	Capacity	Feeding Capability	Emergency Generator Available
Emergency Operations Center	Tewksbury Fire Department (Primary)	21 Town Hall Avenue				No	Yes
	Tewksbury Police Department(Secondary)	918 Main Street				No	Yes
Health Care Facilities	Blair House	10 Erlin Avenue	Level 1 – 4	200		No	No
	The Emeritus	2580 Main Street	Level 4	50	No	No	
	North Fire Station	830 North Street	First Aid	0			
	Center Fire Station	21 Town Hall Avenue	First Aid	0			
	South Fire Station	2342 Main Street	First Aid	0			

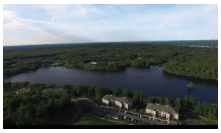
Source: All Hazards Mitigation Plan, 2016. 2-6.

SOCIETAL FEATURES

Population	Tewksbury	Massachusetts
2010	29,090 residents	6,547,790
2018	31,388 residents	6,902,149
Age		
Under 18 years:	19.7%	20%
65+ years:	17.5%	17%
Education		
Bachelor's degree or higher:	33.6%	42.1%
Additional Information		
Median household income:	$93,817	$74,167
Persons in poverty:	5.4%	10.5%
With a disability:	6.2%	7.9%
Language other than English spoken at home:	9.0%	23.1%

Source: U.S. Census Bureau, 2013-2017 ACS Estimates

ENVIRONMENTAL FEATURES



Ponds

Trails

Photo 1: Ames Pond, Airgoz Aerial Photography, Youtube
Photo 2: Foster Park Conservation Area, Town of Tewksbury Website.

Tewksbury's Open Space

- 49% of the town is open space
- Open spaces include:
  - Foster Park Conservation Area
  - Mahoney Park

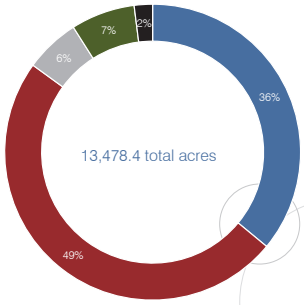
Shawsheen River

Merrimack River

Concord River

Source: Tewksbury Open Space and Recreation Committee.

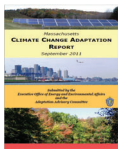
Tewksbury's Land Use



- Residential Housing
- Open Space, Recreation, or Water Use
- Commercial & Industrial Use
- Transportation or Waste Disposal
- Agriculture

Source: Hazard Mitigation Plan for the Northern Middlesex Region, 2015 pg 145

DATA RESOURCES



Within Tewksbury and Throughout Massachusetts

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

Hazard Mitigation Plan for Northern Middlesex Region, 2015

US Census, American Community Survey, 2013-2017

EXISTING CLIMATE ACTION

- Green Communities Initiatives
- Participation in the National Flood Insurance Program (NFIP);
- Policy-related strategies targeting new and redevelopment projects;
- Local drainage improvement and maintenance activities;
- Emergency response planning;
- EPA Phase II Stormwater permit requirements; and
- Public education
- Dam Emergency Action Plans
- Cooperation with local utility companies to perform annual tree maintenance around utility lines
- Placement of power lines underground for new construction to avoid storm related damage.

Source: All Hazards Mitigation Plan. 2016. Town of Winchester.

WRAP-UP & CLOSING REMARKS

Photo: Tewksbury High School. Patch.com.

Municipal Vulnerability Preparedness Planning Grant Project
Monday, November 4, 2019 10:00 am – 11:00 am

Name	Present- Mark with X or Sign
Anna McGinty	
Brian Gilbert	X
Kevin Hardiman	X
Melissa Maniscalco	
Stefania Gallo	
Steve Sadwick	
Vinnie Bomal	X
Michelle Rourden	
Alicia Geiley	
Vincent Bomal	

Municipal Vulnerability Preparedness Planning Grant
Core Team Meeting
Nov 4th, 2019 10:00-11:00
Town Hall, Lower Level Conference Room

Introductions — 5 minutes

Attendance:

- Anna McGinty
- Steve Sadwick
- Brian Gilbert
- Kevin Hardiman
- Stefanio Gallo
- Vinnie Bomal
- Melissa Maniscalco
- Alicia Geilen
- Lindsey Adams
- Amanda Kohn

"Welcome to Tewksbury" event, run by Chamber of commerce and library (community outreach, Robert Hayes), new residents and town staff participated (40-50 people). Library would be a good resource for community engagement and reaching potential stakeholders. **Action Item:** Reach out to library.

Project Overview — 10 minutes

1. MVP Program Overview
    a. MVP Planning Process

Planning on updating HMP separately as regional plan, many other communities in region are going to branch off into their own plans. **Action item:** Set up meeting to discuss integrating.

    b. MVP Action Grants

Potential priority item: update bylaws to include most recent rainfall data used for culvert design.
Action item: Add slide about action items.

2. Core Team Role
    a. Develop/approve list of stakeholders
    b. Active participants in the Community Resilience Building Workshop
    c. Promote the listening session/attend listening session
    d. Inform community priorities/Determine how decisions from Workshop will be used
3. Introduction to Climate Change in Tewksbury

Keep examples relevant to region or Town. **Action Item:** Remove Boston references.

    a. Local hazards/experiences to highlight? - previous flood events, issue areas
    b. Choose 4 hazards
        i. Heavy precipitation and flooding
        ii. snowstorm/ice storm/extreme cold
        iii. extreme heat, drought, wildfire
        iv. severe wind, nor'easters, tornados

Community Resilience Building Workshop and Review of Materials — 15 minutes

1. MVP Risk Matrix
    a. Discuss hazards and key features (infrastructure, society, environment)
2. Review map of key resources/assets

a. Make updates and send critical facilities list

3. Prioritization Process MVP Key Actions
4. Workshop Schedule
    a. 8-hour, 10-6 in January (Wed. Jan 22, snow date Jan 29) (~~15/22 Snow date~~)
5. Presentation Feedback

- Label images of Town with location
- Update dam inspection information

W&S Action Item: Finalize Workshop materials based on Core Team input
Tewskbury Action Item: Help to fill mapping and PowerPoint gaps

Data Sources 5 minutes

1. Interviews with municipal officials

- Interviews with:
    - Engineering/DPW (stormwater flooding and other critical facilities)
    - Other stakeholders as top concerns arise

2. Applicable reports and materials
    a. Hazard Mitigation Plan Update (2016)
    b. Critical assets and infrastructure
    c. Demographics

- Anna has list of climate action measures
- More plans that should be added

3. Ask:
    a. Other ongoing efforts?
    b. Existing climate actions:
        - Updating bylaws
        - Enterprise fund for stormwater management
        - 2017-2021 Housing production plan
        - Plans for budgeting
        - Master plan
        - Annual reports for community development (every department)
        - Warrant articles
        - Tewksbury vision plan
        - Complete streets
        - Pedestrian mobility master plan
        - Warming stations
        - During emergencies, town manager convenes people (health, police, fire, dpw…) to come up with a specif plan depending on hazard, no specific plan developed currently. (informal SOP)
        - Often use Billerica shelter instead of their own if they don't need to use their own
        - Need to update backup if there is issue at water treatment plant/distribution system (Risk and resilience plan is needed)
        - Fire chief is working on updating emergency management plan

W&S Action Item: Review materials and incorporate into Workshop and Report(s)

Tewksbury Action Item: Identify and provide any additional resources

Workshop Participants — 10 minutes

1. Respond to a list of workshop invitees

- Anna will help come up with email addresses
- DCR employee (get name) would like to be involved in more workshops
- Add Justin from NMCOG
- Remove Mr. Johnson who is listed twice
- Add Division of Ecological Restoration – get name from Kevin
- Potentially add CTI (Community Teamwork Incorporated)
- Market Basket operation – find contact – Ask Alex?
- Crock Mill Farms – Jennifer Navo
- Scott Brunk – water & sewer superintendent
- US Army Corp – if there is a reason why we want them

W&S Action Item: Draft invitation to stakeholders
Tewksbury Action Item: Finalize list of invitees; send invitation and track RSVPs, assign participants to tables

Wrap Up and Next Steps — 10 minutes

Map updates (additional updates to make on the map)
Add:

- Senior center
- Ames Hill Water Tank
- Colonial water tank
- Astle St Water tank
- Water altitude valve
- Water pump station (ames hill)
- Sewer syphon
- Label water treatment plant
- Merrimac drive – update pump station to water intake station
- Dog pound and cell tower
- Astle st cell communication
- South station cell tower
- Ames water tank communication tower
- Dispatch/communication tower on Dracut
- Chapman road: National Grid gas storage tanks
- National grid power station (2)
- Evacuation route bridge (frequent flooding in that area, blocks off area of town)

Municipal Vulnerability Preparedness Planning Grant

Core Team Meeting
Feb 19th, 2019 2:00-3:00
Town Hall, Lower Level Conference Room

1. **Review of Updates to the 2015 Hazard Mitigation Plan** — 15 minutes
    a. Review updates to "2015 Existing Mitigation Measures" spreadsheet
    b. Review updates to "2015 Proposed Mitigation Actions" spreadsheet

2. **Review Outcomes from the Community Resilience Building Workshop** — 10 minutes

3. **Review Draft MVP/HMP Priority Actions Table** — 15 minutes
    a. Identify Missing Actions
    b. Identify/Confirm Prioritization, Implementation Responsibility, etc.
    c. Identify three priority project ideas for the MVP Action Grant application

4. **Discuss Options for the Implementation and Update Process** — 10 minutes

5. **Wrap Up and Next Steps** — 10 minutes
    a. Two Upcoming Public Listening Sessions in March
    b. Public Open Comment Period
        i. Length: 1 week to 30 days
        ii. Opportunity to Review Draft Report and Provide Feedback
    c. Action Grant Application (possibly released in April)

Print	Signature
Steve Sadwick	
Kevin Hardiman	
Melissa Manoscalco	
Anna McGinty	
Brian Gilbert	
Stefania Gallo	

Town of Tewksbury
Municipal Vulnerability Preparedness Planning Grant Project
Key Expert Interview Questions

1. What are some of Tewksbury's greatest strengths?

2. What are some of Tewksbury's greatest vulnerabilities?

3. In general, how prepared do you feel Tewksbury is for climate change? Why?

4. How does the goal of improving Tewksbury's climate resilience overlap with your department's mission or objectives?

5. Which climate hazard is likely to have the greatest impact on your department? In other words, which hazard impacts your department's operations most frequently, and what kind of impacts typically occur?

6. What (and where) are your department's critical facilities, infrastructure, or assets? (Review with map and Attachment A: Critical Facilities List).

7. Does your department have a Standard Operating Procedure or Emergency Plan to respond and recover after hazards occur? This could be a formal or informal plan.

8. How has your department taken steps to reduce vulnerabilities to climate change in your operations or to protect the public health and safety in the community? (Review with Attachment B: Existing Protection Matrix from "Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update"). Please provide updates and additional information related to the existing protection identified in 2015.

9. How could Tewksbury adapt to climate change today? In the next five years? In the next 20 years? (Review with Attachment C: Proposed Mitigation Actions from "Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update"). Please provide updates and additional information related to the proposed mitigation actions identified in 2015.

10. How should Tewksbury prioritize its climate adaptation measures (i.e., based on funding, time frame, asset type, or other considerations)? Which adaptation strategies discussed previously should be a top priority?

11. What tools, resources, knowledge, or data would your department need to better mitigate, prepare, respond, recover, or adapt to climate change?

12. How can your department promote resilience within the community or directly with community members?

13. Do you currently coordinate with surrounding communities, state agencies, or regional organizations? What's currently working and what could improve? Examples of regional coordination include:
    a. Receiving water, electric, or other public utilities from another town
    b. Memoranda of understanding between Town departments (for example, between Tewksbury's Fire Department and the Fire Department in an adjacent town)
    c. Participation in regional groups, conferences, or meetings

Appendix B

Additional Hazard Data

Detailed Descriptions of Current and Future Development in Tewksbury:

Katie Estates: Fifty-eight single family homes in a condominium community built 2007-2011. 18 of 58 completed in 2010 through 2011.

Ocean State Job Lot: opened in previously shuttered Purity Supreme space and leased 10,000 square feet to Work Out World.

Tewksbury Memorial High School: demolition of existing high school and construction of new facility.

Walmart Expansion: allowed for full service "super-Walmart" Expansion of an additional 21,000 square feet to the existing facility.

Merrimack Valley Pavilion, Family Entertainment Center: Family entertainment, including laser tag, arcade, mini-golf, pizza and ice cream. Added 4,000 square feet to the existing 4,800 square foot building for family entertainment.

Thermo-Fisher Scientific Relocation: manufacturing of electronic devices, relocation and substantial renovation.

10-80 Wells Drive: eleven single-family homes.

Crystal Circle: eight single-family homes off Crystal Circle.

Wamesit Lanes: demolition of the former Caswell Motel and construction of a bowling facility and family entertainment center.

Heatherwood: 128-unit congregate facility.

Cumberland Farms: Gas Station and Convenience Store.

Sarina Way: mixed use development that includes an office building and 12 residential units.

Winterberry Lane: eleven single-family homes.

Balsam Place/Victor Drive Redevelopment: 192 luxury rental units.

April's Way: fifteen single-family homes.

The Residence at Joan's Farm: ninety-six one- and two-bedroom apartments.

Bella Woods: the project site contains about 25.56 acres of mostly undeveloped land, replacing five single-family homes. The proposal calls for constructing a condominium development with 117 units and its associated roadway and utilities. The units are made up of 43 detached two cars garage units, 48 duplex two cars garage units and 26 duplex one car garage units. Each unit has additional parking in front of the garage with additional guest parking spaces being provide throughout the development.

Ames Run: a project that included the development of Prospect Hill Drive and an extension of Catamount Road.

Scenic Drive: a new development of three housing lots off Catamount Road.

Harvest Lane: eight single-family homes.

Elaina Estates: two-story mixed use, new construction. The building includes 4 rental units on the second floor and 14 townhouses in the rear of the property. The commercial space is used by the NEEDS Center (North East Education and Development Support Center).

Border Road: four single-family homes.

Poland Ave Open Space Residential Development (OSRD): a seven-lot, residential subdivision with open space at the intersection of Dickson Ave, Poland Ave, and Foster Lane.

Circle Health Medical Office: commercial development, also known as Victor Drive Redevelopment.

937 Main Street: new construction of a mixed-use building.

Discount Madness: a complex that includes four residential buildings with fourteen townhouses, and one mixed use building with five retail units and seven residential units.

Robertson Estates, Thomas Estates: twenty-five single-family homes (spanning from 20 to 141 Frasier Lane). As of April 2019, 3 units of 25 were not built, pending building permits.

Sarina's Way: a three story, six unit mixed use building. Demolition was completed in November 2018. The resulting structure includes one professional office space, two residential units above, and three residential units, townhouse-style.

1455 Main Street: mixed-use 4 residential units with 2200 square feet of retail and commercial space, and 8 townhouses.

2230 Main Street: 10,000 square feet of office and retail space on the first floor, along with 30 rental apartments.

960 Main Street: office and retail building at the front of 960 Main Street, with an 8-unit residential building at the rear of the lot.

24 Sunnyslope Ave: a commercial/industrial use building with a contractor's yard.

Hilton Hotel: a five story, 132-room hotel with associated parking and amenities.

Comfort Dental: professional office space.

24 Pleasant Street: bank drive-through and offices with associated parking.

160 Dascomb Road: a single story building sited in both the Towns of Andover and Tewksbury.

Regional Emergency Communications Center (RECC): a single-story municipal building with a regional emergency communications center, communication tower, and associated parking.

725 Main Street: a two-story mixed-use structure that would feature two commercial office suites and one residential unit on the ground floor, and four residential units on the second floor.

82 Pleasant Street: a two-story, mixed-use carriage housing with a sale shop and one residential unit.

2122 Main Street: one commercial building with two tenant spaces and nine retail townhouse units. There will be one three-unit building and three two-unit buildings. The residential units will provide approximately 1200 square feet of living space with a loft and a 12' x 20' garage.

2131 Main Street: fifteen townhouses and residential units, along with a commercial building.

Naomi Way: two single family homes.

138 Astle Street: four single family homes, all Open Space Residential Development (OSRD).

105 Lowell Street: commercial office, garage and storage buildings.

1583 Andover Street: coffee shop with associated parking.

1625 Andover Street: restaurant with associated parking.

Detailed Descriptions of Current Planning Board Applications in Tewksbury:

Burtt Road Development: this development would include two warehouses. The first warehouse is 195,150 square feet total, which spans across the Towns of Andover and Tewksbury. The second warehouse is in the Town of Andover and would total 29,750 square feet.

Riverview: a single-story warehouse totaling 715,00 square feet. This proposal includes a buildable lot spanning across the Towns of Andover and Tewksbury, as well as a non-buildable part of a lot in Lowell.

Hazus: Hurricane Global Risk Report

Region Name: Tewksbury_HMP

Hurricane Scenario: Probabilistic 100-year Return Period

Print Date: Friday, February 14, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific Hurricane. These results can be improved by using enhanced inventory data.

Table of Contents

General Description of the Region

Hazus is a regional multi-hazard loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The hurricane loss estimates provided in this report are based on a region that includes 1 county(ies) from the following state(s):

- Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 21.13 square miles and contains 6 census tracts. There are over 10 thousand households in the region and a total population of 28,961 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 10 thousand buildings in the region with a total building replacement value (excluding contents) of 4,524 million dollars (2014 dollars). Approximately 91% of the buildings (and 80% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 10,479 buildings in the region which have an aggregate total replacement value of 4,524 million (2014 dollars). Table 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

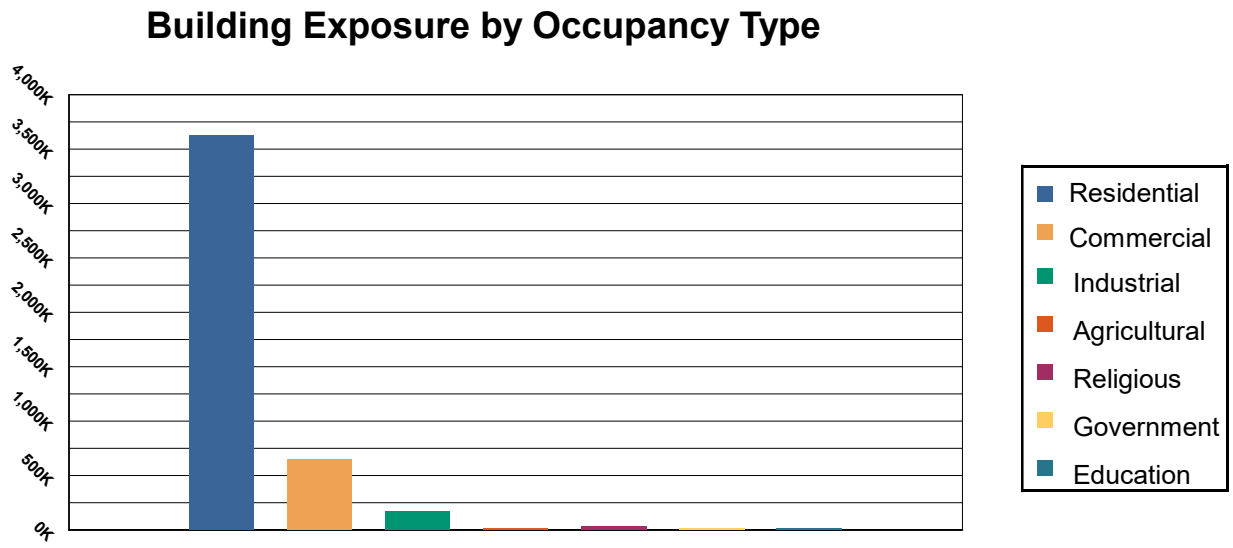


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	3,626,819	80.18 %
Commercial	649,767	14.36%
Industrial	168,637	3.73%
Agricultural	14,175	0.31%
Religious	32,316	0.71%
Government	13,387	0.30%
Education	18,526	0.41%
Total	**4,523,627**	**100.00%**

Essential Facility Inventory

For essential facilities, there are 1 hospitals in the region with a total bed capacity of 720 beds. There are 9 schools, 3 fire stations, 1 police stations and no emergency operation facilities.

Hurricane Scenario

Hazus used the following set of information to define the hurricane parameters for the hurricane loss estimate provided in this report.

Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 10 buildings will be at least moderately damaged. This is over 0% of the total number of buildings in the region. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

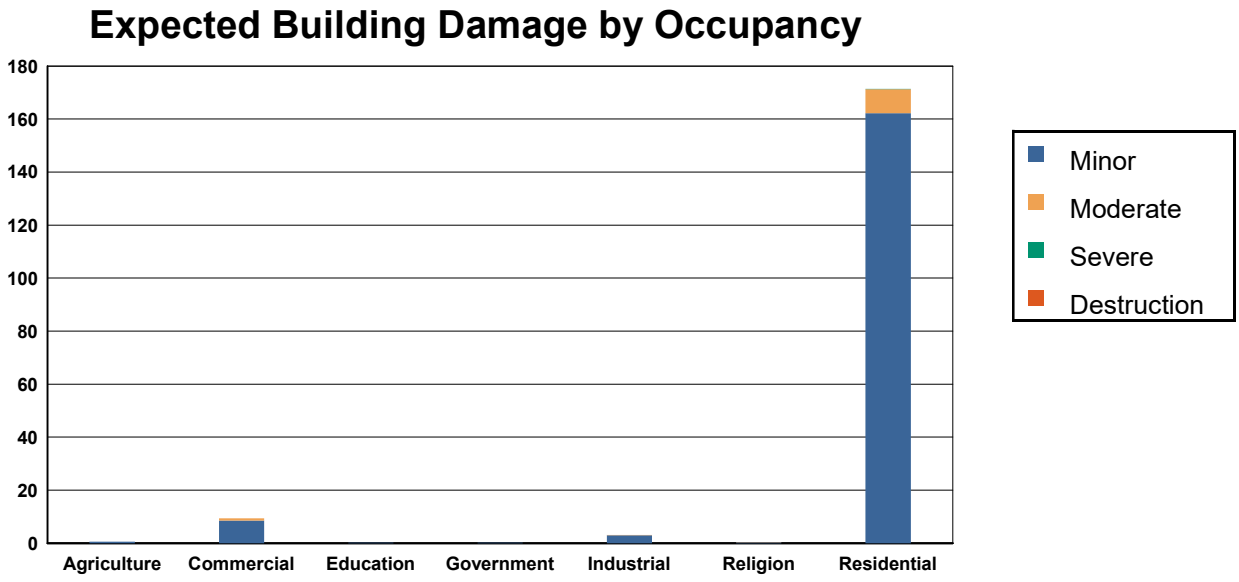


Table 2: Expected Building Damage by Occupancy : 100 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	33.41	98.28	0.52	1.52	0.05	0.16	0.01	0.04	0.00	0.00
Commercial	611.65	98.49	8.57	1.38	0.76	0.12	0.02	0.00	0.00	0.00
Education	13.80	98.54	0.20	1.43	0.00	0.03	0.00	0.00	0.00	0.00
Government	13.79	98.52	0.20	1.46	0.00	0.02	0.00	0.00	0.00	0.00
Industrial	204.93	98.52	2.95	1.42	0.10	0.05	0.02	0.01	0.00	0.00
Religion	29.61	98.71	0.38	1.25	0.01	0.03	0.00	0.00	0.00	0.00
Residential	9,386.65	98.21	162.19	1.70	9.03	0.09	0.13	0.00	0.00	0.00
Total	**10,293.85**		**175.01**		**9.96**		**0.18**		**0.00**	

Table 3: Expected Building Damage by Building Type : 100 - year Event

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	53	98.07	1	1.89	0	0.04	0	0.00	0	0.00
Masonry	489	97.07	12	2.46	2	0.46	0	0.01	0	0.00
MH	199	99.90	0	0.07	0	0.02	0	0.00	0	0.00
Steel	404	98.48	6	1.41	0	0.11	0	0.01	0	0.00
Wood	8,805	98.39	140	1.56	4	0.04	0	0.00	0	0.00

Essential Facility Damage

Before the hurricane, the region had 720 hospital beds available for use. On the day of the hurricane, the model estimates that 720 hospital beds (only 100.00%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, 100.00% of the beds will be in service. By 30 days, 100.00% will be operational.

Thematic Map of Essential Facilities with greater than 50% moderate

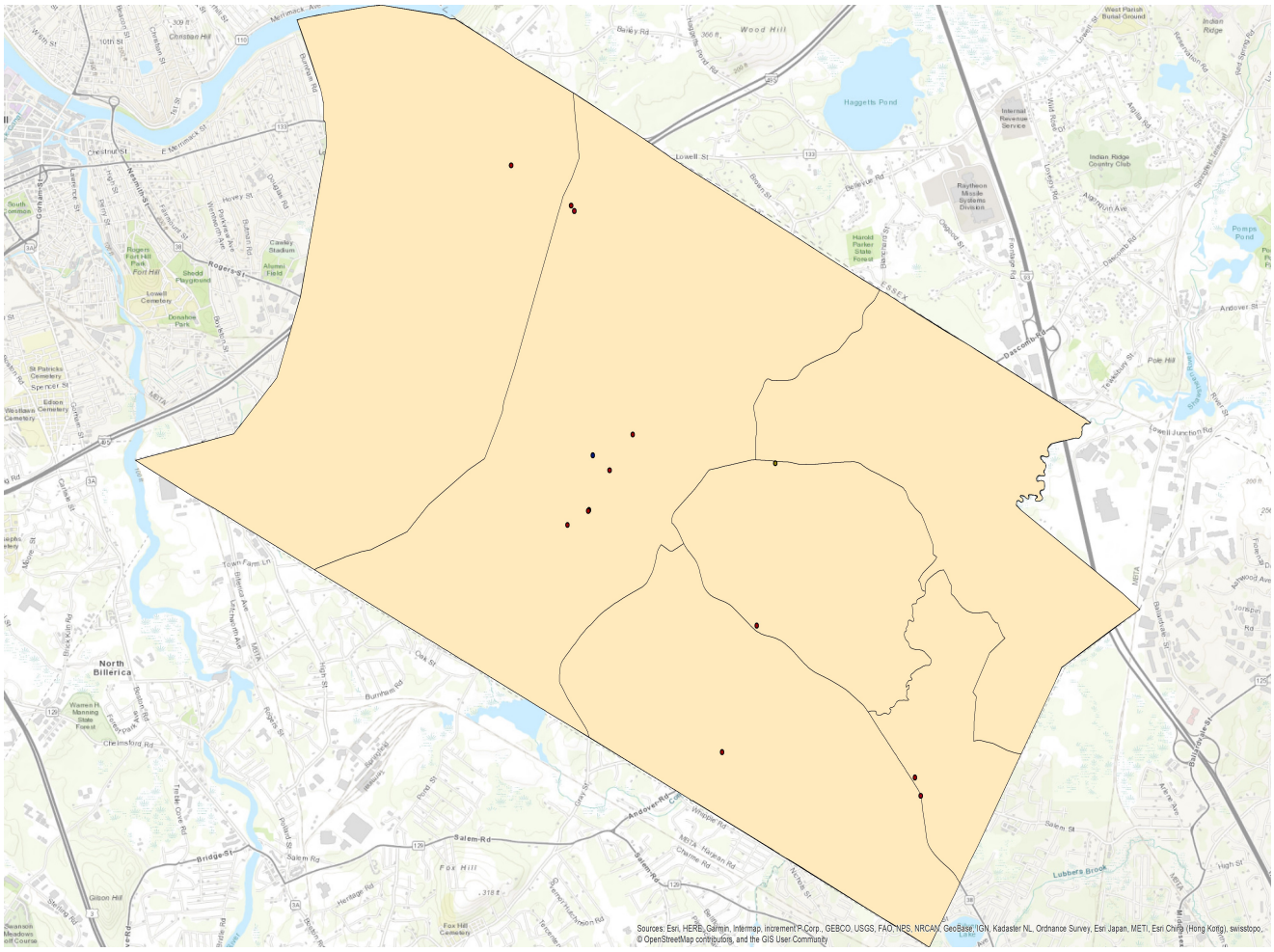
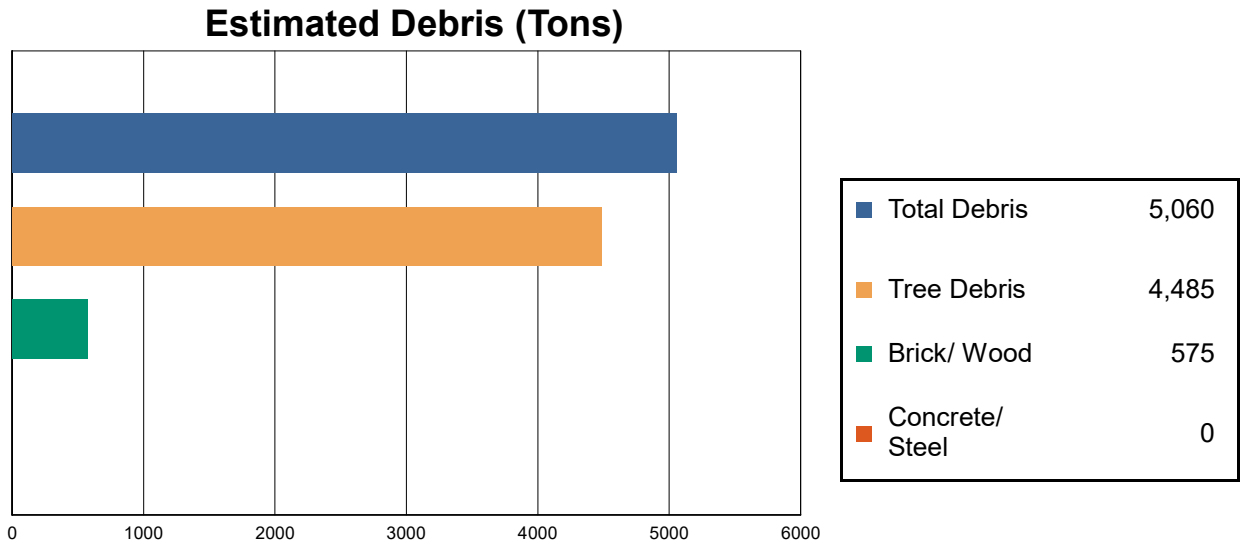


Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**Probability of at Least Moderate Damage > 50%**	**Probability of Complete Damage > 50%**	**Expected Loss of Use < 1 day**
Fire Stations	3	0	0	3
Hospitals	1	0	0	1
Police Stations	1	0	0	1
Schools	9	0	0	9

Induced Hurricane Damage

Debris Generation

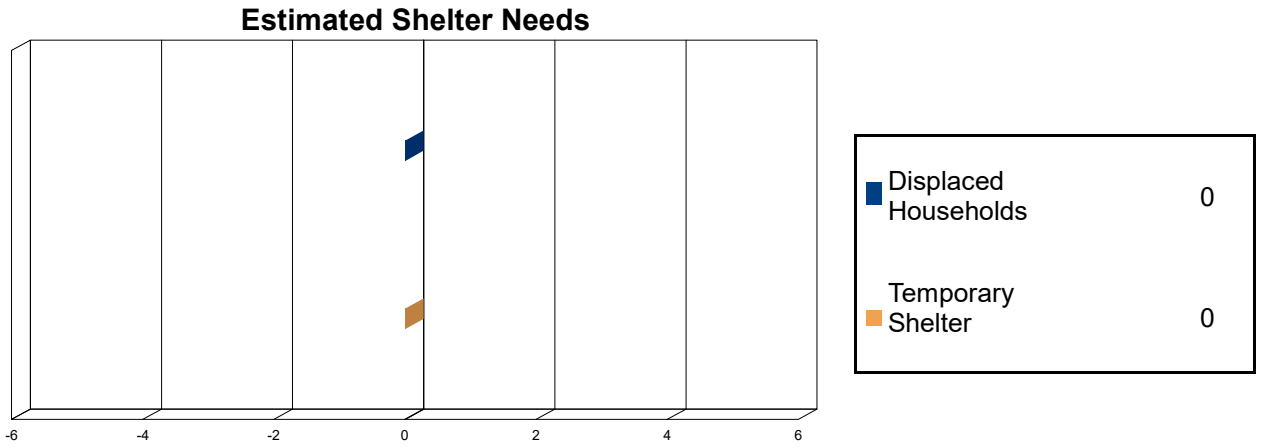


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 5,060 tons of debris will be generated. Of the total amount, 2,173 tons (43%) is Other Tree Debris. Of the remaining 2,887 tons, Brick/Wood comprises 20% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 23 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 2,312 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 0 households to be displaced due to the hurricane. Of these, 0 people (out of a total population of 28,961) will seek temporary shelter in public shelters.

Economic Loss

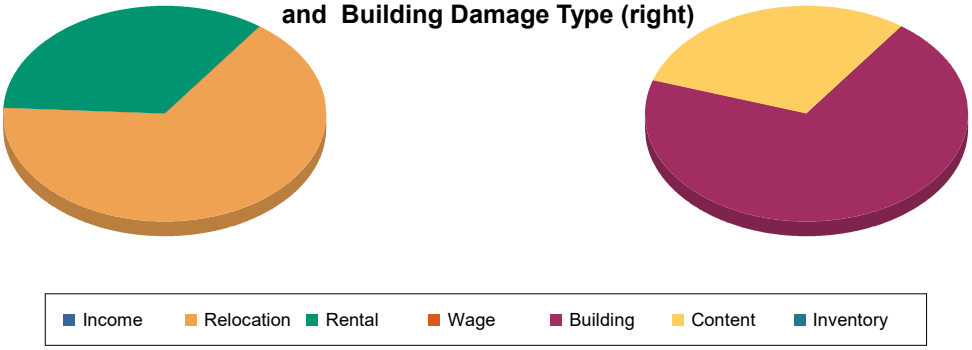
The total economic loss estimated for the hurricane is 21.7 million dollars, which represents 0.48 % of the total replacement value of the region's buildings.

Building-Related Losses

The building related losses are broken into two categories: direct property damage losses and business interruption losses. The direct property damage losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the hurricane. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the hurricane.

The total property damage losses were 22 million dollars. 2% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 98% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.

Loss by Business Interruption Type (left) and Building Damage Type (right)



Loss Type by General Occupancy

Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	14,510.66	290.58	54.50	31.33	14,887.06
	Content	6,394.96	20.88	1.88	0.62	6,418.33
	Inventory	0.00	0.47	0.32	0.06	0.84
	Subtotal	**20,905.61**	**311.92**	**56.70**	**32.00**	**21,306.24**
Business Interruption Loss						
	Income	0.00	0.24	0.00	0.00	0.24
	Relocation	231.49	7.03	0.19	0.26	238.97
	Rental	123.31	0.10	0.00	0.00	123.41
	Wage	0.00	0.08	0.00	0.00	0.08
	Subtotal	**354.79**	**7.45**	**0.19**	**0.26**	**362.70**

Total

Total	**21,260.41**	**319.38**	**56.89**	**32.27**	**21,668.94**

Appendix A: County Listing for the Region

Massachusetts
- Middlesex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Middlesex	28,961	3,626,819	896,808	4,523,627
Total	**28,961**	**3,626,819**	**896,808**	**4,523,627**
Study Region Total	**28,961**	**3,626,819**	**896,808**	**4,523,627**

Hazus: Hurricane Global Risk Report

Region Name: Tewksbury_HMP

Hurricane Scenario: Probabilistic 500-year Return Period

Print Date: Friday, February 14, 2020

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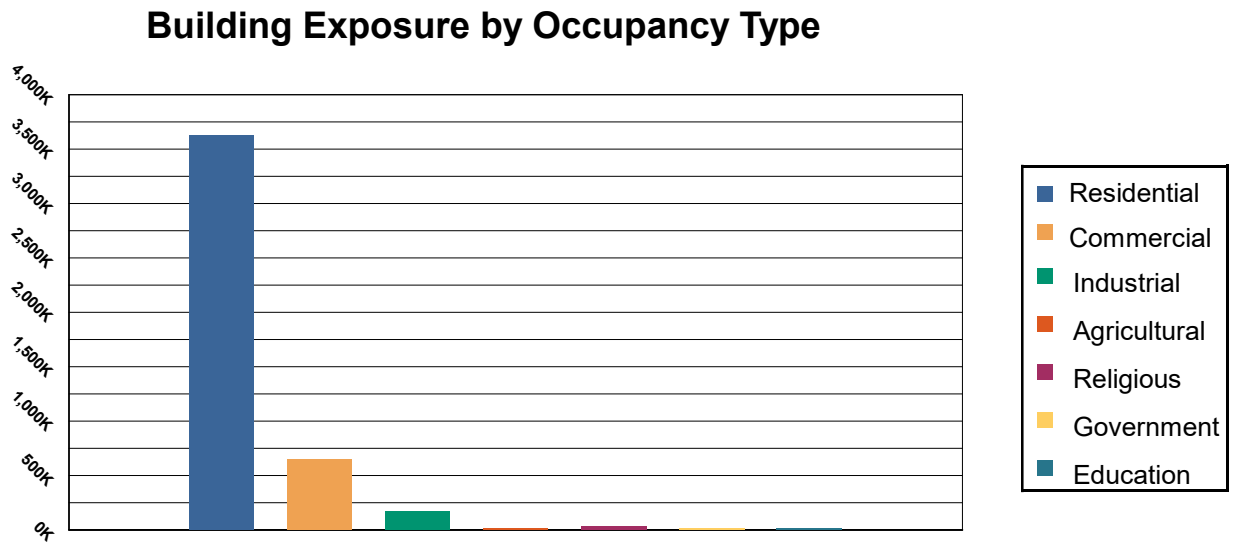

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Hurricane Scenario

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Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 180 buildings will be at least moderately damaged. This is over 2% of the total number of buildings in the region. There are an estimated 3 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

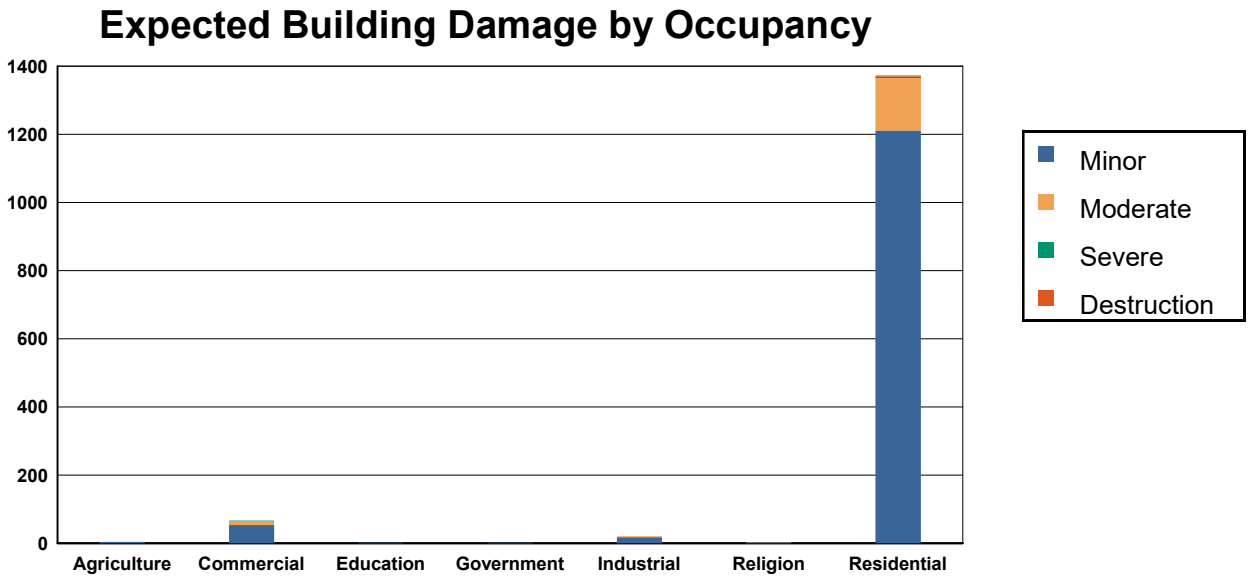


Table 2: Expected Building Damage by Occupancy : 500 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	29.29	86.14	3.53	10.38	0.79	2.32	0.36	1.07	0.03	0.09
Commercial	555.04	89.38	53.29	8.58	11.07	1.78	1.60	0.26	0.00	0.00
Education	12.59	89.94	1.22	8.74	0.18	1.27	0.01	0.06	0.00	0.00
Government	12.61	90.05	1.21	8.62	0.18	1.29	0.01	0.05	0.00	0.00
Industrial	187.32	90.06	17.04	8.19	3.00	1.44	0.61	0.29	0.04	0.02
Religion	26.98	89.93	2.72	9.05	0.29	0.97	0.01	0.05	0.00	0.00
Residential	8,185.94	85.64	1,210.64	12.67	154.58	1.62	3.58	0.04	3.26	0.03
Total	**9,009.76**		**1,289.64**		**170.08**		**6.18**		**3.33**	

Table 3: Expected Building Damage by Building Type : 500 - year Event

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	48	88.20	5	9.88	1	1.89	0	0.03	0	0.00
Masonry	424	84.07	57	11.37	22	4.31	1	0.22	0	0.02
MH	192	96.61	5	2.31	2	0.80	0	0.02	1	0.26
Steel	369	90.10	32	7.78	7	1.81	1	0.31	0	0.00
Wood	7,700	86.05	1,134	12.68	108	1.21	4	0.04	2	0.03

Essential Facility Damage

Before the hurricane, the region had 720 hospital beds available for use. On the day of the hurricane, the model estimates that 720 hospital beds (only 100.00%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, 100.00% of the beds will be in service. By 30 days, 100.00% will be operational.

Thematic Map of Essential Facilities with greater than 50% moderate

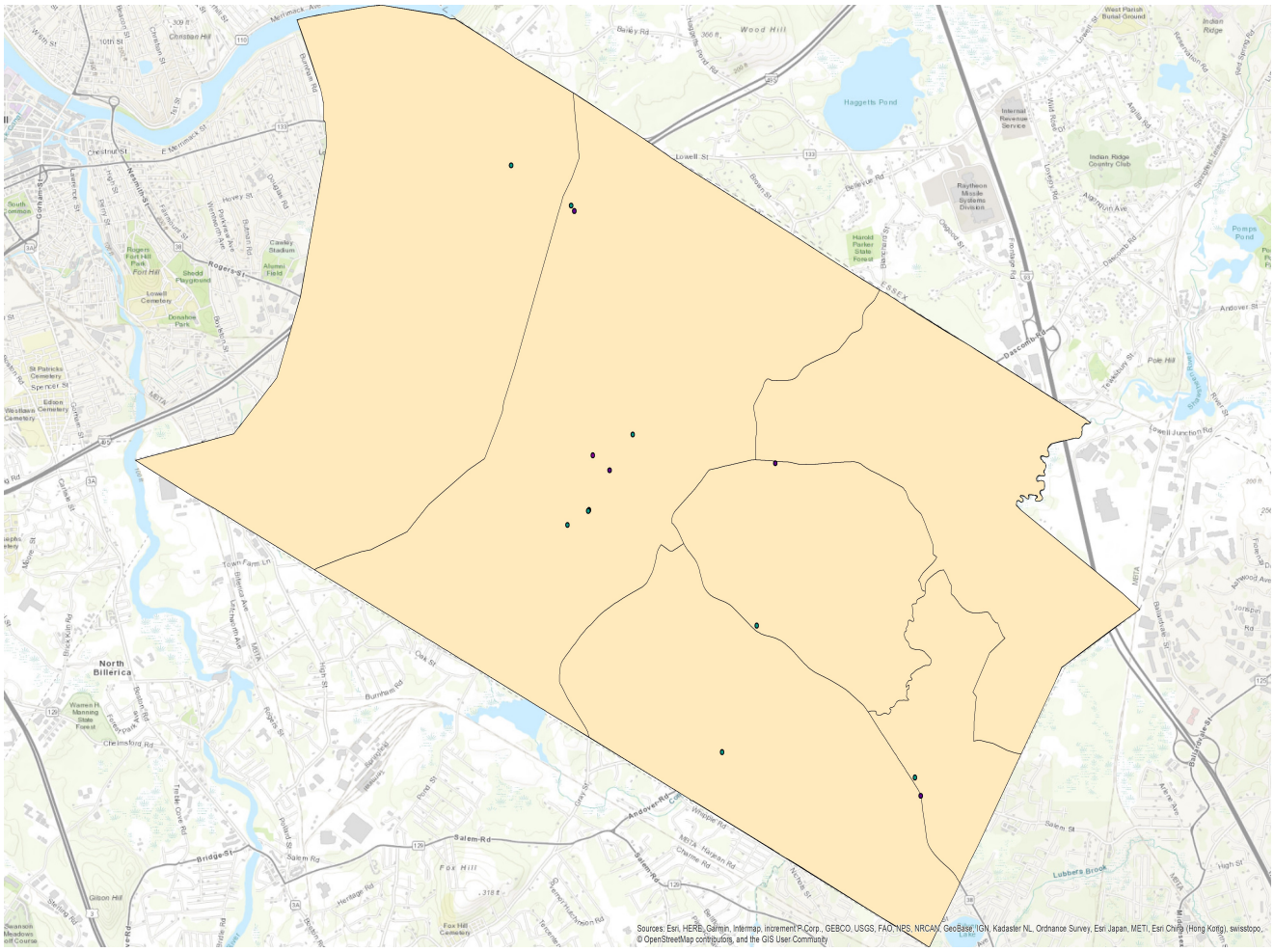
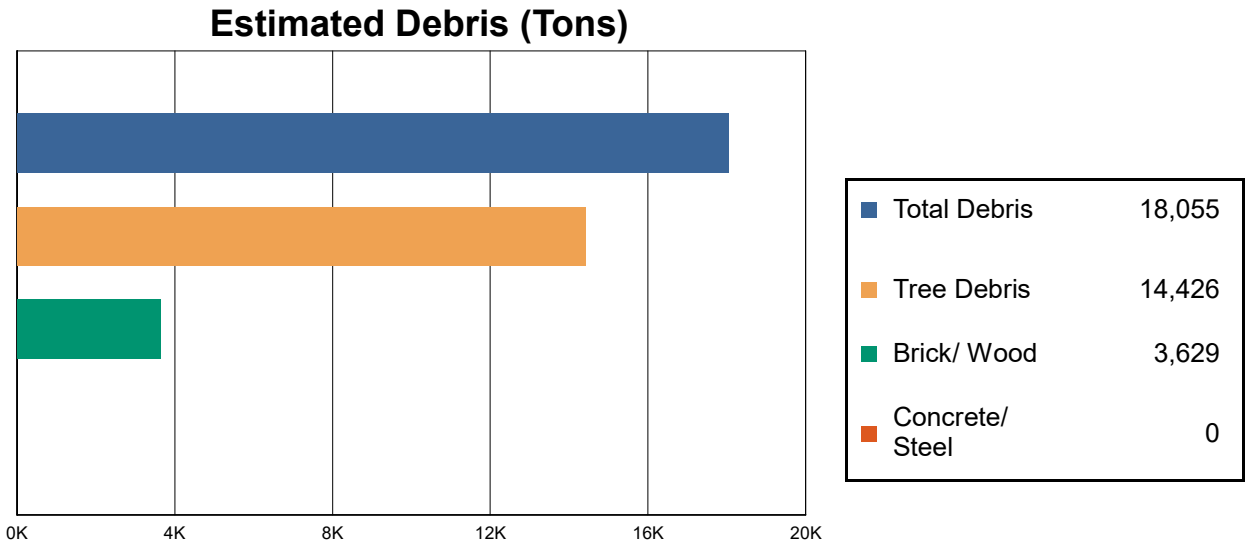


Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**Probability of at Least Moderate Damage > 50%**	**Probability of Complete Damage > 50%**	**Expected Loss of Use < 1 day**
Fire Stations	3	0	0	3
Hospitals	1	0	0	1
Police Stations	1	0	0	1
Schools	9	0	0	9

Induced Hurricane Damage

Debris Generation

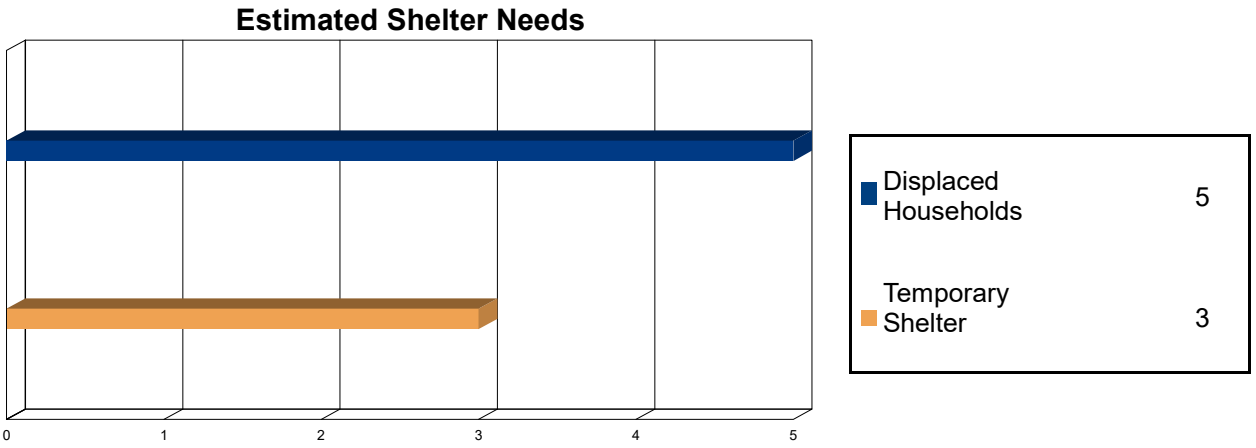


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 18,055 tons of debris will be generated. Of the total amount, 7,216 tons (40%) is Other Tree Debris. Of the remaining 10,839 tons, Brick/Wood comprises 33% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 145 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 7,210 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 5 households to be displaced due to the hurricane. Of these, 3 people (out of a total population of 28,961) will seek temporary shelter in public shelters.

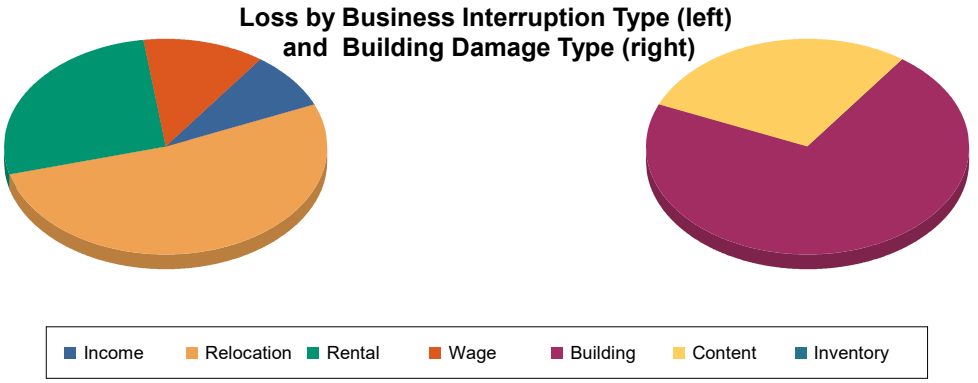
Economic Loss

The total economic loss estimated for the hurricane is 79.1 million dollars, which represents 1.75 % of the total replacement value of the region's buildings.

Building-Related Losses

The building related losses are broken into two categories: direct property damage losses and business interruption losses. The direct property damage losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the hurricane. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the hurricane.

The total property damage losses were 79 million dollars. 4% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 93% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.



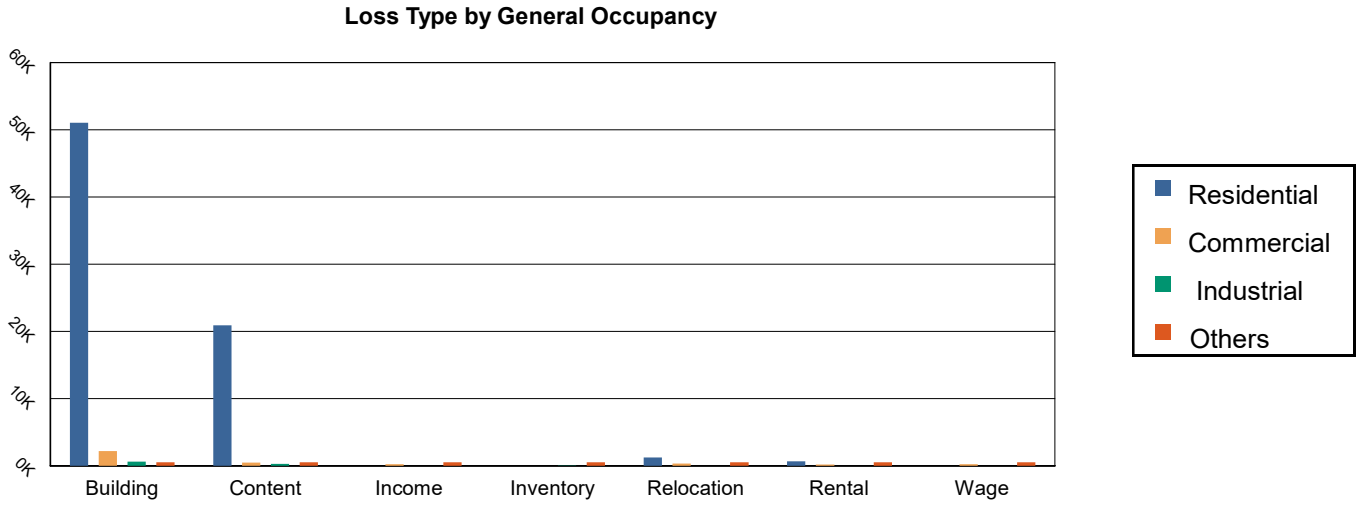


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	51,052.67	2,194.27	618.56	276.06	54,141.56
	Content	20,891.36	494.75	307.13	61.84	21,755.08
	Inventory	0.00	14.79	47.13	2.97	64.89
	Subtotal	**71,944.03**	**2,703.82**	**972.82**	**340.88**	**75,961.54**
Business Interruption Loss						
	Income	0.00	244.06	6.86	23.63	274.55
	Relocation	1,236.62	340.68	27.29	37.29	1,641.88
	Rental	660.92	180.54	5.18	3.24	849.89
	Wage	0.00	258.67	11.26	113.66	383.60
	Subtotal	**1,897.54**	**1,023.95**	**50.59**	**177.82**	**3,149.91**

Total

Total	**73,841.58**	**3,727.77**	**1,023.41**	**518.69**	**79,111.45**

Appendix A: County Listing for the Region

Massachusetts
- Middlesex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Middlesex	28,961	3,626,819	896,808	4,523,627
Total	**28,961**	**3,626,819**	**896,808**	**4,523,627**
Study Region Total	**28,961**	**3,626,819**	**896,808**	**4,523,627**

Hazus: Earthquake Global Risk Report

Region Name	Tewksbury_HMP
Earthquake Scenario:	Tewksbury Magnitude 5.0 Earthquake
Print Date:	February 14, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus-MH is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 21.12 square miles and contains 6 census tracts. There are over 10 thousand households in the region which has a total population of 28,961 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 10 thousand buildings in the region with a total building replacement value (excluding contents) of 4,523 (millions of dollars). Approximately 91.00 % of the buildings (and 80.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 971 and 20 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 10 thousand buildings in the region which have an aggregate total replacement value of 4,523 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 86% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 1 hospitals in the region with a total bed capacity of 720 beds. There are 9 schools, 3 fire stations, 1 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 19 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 991.00 (millions of dollars). This inventory includes over 59.03 miles of highways, 16 bridges, 640.63 miles of pipes.

Table 1: Transportation System Lifeline Inventory

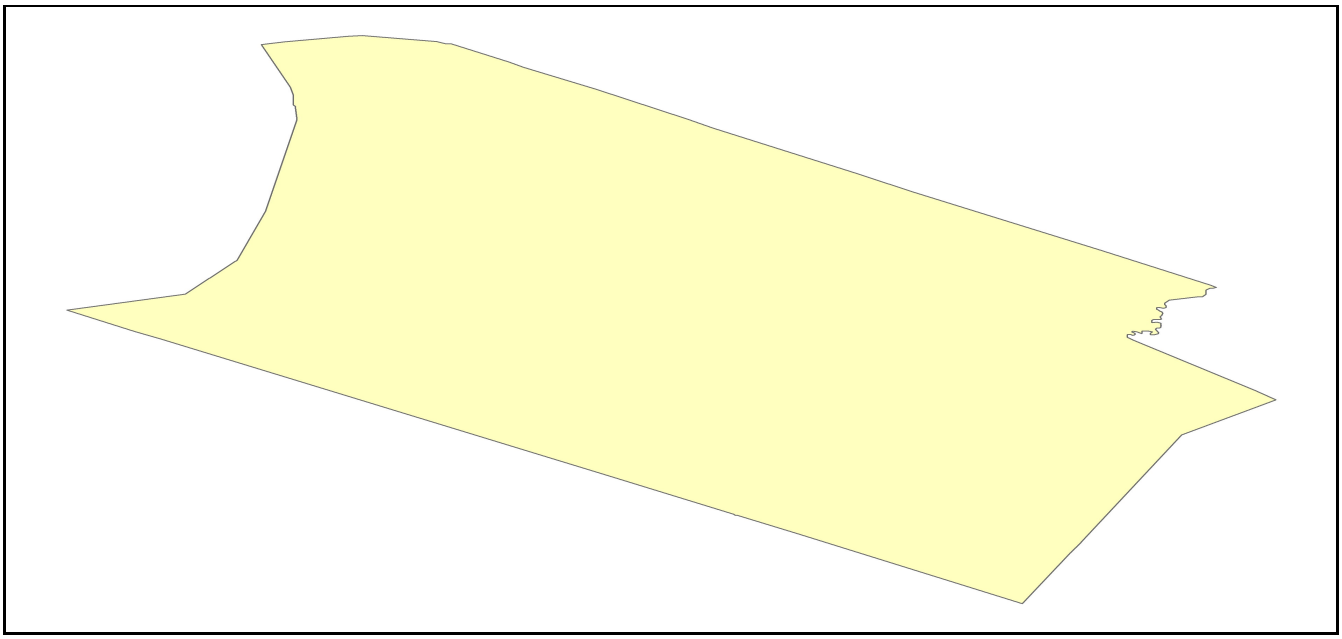
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	16	199.8352
	Segments	68	677.9411
	Tunnels	0	0.0000
		Subtotal	**877.7763**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	68	61.9948
	Tunnels	0	0.0000
		Subtotal	**61.9948**
Light Rail	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	8	30.8062
	Tunnels	0	0.0000
		Subtotal	**30.8062**
Bus	Facilities	1	1.2644
		Subtotal	**1.2644**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**971.80**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	10.3140
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**10.3140**
Waste Water	Distribution Lines	NA	6.1884
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**6.1884**
Natural Gas	Distribution Lines	NA	4.1256
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**4.1256**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	0	0.0000
		Subtotal	**0.0000**
Communication	Facilities	0	0.0000
		Subtotal	**0.0000**
		Total	**20.60**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.



Scenario Name	Tewksbury Magnitude 5.0 Earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.23
Latitude of Epicenter	42.61
Earthquake Magnitude	5.00
Depth (km)	10.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 2,211 buildings will be at least moderately damaged. This is over 21.00 % of the buildings in the region. There are an estimated 112 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

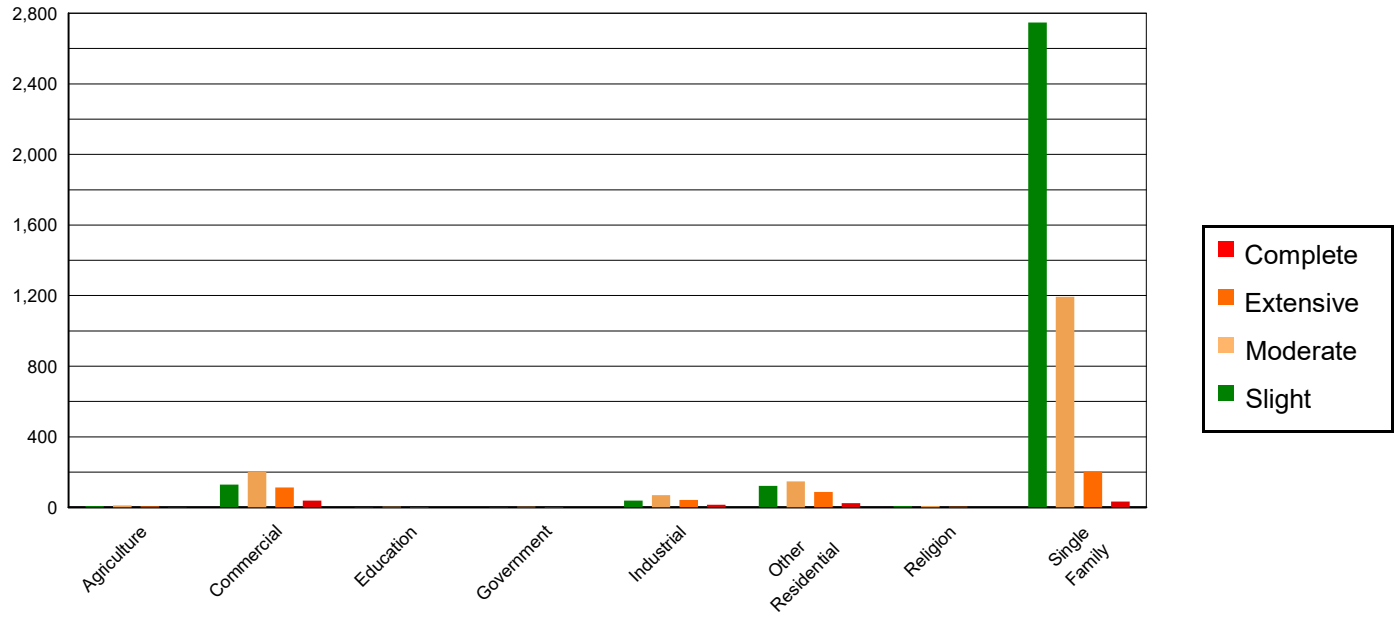


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	7.50	0.14	8.26	0.27	11.30	0.69	5.20	1.13	1.75	1.55
Commercial	139.82	2.68	128.96	4.22	202.00	12.32	112.30	24.49	37.92	33.61
Education	3.36	0.06	2.86	0.09	4.54	0.28	2.45	0.53	0.80	0.71
Government	2.96	0.06	2.59	0.08	4.66	0.28	2.82	0.62	0.96	0.85
Industrial	44.12	0.85	38.72	1.27	68.87	4.20	42.04	9.17	14.24	12.63
Other Residential	157.92	3.03	120.90	3.96	147.84	9.02	87.17	19.01	23.16	20.53
Religion	10.82	0.21	7.09	0.23	7.11	0.43	3.77	0.82	1.21	1.07
Single Family	4844.94	92.97	2746.88	89.88	1193.64	72.78	202.77	44.22	32.78	29.05
Total	**5,211**		**3,056**		**1,640**		**459**		**113**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	4889.02	93.81	2771.02	90.67	1170.88	71.40	161.18	35.15	12.06	10.69
Steel	83.97	1.61	71.67	2.34	149.89	9.14	96.52	21.05	34.14	30.26
Concrete	12.43	0.24	10.97	0.36	25.81	1.57	16.54	3.61	5.01	4.44
Precast	4.94	0.09	3.57	0.12	9.07	0.55	8.98	1.96	2.69	2.39
RM	27.83	0.53	13.42	0.44	28.17	1.72	22.72	4.95	4.04	3.58
URM	163.03	3.13	143.32	4.69	169.12	10.31	92.29	20.13	39.69	35.18
MH	30.20	0.58	42.30	1.38	87.02	5.31	60.30	13.15	15.18	13.46
Total	**5,211**		**3,056**		**1,640**		**459**		**113**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 720 hospital beds available for use. On the day of the earthquake, the model estimates that only 165 hospital beds (23.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 45.00% of the beds will be back in service. By 30 days, 74.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	1	1	0	0
Schools	9	9	0	0
EOCs	0	0	0	0
PoliceStations	1	1	0	0
FireStations	3	3	0	0

Transportation Lifeline Damage

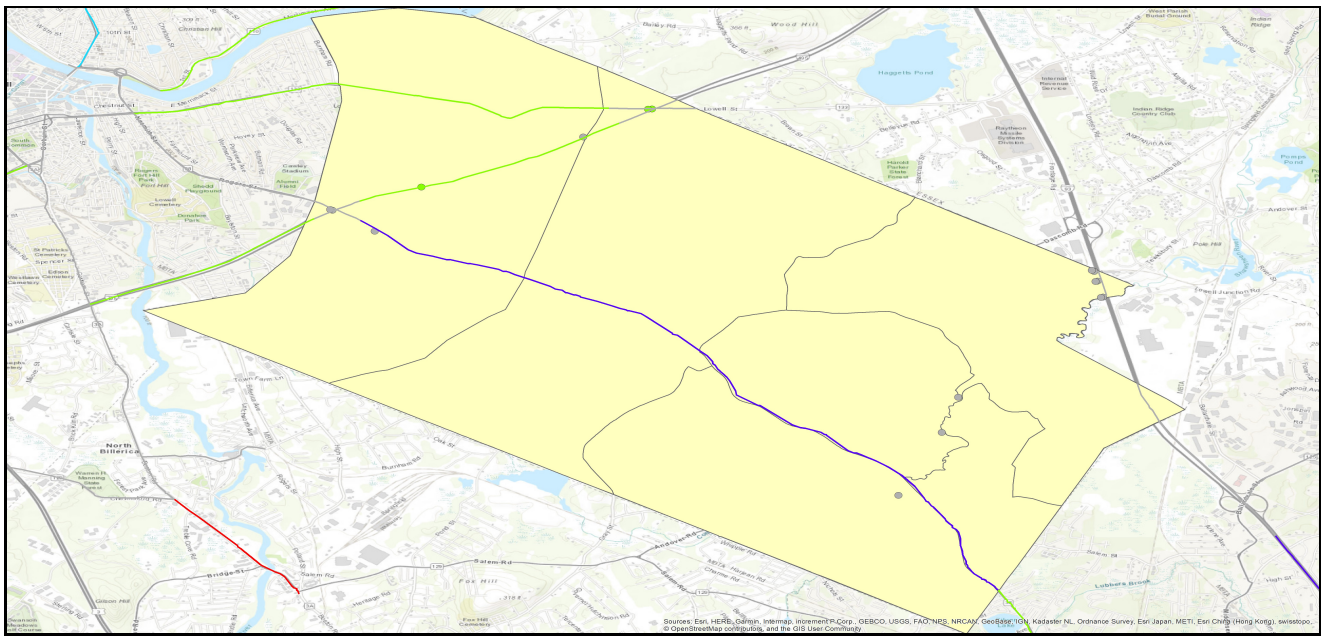


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	68	0	0	66	66
	Bridges	16	5	0	11	16
	Tunnels	0	0	0	0	0
Railways	Segments	68	0	0	17	17
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	8	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	320	83	21
Waste Water	192	42	10
Natural Gas	128	14	4
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	10,492	0	0	0	0	0
Electric Power		8,779	5,784	2,385	422	10

Induced Earthquake Damage

Fire Following Earthquake

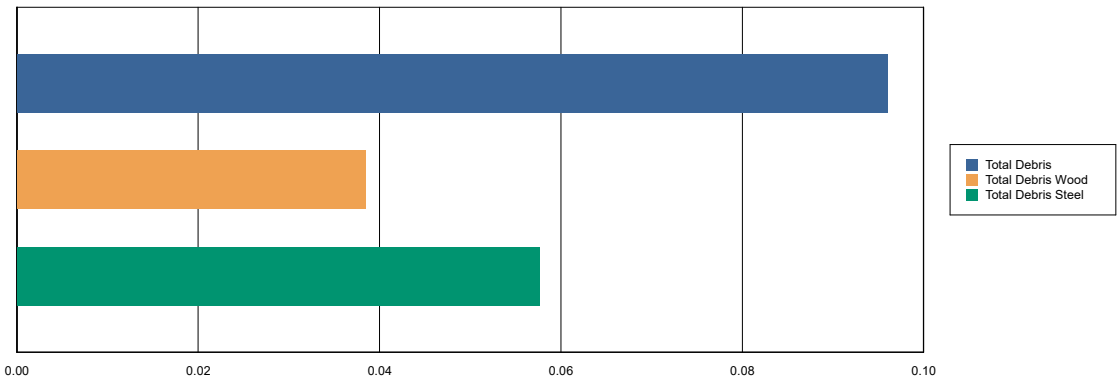
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 96,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 40.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 3,840 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



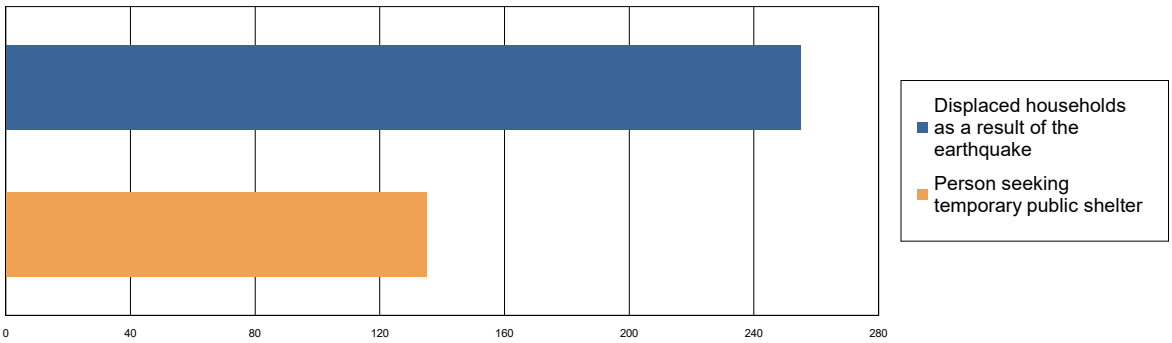
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.04	0.06	0.10	3,840 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 255 households to be displaced due to the earthquake. Of these, 135 people (out of a total population of 28,961) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
255	135

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	1.89	0.47	0.06	0.13
	Commuting	0.02	0.02	0.04	0.01
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	2.86	0.72	0.10	0.20
	Other-Residential	23.46	5.70	0.79	1.55
	Single Family	28.78	4.92	0.51	0.98
	Total	**57**	**12**	**2**	**3**
2 PM	Commercial	106.48	26.27	3.63	7.08
	Commuting	0.16	0.19	0.34	0.06
	Educational	39.33	10.00	1.48	2.88
	Hotels	0.00	0.00	0.00	0.00
	Industrial	21.15	5.30	0.75	1.45
	Other-Residential	4.62	1.14	0.16	0.31
	Single Family	5.31	0.94	0.10	0.19
	Total	**177**	**44**	**6**	**12**
5 PM	Commercial	75.95	18.81	2.63	5.05
	Commuting	3.14	3.77	6.87	1.30
	Educational	3.07	0.78	0.12	0.23
	Hotels	0.00	0.00	0.00	0.00
	Industrial	13.22	3.31	0.47	0.91
	Other-Residential	9.15	2.25	0.32	0.61
	Single Family	11.31	2.00	0.22	0.41
	Total	**116**	**31**	**11**	**9**

Economic Loss

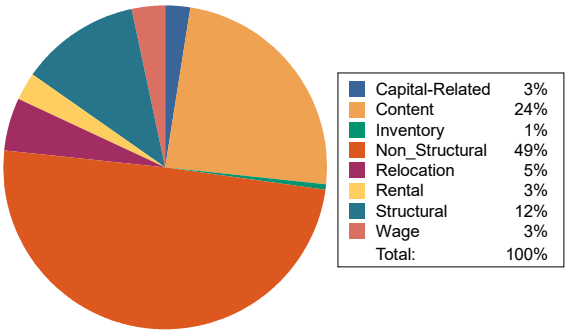
The total economic loss estimated for the earthquake is 606.51 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 578.41 (millions of dollars); 14 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 58 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

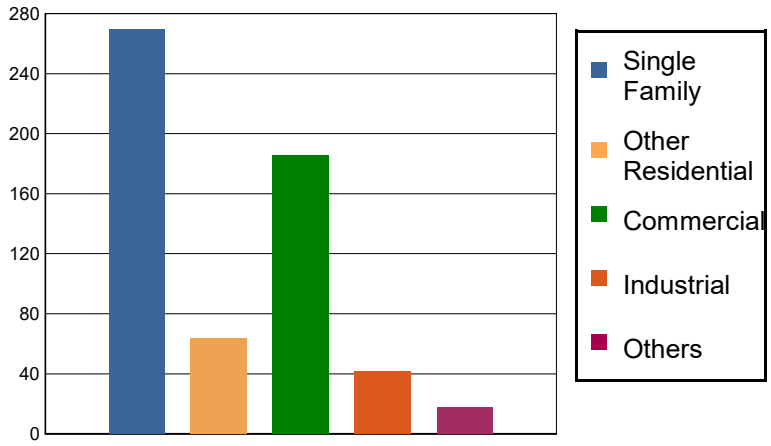


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	1.4510	16.1151	0.8908	0.6066	19.0635
	Capital-Related	0.0000	0.6170	13.3367	0.5299	0.1036	14.5872
	Rental	2.9666	3.6428	8.6838	0.2412	0.2366	15.7710
	Relocation	10.6249	2.0656	14.3197	1.3262	1.7460	30.0824
	Subtotal	**13.5915**	**7.7764**	**52.4553**	**2.9881**	**2.6928**	**79.5041**
Capital Stock Losses							
	Structural	25.7772	8.0023	27.4986	5.5270	3.0388	69.8439
	Non_Structural	155.3406	37.2717	67.2017	18.7208	7.3635	285.8983
	Content	74.6528	10.8788	37.4538	12.3697	4.3647	139.7198
	Inventory	0.0000	0.0000	1.1822	2.1722	0.0927	3.4471
	Subtotal	**255.7706**	**56.1528**	**133.3363**	**38.7897**	**14.8597**	**498.9091**
	Total	**269.36**	**63.93**	**185.79**	**41.78**	**17.55**	**578.41**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	677.9411	0.0000	0.00
	Bridges	199.8352	26.9126	13.47
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**877.7763**	**26.9126**	
Railways	Segments	61.9948	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**61.9948**	**0.0000**	
Light Rail	Segments	30.8062	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**30.8062**	**0.0000**	
Bus	Facilities	1.2644	0.5501	43.51
	Subtotal	**1.2644**	**0.5501**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**971.84**	**27.46**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	10.3140	0.3748	3.63
	Subtotal	**10.3140**	**0.3748**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	6.1884	0.1883	3.04
	Subtotal	**6.1884**	**0.1883**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	4.1256	0.0645	1.56
	Subtotal	**4.1256**	**0.0645**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Communication	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**20.63**	**0.63**	

Appendix A: County Listing for the Region

Middlesex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Middlesex	28,961	3,626	896	4,523
Total Region		**28,961**	**3,626**	**896**	**4,523**

Hazus: Earthquake Global Risk Report

Region Name	Tewksbury_HMP
Earthquake Scenario:	Tewksbury magnitude 7.0 earthquake
Print Date:	February 14, 2020

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus-MH is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Massachusetts

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 21.12 square miles and contains 6 census tracts. There are over 10 thousand households in the region which has a total population of 28,961 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 10 thousand buildings in the region with a total building replacement value (excluding contents) of 4,523 (millions of dollars). Approximately 91.00 % of the buildings (and 80.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 971 and 20 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 10 thousand buildings in the region which have an aggregate total replacement value of 4,523 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 86% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 1 hospitals in the region with a total bed capacity of 720 beds. There are 9 schools, 3 fire stations, 1 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 19 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 991.00 (millions of dollars). This inventory includes over 59.03 miles of highways, 16 bridges, 640.63 miles of pipes.

Table 1: Transportation System Lifeline Inventory

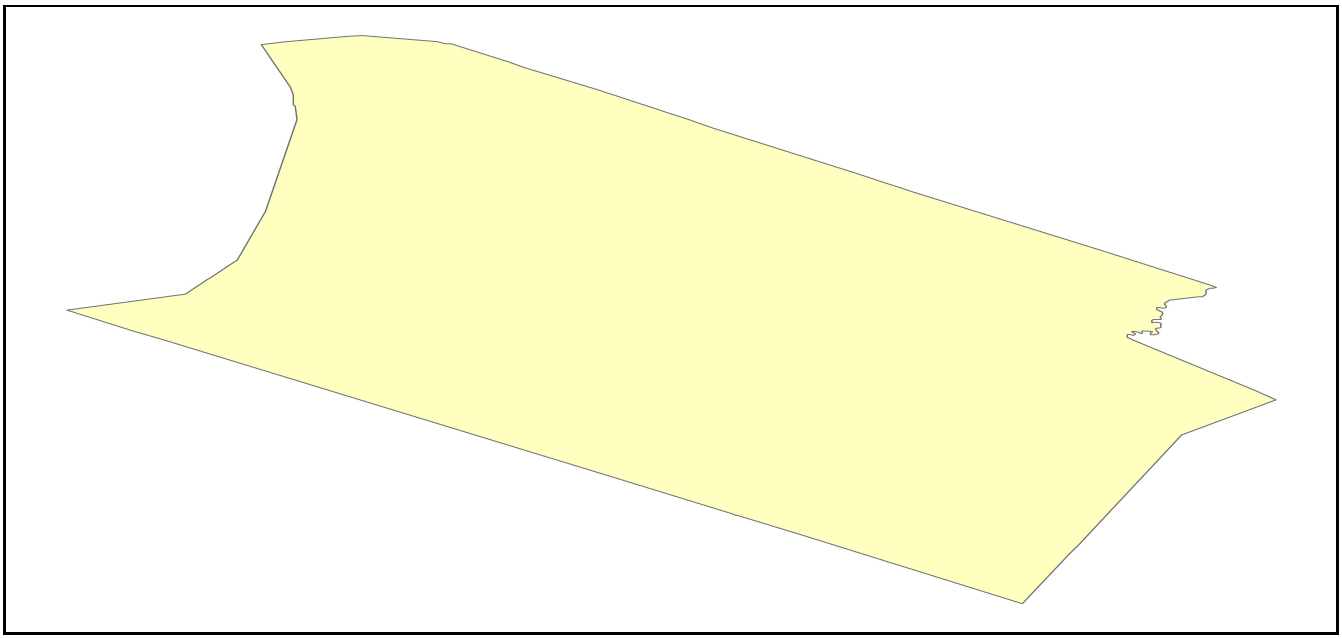
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	16	199.8352
	Segments	68	677.9411
	Tunnels	0	0.0000
		Subtotal	**877.7763**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	68	61.9948
	Tunnels	0	0.0000
		Subtotal	**61.9948**
Light Rail	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	8	30.8062
	Tunnels	0	0.0000
		Subtotal	**30.8062**
Bus	Facilities	1	1.2644
		Subtotal	**1.2644**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**971.80**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	10.3140
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**10.3140**
Waste Water	Distribution Lines	NA	6.1884
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**6.1884**
Natural Gas	Distribution Lines	NA	4.1256
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**4.1256**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	0	0.0000
		Subtotal	**0.0000**
Communication	Facilities	0	0.0000
		Subtotal	**0.0000**
		Total	**20.60**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.



Scenario Name	Tewksbury magnitude 7.0 earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.23
Latitude of Epicenter	42.61
Earthquake Magnitude	7.00
Depth (km)	12.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 10,103 buildings will be at least moderately damaged. This is over 96.00 % of the buildings in the region. There are an estimated 4,869 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

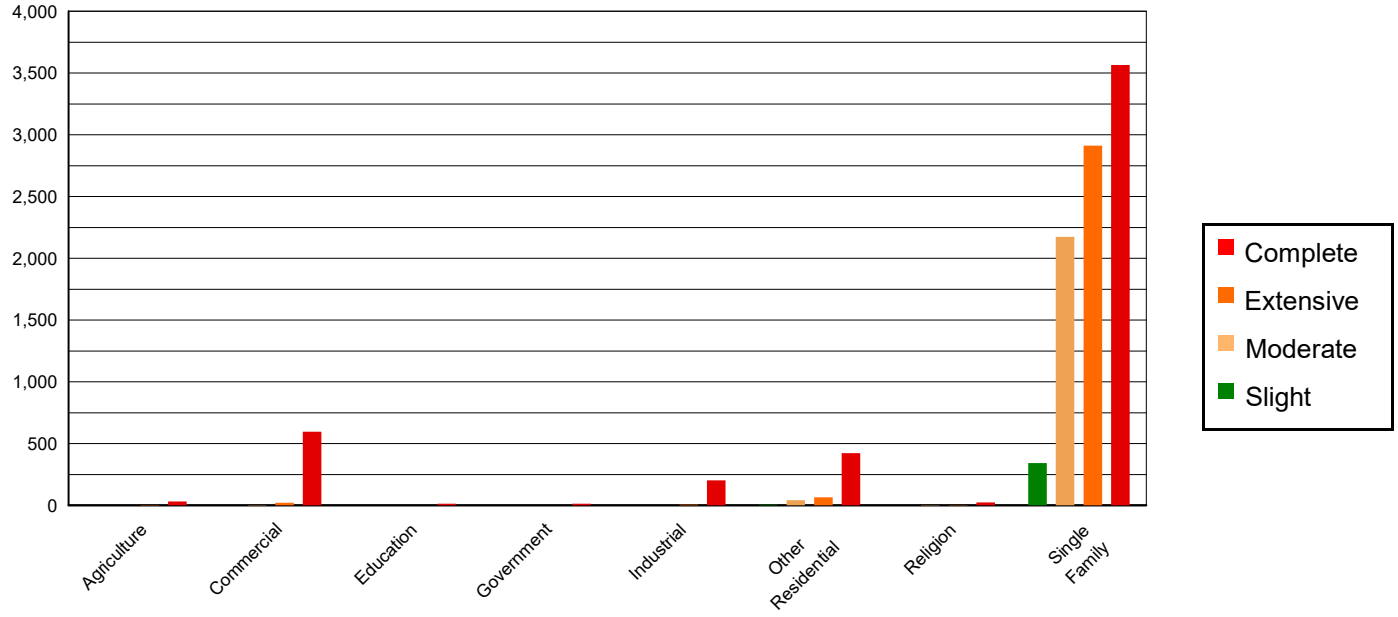


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0.00	0.00	0.01	0.00	0.17	0.01	1.82	0.06	32.00	0.66
Commercial	0.03	0.10	0.16	0.05	2.36	0.11	21.42	0.71	597.03	12.26
Education	0.00	0.00	0.00	0.00	0.05	0.00	0.44	0.01	13.50	0.28
Government	0.00	0.00	0.00	0.00	0.03	0.00	0.33	0.01	13.63	0.28
Industrial	0.01	0.03	0.04	0.01	0.54	0.02	5.34	0.18	202.07	4.15
Other Residential	0.41	1.58	5.92	1.69	41.40	1.86	66.30	2.20	422.97	8.69
Religion	0.04	0.14	0.46	0.13	2.88	0.13	4.09	0.14	22.53	0.46
Single Family	25.74	98.13	342.96	98.11	2174.36	97.87	2912.11	96.69	3565.84	73.23
Total	**26**		**350**		**2,222**		**3,012**		**4,870**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	26.18	99.82	349.07	99.86	2216.39	99.76	2976.61	98.83	3435.91	70.56
Steel	0.02	0.09	0.02	0.01	0.40	0.02	7.40	0.25	428.35	8.80
Concrete	0.00	0.00	0.01	0.00	0.08	0.00	0.93	0.03	69.75	1.43
Precast	0.00	0.00	0.01	0.00	0.06	0.00	0.20	0.01	28.99	0.60
RM	0.02	0.08	0.02	0.01	0.41	0.02	1.25	0.04	94.47	1.94
URM	0.01	0.02	0.37	0.11	3.88	0.17	19.65	0.65	583.55	11.98
MH	0.00	0.00	0.05	0.02	0.57	0.03	5.81	0.19	228.56	4.69
Total	**26**		**350**		**2,222**		**3,012**		**4,870**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 720 hospital beds available for use. On the day of the earthquake, the model estimates that only 0 hospital beds (0.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 0.00% of the beds will be back in service. By 30 days, 1.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	1	1	1	0
Schools	9	9	9	0
EOCs	0	0	0	0
PoliceStations	1	1	1	0
FireStations	3	3	3	0

Transportation Lifeline Damage

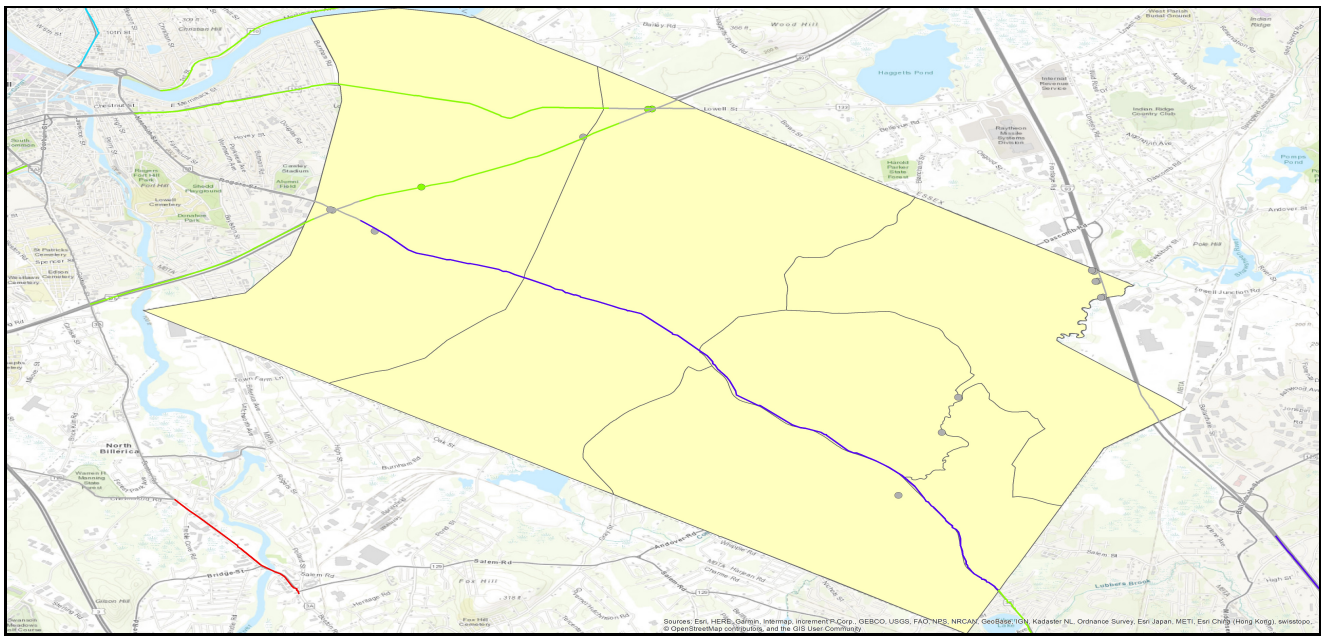


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	68	0	0	66	66
	Bridges	16	16	16	0	0
	Tunnels	0	0	0	0	0
Railways	Segments	68	0	0	17	17
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	8	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	1	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	320	2679	670
Waste Water	192	1346	336
Natural Gas	128	461	115
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	10,492	10,475	10,470	10,450	0	0
Electric Power		10,111	9,538	7,868	3,329	10

Induced Earthquake Damage

Fire Following Earthquake

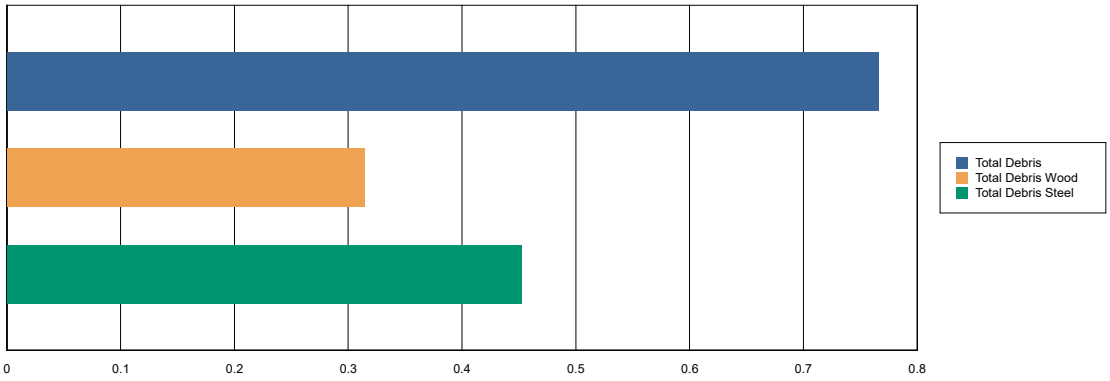
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 766,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 41.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 30,640 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



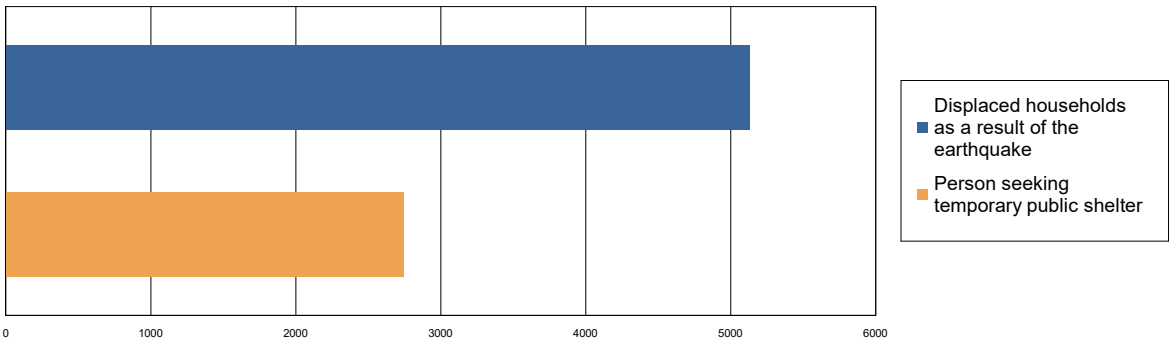
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.31	0.45	0.77	30,640 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 5,131 households to be displaced due to the earthquake. Of these, 2,743 people (out of a total population of 28,961) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
5,131	2,743

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	19.28	6.16	0.98	1.93
	Commuting	0.14	0.22	0.34	0.07
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	27.18	8.84	1.44	2.84
	Other-Residential	269.28	83.98	12.51	24.35
	Single Family	727.64	183.01	15.35	27.15
	Total	**1,044**	**282**	**31**	**56**
2 PM	Commercial	1089.25	348.05	55.48	108.65
	Commuting	1.29	1.98	3.03	0.60
	Educational	412.82	135.12	22.61	44.07
	Hotels	0.00	0.00	0.00	0.00
	Industrial	201.79	65.56	10.75	20.96
	Other-Residential	53.67	16.82	2.59	4.80
	Single Family	138.45	35.02	3.42	5.21
	Total	**1,897**	**603**	**98**	**184**
5 PM	Commercial	781.48	249.89	40.27	77.38
	Commuting	26.05	40.72	61.51	12.28
	Educational	32.20	10.54	1.76	3.44
	Hotels	0.00	0.00	0.00	0.00
	Industrial	126.12	40.98	6.72	13.10
	Other-Residential	106.37	33.34	5.15	9.53
	Single Family	293.52	74.21	7.25	11.06
	Total	**1,366**	**450**	**123**	**127**

Economic Loss

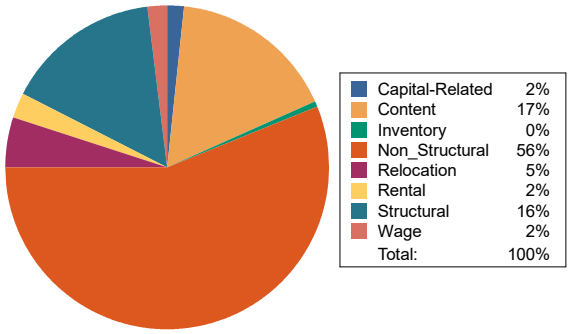
The total economic loss estimated for the earthquake is 4,444.61 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 4,301.34 (millions of dollars); 11 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 68 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

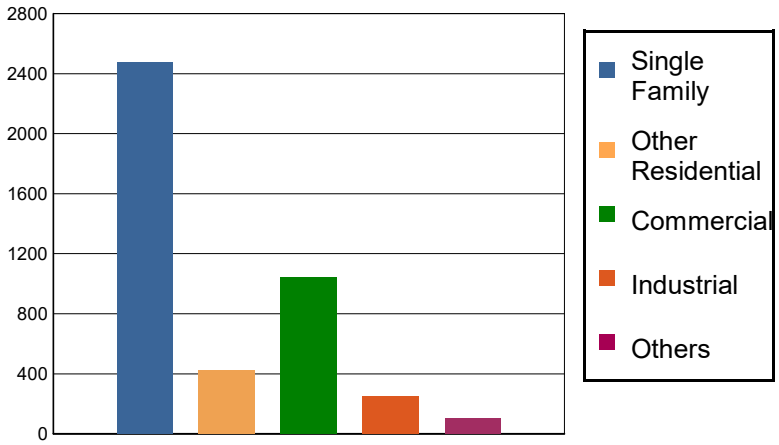


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	8.3337	69.5059	3.7556	2.4659	84.0611
	Capital-Related	0.0000	3.5436	59.9578	2.2132	0.5784	66.2930
	Rental	45.2796	22.5294	31.7801	0.8542	1.0477	101.4910
	Relocation	149.1442	11.2939	48.4861	3.9579	7.9960	220.8781
	Subtotal	**194.4238**	**45.7006**	**209.7299**	**10.7809**	**12.0880**	**472.7232**
Capital Stock Losses							
	Structural	432.6208	52.3371	141.8013	26.0841	17.3359	670.1792
	Non_Structural	1509.9856	271.2613	455.6423	124.2036	50.7893	2,411.8821
	Content	341.0730	58.3642	227.4882	73.4889	25.4133	725.8276
	Inventory	0.0000	0.0000	7.2325	12.9225	0.5757	20.7307
	Subtotal	**2283.6794**	**381.9626**	**832.1643**	**236.6991**	**94.1142**	**3828.6196**
	Total	**2478.10**	**427.66**	**1041.89**	**247.48**	**106.20**	**4301.34**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	677.9411	0.0000	0.00
	Bridges	199.8352	121.9833	61.04
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**877.7763**	**121.9833**	
Railways	Segments	61.9948	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**61.9948**	**0.0000**	
Light Rail	Segments	30.8062	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**30.8062**	**0.0000**	
Bus	Facilities	1.2644	1.1039	87.31
	Subtotal	**1.2644**	**1.1039**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**971.84**	**123.09**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	10.3140	12.0536	116.87
	Subtotal	**10.3140**	**12.0536**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	6.1884	6.0548	97.84
	Subtotal	**6.1884**	**6.0548**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	4.1256	2.0743	50.28
	Subtotal	**4.1256**	**2.0743**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Communication	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**20.63**	**20.18**	

Appendix A: County Listing for the Region

Middlesex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Middlesex	28,961	3,626	896	4,523
Total Region		**28,961**	**3,626**	**896**	**4,523**

Appendix C

Workshop Materials

TOWN OF TEWKSBURY

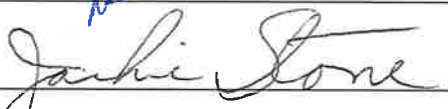
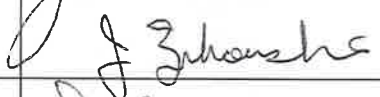
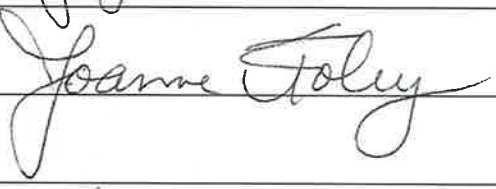
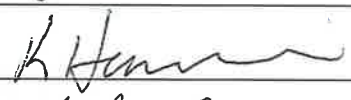
Municipal Vulnerability Preparedness Planning Grant & Hazard Mitigation Planning Project

Community Resilience Building Workshop

Lowell 5 Corporate Building (Community Room), 30 International Place, Tewksbury
Wednesday, January 22
10:00 am – 6:00 pm

10:00 am – 10:15 am	Registration and Refreshments
10:15 am – 10:30 am	Welcome and Introductions
10:30 am – 10:45 am	MVP Workshop Purpose and Overview
10:45 am – 11:30 am	Data Resources and Overview of Science
	Risk Matrix
11:30 am – 11:50 am	Large Group Exercise #1 – Top Hazards
11:50 am – 12:10 pm	Small Group Exercise #1 – Infrastructure Features
12:10 pm – 12:30 pm	Small Group Exercise #2– Societal Features
12:30 pm – 1:30 pm	Lunch
1:30 pm – 1:50 pm	Small Group Exercise #3– Environmental Features
1:50 pm – 2:20 pm	MVP Community Actions
2:20 pm – 3:05 pm	Small Group Exercise #4 – Infrastructure Actions
3:05 pm – 3:20 pm	BREAK
3:20 pm – 4:00 pm	Small Group Exercise #5 – Societal Actions
4:00 pm – 4:45 pm	Small Group Exercise #6 – Environmental Actions
4:45 pm – 5:45 pm	Large Group Exercise #2 – Prioritization
5:45 pm – 6:00 pm	Wrap-up and Closing Remarks

Town of Tewksbury
Wednesday, January 22, 10:00 am – 6:00 pm
Community Resilience Building Workshop

Name	Table	Signature
Al Vasas	3	
Alicia Geilen	4	
Anna McGinty	1	
Barry Finegold Representative	2	
Chester Cheng	4	
David Lochiatto	3	
Jackie Stone	2	
Jeffrey Zukowski	1	
Joanne Foley	4	
Jon Marchand	4	
Kevin Hardiman	3	
Melissa Maniscalco	2	
Michael Saccone / Christina Saccone	4	

Town of Tewksbury
Wednesday, January 22, 10:00 am – 6:00 pm
Community Resilience Building Workshop

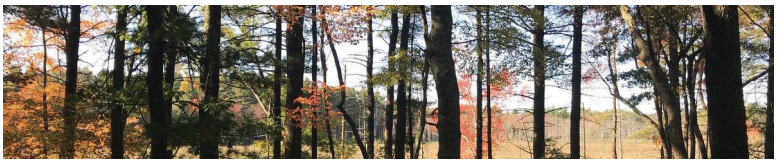
Name	Table	Signature
Michelle Rowan	3	
Nicole Hutcheon	3	
Paige Impink	3	
Raymond Barry	1	
Richard Harrington	1	
Richard Montuori	3	
Scott Brinch	2	
Scott Consaul	4	
Scott Gaynor	1	
Stefanie Gallo	4	
Steve Sadwick	2	
Susan Griffin	1	
Susan Sawyer	2	
Thomas Cooke	4	
Tom Hosey	2	
Vinnie Bomal	1	

NAME	TABLE	CONTACT
Marilyn Murphy	4	COA
Brad Gilbert	2	DPW
Heather Tecca	1	MEMA

TOWN OF TEWKSBURY

COMMUNITY RESILIENCE BUILDING WORKSHOP

Wednesday January 22, 2019

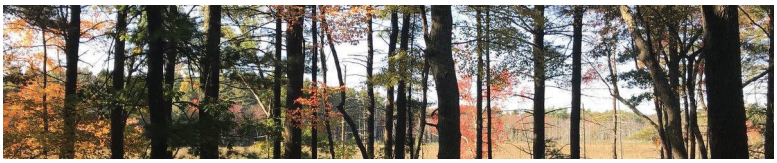


WELCOME W&S

Amanda Kohn
Steve Roy
Lindsey Adams
Adria Boynton
Jaurice Schwartz

WELCOME CORE TEAM

Anna McGinty	Stefania Gallo	Al Vasas
Brian Gilbert	Steve Sadwick	Eva Durkin
Kevin Hardiman	Vinnie Bomal	Scott Gaynor
Melissa Maniscalco	Chester Cheng	



WELCOME PARTICIPANTS

Your name
Organization/Relationship to Tewksbury
Favorite thing about Tewksbury

WORKSHOP OUTLINE

PRESENTATION:
- Overview of Science & Data
- Characterization of Hazards

- BREAK -

INDIVIDUAL TABLES:
- Identify Community Features

- LUNCH -

INDIVIDUAL TABLES:
- Identify and Prioritize Actions

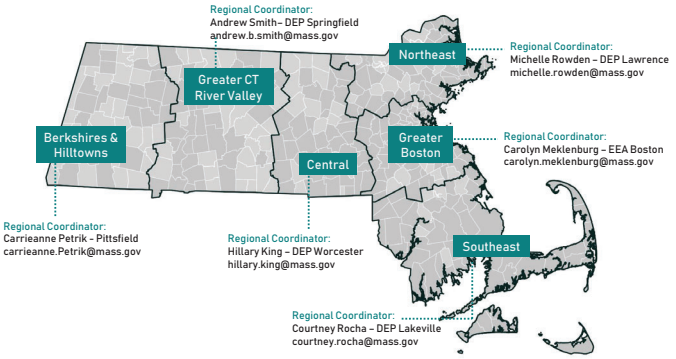
- BREAK -

LARGE GROUP DISCUSSION:
- Determine Overall Priority Actions

Municipal Vulnerability Preparedness Program

Michelle Rowden,
MVP Northeast Regional Coordinator
MA Executive Office of Energy and Environmental Affairs

MVP Regions & Regional Coordinators



Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) - September 2018

- Acknowledges that climate change is already worsening natural hazards, integrating information and planning elements for 14 natural hazards that affect the Commonwealth
- Uses best scientific data and projections to assess risk and vulnerability
- Evaluates the Commonwealth's existing capabilities to implement agency-specific and statewide activities to reduce risk and increase resilience

MVP Principles

A community-led, accessible process that

- Employs local knowledge and buy-in
- Utilizes partnerships and leverages existing efforts
- Is based in best available climate projections and data
- Incorporates principles of nature-based solutions
- Demonstrates pilot potential and is proactive
- Reaches and responds to risks faced by EJ communities and vulnerable populations

Why nature-based?

Where appropriate, nature-based solutions can be more cost-effective, protect water quality and quantity, sustain lands that provide food and recreation opportunities, reduce erosion, and minimize temperature increases associated with developed areas and climate change.

MVP Process/ Grant Types

COMMUNITY RESILIENCE BUILDING WORKSHOP(S)

- Define and characterize hazards using latest science and data
- Identify existing and future community vulnerabilities and strengths
- Develop and prioritize community adaptation actions
- Determine overall priority actions
- Receive MVP designation

✓ MVP Planning Grant

MVP Action Grant

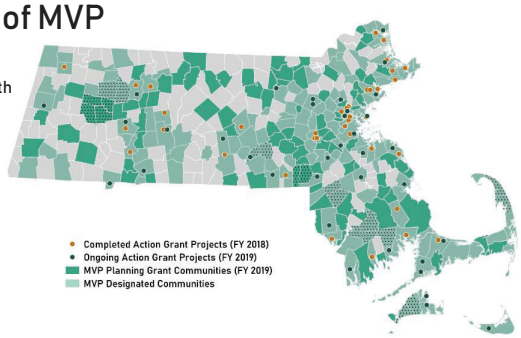
Implement priority adaptation actions identified through planning process

Three Years of MVP

MVP Designations
71% of the Commonwealth
249 communities

Action Grant Projects
FY18: 37
FY19: 36

Total Awards
$17M+ in planning and action grants to date



MVP Action Grants: Project Types

- Detailed Vulnerability and Risk Assessment*
- Community Outreach and Education
- Local Bylaws, Ordinances, Plans, and Other Management Measures
- Redesigns and Retrofits***
- Nature-Based Flood Protection, Drought Mitigation, Water Quality, and Water Infiltration Techniques**
- Nature-Based, Infrastructure and Technology Solutions to Reduce Vulnerability to Extreme Heat and Poor Air Quality

* Most common project type
** Second-most common project type
***Third-most common project type

MVP Action Grants: Project Types (cont.)

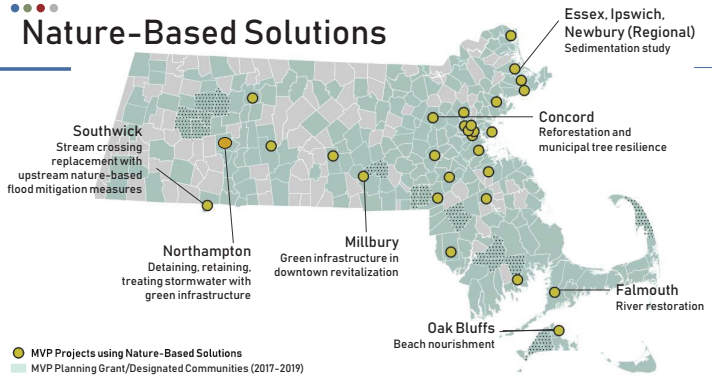
- Nature-Based Solutions to Reduce Vulnerability to other Climate Change Impacts
- Ecological Restoration and Habitat Management to Increase Resiliency

NEW IN 2019

- Energy Resilience
- Chemical Safety
- Land Acquisition for Resilience
- Subsidized Low-Income Housing Resilience Strategies
- Mosquito Control Districts

\+ Expanded eligibility of project location

Nature-Based Solutions



Example MVP Action Grant Projects

Nature-Based Flood Protection, Drought Prevention, Water Quality, and Water Infiltration Techniques

Millbury

Utilizing green infrastructure like stormwater planters, bioretention bump outs, rain gardens, and other measures like porous pavers and pervious pavement to reduce heat island effects and stormwater runoff into the Blackstone River.

Nature-based solutions

Example MVP Action Grant Projects

Local Bylaws, Ordinances, Plans, and Other Management Measures
Redesigns and Retrofits

Boston

Developing its first ever resilient building code so that development in the future floodplain is prepared for at least three feet of sea level rise, the likely scenario by late century.

Retrofitting a major waterfront park into a legacy park that uses nature-based solutions to address climate vulnerabilities while providing important access to recreation for residents.

Proactive
Pilot potential

Nature-based solutions
Community co-benefits

Example MVP Action Grant Projects

Redesigns and Retrofits

Salisbury

Increasing the resilience of the neighborhood of Ring's Island by raising its access/egress roads and by improving tidal flushing through culvert replacements

Vulnerable communities

Example MVP Action Grant Projects

Nature-Based Flood Protection, Drought Mitigation, Water Quality, and Water Infiltration Techniques

Belchertown

Designing and permitting for a replacement water storage tank that would increase storage capacity and resiliency to drought, and completing a feasibility/ concept design of a rainwater harvesting system at Belchertown High School to irrigate the athletic fields.

Nature-based solutions
Pilot potential

Bill S.10:

An Act for Climate Change Adaptation Infrastructure Investments in the Commonwealth

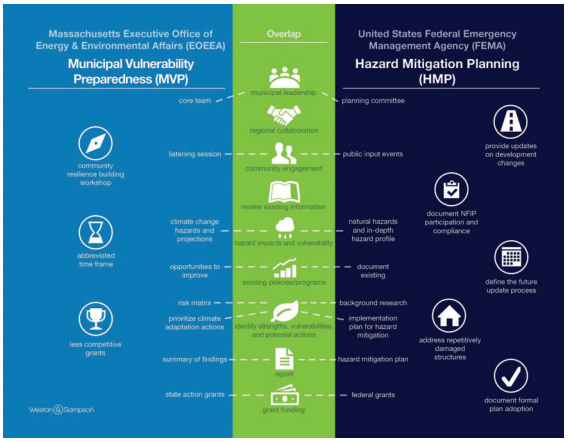
- Building on success of existing programs like MVP: Proposed new source of revenue for loans, grants, and technical assistance to municipalities and regional partnerships for priority adaptation projects
  - Proposed deeds excise increase → est. $137M annually ($1B in ten years)
  - Recurring, long-term revenue stream for multi-year project feasibility

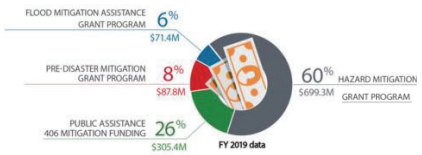
MA 2050 Decarbonization Plan

- EEA is conducting an **80x50 Study** to identify the strategies, policies, and implementation pathways for MA to achieve at least 80% Greenhouse Gas reductions by 2050.
- The results of that research will be published in a **2050 Roadmap report** and will inform the setting of a **2030 GHG emissions limit** and the development of the **Clean Energy and Climate Plan for 2030**.
- More information and opportunities to get involved:
- www.mass.gov/2050Roadmap

Massachusetts Global Warming Solutions

Michelle.Rowden@mass.gov
https://www.mass.gov/municipal-vulnerability-preparedness-program

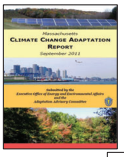




In FY 2019 more than $1.16B

FEMA

Within Tewksbury and Massachusetts



CLIMATE AND HAZARD DATA RESOURCES

Massachusetts Climate Change Projections, 2018)

Massachusetts State Hazard and Climate Adaptation Plan, 2018

Massachusetts Climate Change Adaptation Report, 2011

Hazard Mitigation Plan for Northern Middlesex Region, 2015

US Census, American Community Survey, 2013-2017

Weston & Sampson

CLIMATE DATA SCALE

CLIMATE
Regional
Long Term Patterns

VS.

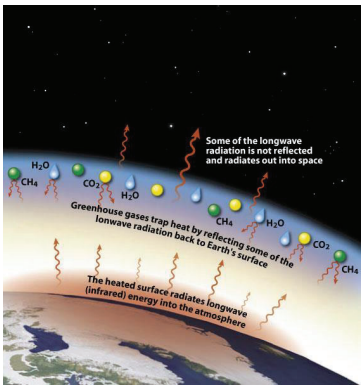
WEATHER
Local
Short Term Conditions

- Hyperlocal variations in climate change projections are most often **within the projected margin of error of models.**
- Climate data at **a regional scale is most appropriate** for planning. Climate projections for Massachusetts is available at the watershed and county scale.
- **The resolution of climate data is not usually a limiting factor in planning**. At the local scale, other factors may play a larger role.

GREENHOUSE GASES (GHG)

- Naturally occurring
- Act as a blanket
- Examples: carbon dioxide and methane

Climate mitigation ensures there is less to adapt to and is a key component of our community's resilience



Smithsonian Environmental Research Center. "Too Much of a Good Thing." http://forces.si.edu/atmosphere/02_04_07.html

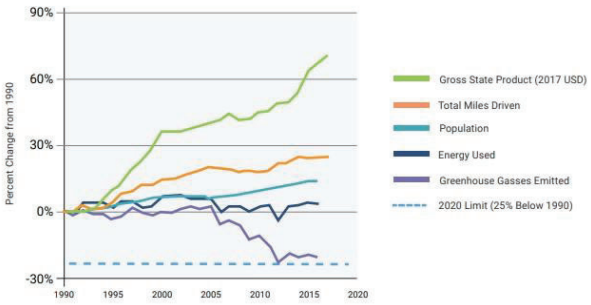
MA GHG GOALS

- Established by the Global Warming Solutions Act (GWSA) of 2008
- 25% reduction in GHG emissions by 2020
- 80% reduction in GHG emissions by 2050
- 1990 is the baseline year

Photo: Tewksbury Engineering Department Vehicle

Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report," 10.

FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report," 10.

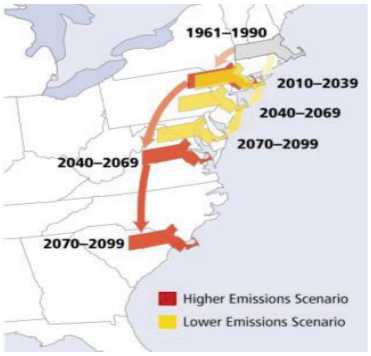


Photo: NECIA/UCS, 2007.

HAZARDS IN TEWKSBURY

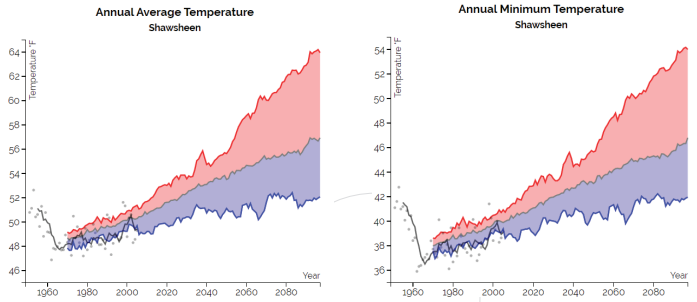
- Extreme Temperatures
- Flooding
- Severe Thunderstorms, Wind, Hurricanes
- Drought, Wildfire
- Severe Snowstorms, Ice Storms, Nor'easters
- Erosion, Earthquakes, Landslides

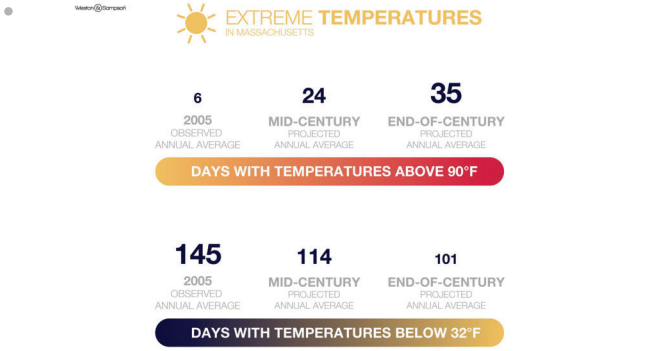
EXTREME TEMPERATURES

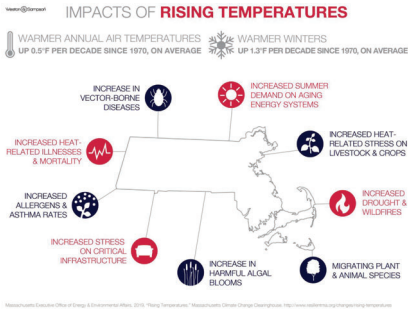
WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

EXTREME TEMPERATURES

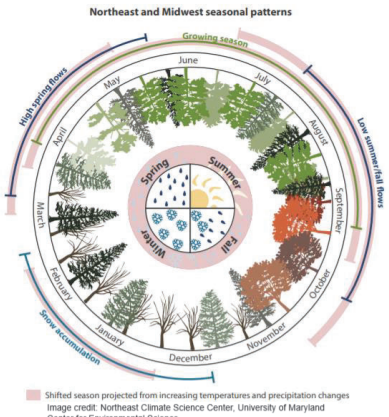






Tewksbury Health Department Alerts Residents after Mosquitos in Neighboring Communities Test Positive for EEE

Source: Tewksbury Website, News



The most notable recent drought event was in
2016

The occurrence of droughts
lasting 1 to 3 months
could go up by as much as
75% over existing conditions
by the end of the century,
under the high emissions scenario

CHANGES IN PRECIPITATION

MORE **INTENSE & FREQUENT** EXTREME RAIN EVENTS

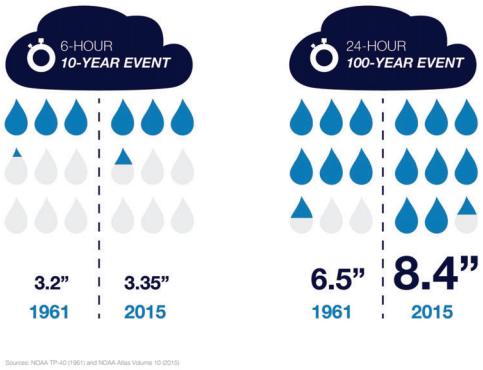
PRECIPITATION DURING **HEAVY EVENTS** IN THE NORTHEAST **INCREASED BY MORE THAN**

70%

BETWEEN 1958-2010

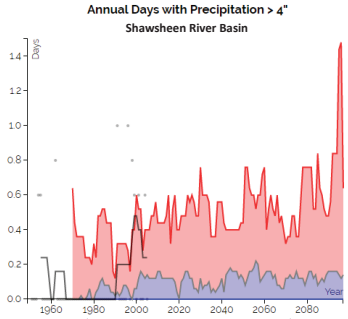
Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. Resilientma.org/changes/changes-in-precipitation

CHANGES IN **PRECIPITATION**



Sources: NOAA TP-40 (1961) and NOAA Atlas Volume 10 (2015)

EXTREME PRECIPITATION



EXTREME PRECIPITATION

8%

Increase in extreme precipitation events in the northeastern U.S. by midcentury

13%

Increase in extreme precipitation events in the northeastern U.S. by 2100

FLOODING

ZONE	ANNUAL CHANCE	FLOODPLAIN
A, AE, A1-A30	1% ANNUAL CHANCE	100-YEAR FLOODPLAIN
X	0.2% ANNUAL CHANCE	500-YEAR FLOODPLAIN

Image at left: a portion of the FEMA Flood Insurance Rate Map (FIRM) for Tewksbury, showing the extent of the FEMA-defined 100- and 500-year floodplain

FLOODING

8

REPETITIVE FLOOD LOSS STRUCTURES

“Areas south and east Tewksbury have experienced substantial flooding, septic system failures and nutrient loading resulting from development in close proximity to wetlands.”

“The Town has initiated a project to flood proof the existing sewer manhole structures located within the 100-year floodplain.”

–Tewksbury 2016 Master Plan

AREAS IN TOWN PRONE TO FLOODING

Bridge Street and South Street

Shawsheen Street and Mohawk Street

East Street near Strong Water Brook

Pinnacle Street

Shawsheen Street Near Main Street/Route 38

Brown Street at Whipple Road

Pond Street

Bonnie Lane

Sutton Street

Photo: Pupkis Road Flooding

STORMWATER FLOODING

Caused by…
Poor drainage
High amounts of impervious surface
Undersized culverts

Examples of Vulnerable Areas in Tewksbury

- Lake Street
- Pupkis near Heath
- Starr Ave at Mitchell
- Veranda St
- Water St at Adelaide Rd
- Greenwood Near Woburn Street
- Vernon Street
- Cayuga Street

Flood-Related Culvert Work in Tewksbury
River Road at Trull Brook
31 Shawsheen Street

- Wolcott Street at Tewmac Terrace
- Van Buren Road at Marston Street
- Dewey Street at Town Hall Avenue
- Whipple Road at Chandler Street
- Claire Street at Marie Street
- Algonquin Drive at Shawsheen Street

Photo: Water Street at Adelaide Road Flooding

WINTER MONTHS

The blizzard of 2013 left nearly **400,000 Massachusetts residents without power**

Rain, Warmth Close Outdoor Rink In Tewksbury

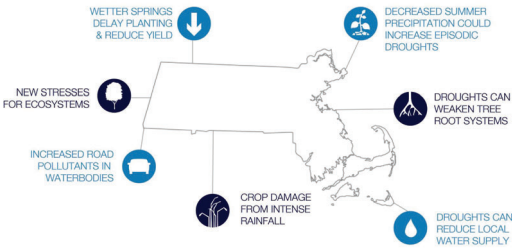
The town said in a notice on its Website that the rink would be closed "until further notice."

By Dave Copeland, Patch Staff
Jan 25, 2019 3:23 pm ET
Source: Patch.com

"Heavy blizzards are among the **most costly and disruptive** weather events for Massachusetts communities."

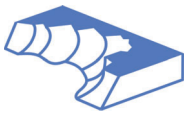
IMPACTS OF CHANGING PRECIPITATION

HIGHER AVERAGE ANNUAL PRECIPITATION
INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/changes-in-precipitation

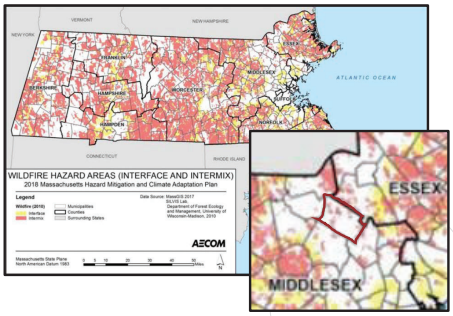
EROSION



- Caused by riverine flow & stormwater[1]
- Increased precipitation, including winter rains, could increase erosion[1]
- Drier soils will reduce resistance to erosion

1. Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 42.

BRUSH FIRE



Moderate Risk

Tewksbury State Hospital
Great Swamp Area

HURRICANES AND EARTHQUAKES

HURRICANE
Sandy
and nor'easters
cause downed trees and power lines

Upward trend in North Atlantic hurricane activity since 1970

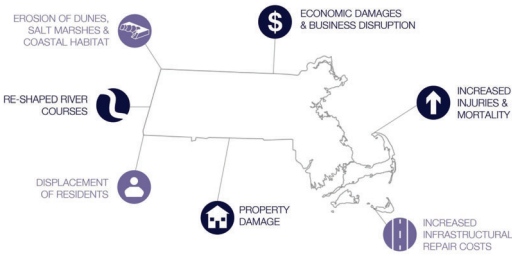
Nor'easters along the Atlantic coast are increasing in frequency and intensity

EARTHQUAKE
30-40
Earthquakes occur in New England each year, although most are not felt.

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)Northern Middlesex Council of Governments. 2015. "Hazard Mitigation Plan for the Northern Middlesex Region," 159-160.

IMPACTS OF **EXTREME WEATHER**

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Extreme Weather." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/extreme-weather

HAZARD POTENTIAL OF DAMS

Hazard Classification of Tewksbury Dams			
Dam Name	**Impoundment Name**	**Hazard Class**	**Downstream Population**
Dams in Tewksbury			
Ames Pond Dike A	Ames Pond	High	5,000
Ames Pond Dam	Ames Pond	High	5,000
Ames Pond Dike B	Ames Pond	Low	5,000

As an FYI: Boston Sea Level Rise Projections (ft)

Increased coastal flooding

Permanently inundated low-lying coastal areas

Increased shoreline erosion

Emission Scenario	2030	2050	2070	2100
Intermediate	0.7	1.4	2.3	4.0
Intermediate-High	0.8	1.7	2.9	5.0
High	1.2	2.4	4.2	7.6
Extreme	1.4	3.1	5.4	10.2

(Source: Northeast Climate Adaption Science Center)

RISK MATRIX


Photo: Tewksbury Congregational Church, 2010

RISK MATRIX

Community Resilience Building Risk Matrix www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S					Priority H-M-L	Time Short &/or Long Ongoing
Infrastructural									
Societal									
Environmental									

IDENTIFY HAZARDS


Photo: Tewksbury Twitter

RISK MATRIX: HAZARDS

Community Resilience Building Risk Matrix — www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Priority H-M-L	Time Short Long Ongoing
Infrastructural					
Societal					
Environmental					

HAZARDS IN TEWKSBURY

4 CATEGORIES FOR TODAY

Heavy Precipitation and Flooding

Severe Snowstorms, Ice Storms, Extreme Cold

Severe Thunderstorms, Wind, Nor'easters, Tornado

Extreme Temperatures, Drought, Wildfire

15 MINUTE BREAK!

Photo: Tewksbury Police, Tewksbury Twitter

FEATURES IN TEWKSBURY

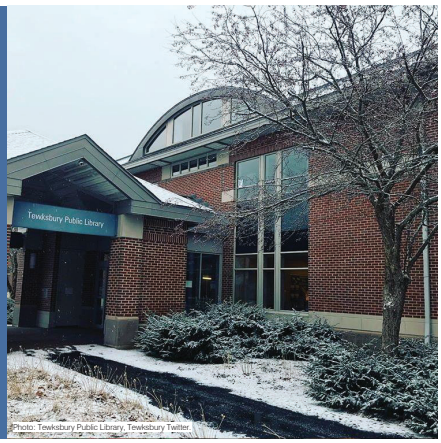

Photo: Tewksbury Public Library, Tewksbury Twitter.

RISK MATRIX: FEATURES

Community Resilience Building Risk Matrix — www.CommunityResilienceBuilding.com

H-M-L priority for action over the Short or Long term (and Ongoing)
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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Priority H-M-L	Time Short Long Ongoing
Infrastructural					
Societal					
Environmental					

RISK MATRIX: FEATURES

H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Features	Location	Ownership	V or S
Infrastructural			
Societal			
Environmental			

INFRASTRUCTURAL FEATURES

Fire Department

Photo by minutemantrucks.com

Wastewater Treatment & Collection

Police Department

Photo by the Northeastern MA Law Enforcement Council

Roadways

Photo provided by the Town

Water Supply

INFRASTRUCTURAL FEATURES

CRITICAL FACILITIES

Facility Type	Common Name	Street Address	Health Facility Type	Average Daily Patient Capacity	Capacity	Feeding Capability	Emergency Generator Available
Emergency Operations Center	Tewksbury Fire Department (Primary)	21 Town Hall Avenue				No	Yes
	Tewksbury Police Department(Secondary)	918 Main Street				No	Yes
Health Care Facilities	Blair House	10 Erlin Avenue	Level 1 – 4	200		No	No
	The Emeritus	2580 Main Street	Level 4	50	No	No	
	North Fire Station	830 North Street	First Aid	0			
	Center Fire Station	21 Town Hall Avenue	First Aid	0			
	South Fire Station	2342 Main Street	First Aid	0			

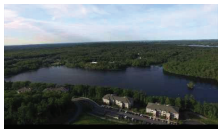
Source: All Hazards Mitigation Plan. 2016. 2-6.

SOCIETAL FEATURES

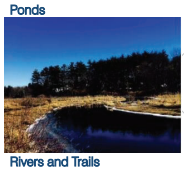
Population	Tewksbury	Massachusetts
2010	29,090 residents	6,547,790
2018	31,388 residents	6,902,149
Age		
Under 18 years:	19.7%	20%
65+ years:	17.5%	17%
Education		
Bachelor's degree or higher:	33.6%	42.1%
Additional Information		
Median household income:	$93,817	$74,167
Persons in poverty:	5.4%	10.5%
With a disability:	6.2%	7.9%
Language other than English spoken at home:	9.0%	23.1%

Source: U.S. Census Bureau, 2013-2017 ACS Estimates

ENVIRONMENTAL FEATURES



Ponds



Rivers and Trails

Photo 1: Ames Pond, Airgoz Aerial Photography, Youtube
Photo 2: Foster Park Conservation Area, Town of Tewksbury Website.

Tewksbury's Open Space

- 49% of the town is open space
- Open spaces include:
  - Foster Park Conservation Area
  - Mahoney Park

Shawsheen River

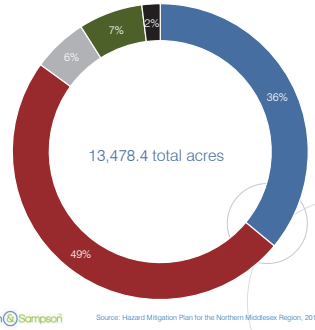
Merrimack River

Concord River

Ipswich River

Source: Tewksbury Open Space and Recreation Committee

TEWKSBURY LAND USE



- Residential Housing
- Open Space, Recreation, or Water Use
- Commercial & Industrial Use
- Transportation or Waste Disposal
- Agriculture

Weston & Sampson

Source: Hazard Mitigation Plan for the Northern Middlesex Region, 2015 pg 145

RISK MATRIX: FEATURES

FEATURES	LOCATION	OWNERSHIP	VULNERABILITY OR STRENGTH
Infrastructural	Town wide	State	Vulnerability
Societal	Multi- vs. Single-neighborhood	Town	Strength
Environmental	Specific location	Private	Both
		Shared	

IDENTIFY FEATURES IN TEWKSBURY

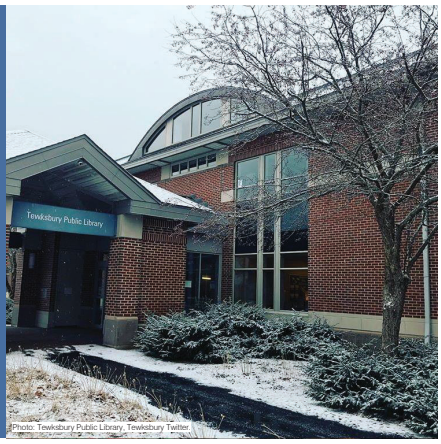


Photo: Tewksbury Public Library, Tewksbury Twitter

LUNCH


Photo Source: Tewksbury Twitter

ADAPTATION STRATEGIES

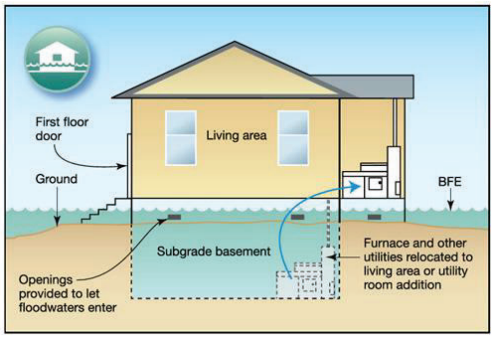
EXISTING CLIMATE ACTION

- Participation in the National Flood Insurance Program (NFIP)
- Participation in the Community Rating System (CRS)
- Floodplain Overlay District Zoning Bylaw
- Discharges to municipal storm sewers by-law has been adopted
- Local Wetlands Protection Bylaw
- Subdivision regulations address drainage, erosion and sediment control, had have additional standards for the floodplain district
- Green Community Designation
- Open Space and Recreation Plan addresses Natural Disaster Mitigation
- Capital Improvement Plan
- Repair of Ames Pond Dam and Dikes
- Street Sweeping Program
- DWP Forestry Department Tree Maintenance Program
- Measures to address wildfire risk
- Groundwater Protection Overlay District
- FMA and HMGP Grants
- Enterprise fund for stormwater management
- 2017-2021 Housing production plan
- Tewksbury Master Plan
- Annual reports for community development
- Tewksbury Vision Plan
- Warrant Articles
- Complete Streets Plan
- Informal disaster SOP
- Updating Emergency Management Plan

Weston & Sampson Sources: HMP for the Northern Middlesex Region, Core Team Members

COMMUNITY ACTIONS

WET FLOODPROOFING

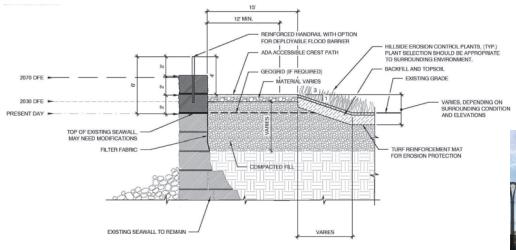


PREVENTING SEWER BACKFLOW

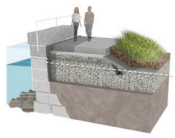
RAISED BUILDINGS

RETROFITTED FLOODPROOF DOORWAYS

FLOOD WALLS



HARBORWALK BARRIER SEAWALL SAMPLE SECTION



DEPLOYABLE FLOOD BARRIER

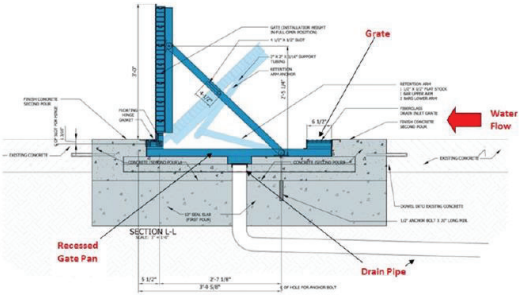
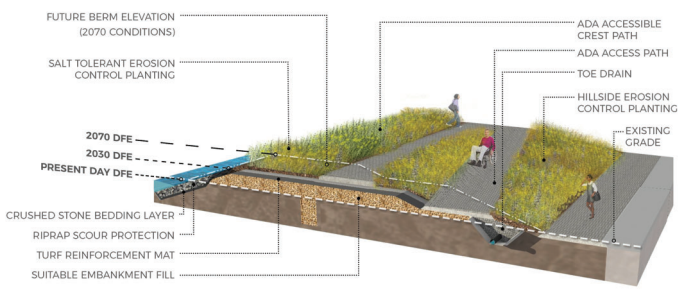


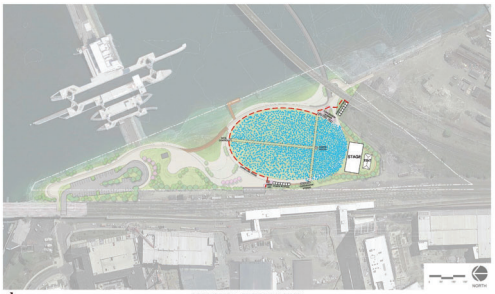
FIGURE 1 | A FloodBreak barrier gate diagram

VEGETATED BERM



MULTI-PURPOSE FLOOD STORAGE

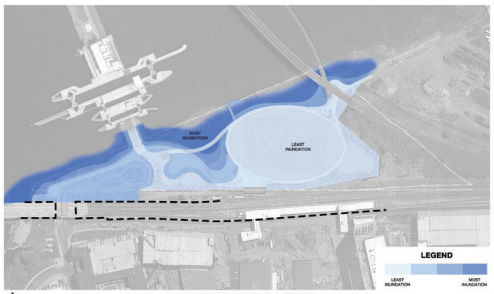
LANDSCAPE DESIGN TO ACCOMMODATE WATER



CONCEPT #1 - CROWD DIAGRAM

DRAW SEVEN PARK

LANDSCAPE DESIGN TO ACCOMMODATE WATER

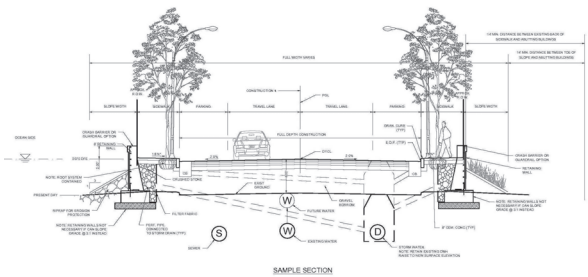


CONCEPT #1 - INUNDATION DIAGRAM

DRAW SEVEN PARK

CULVERT WIDENING TO IMPROVE HABITAT & FLOW

RAISED ROADWAYS

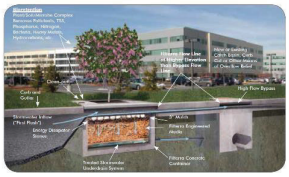


SAMPLE SECTION

LOW IMPACT DEVELOPMENT (LID)

Stormwater infiltration / rain gardens

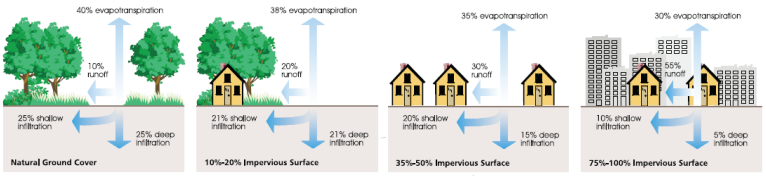
Porous asphalt & permeable pavers



Street trees & tree box filters

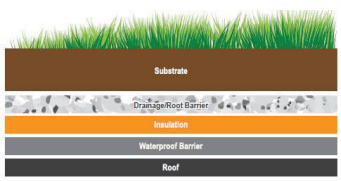
STORMWATER DETENTION & RETENTION

REDUCE IMPERVIOUS AREAS

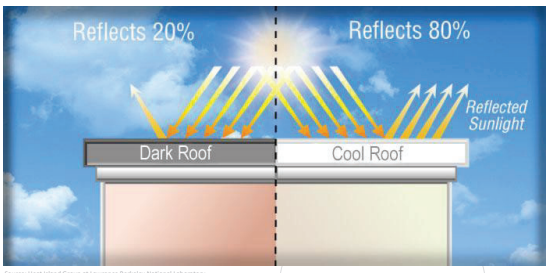


CLOUDBURST STREETS

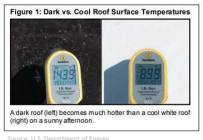
GREEN ROOFS



COOL ROOFS



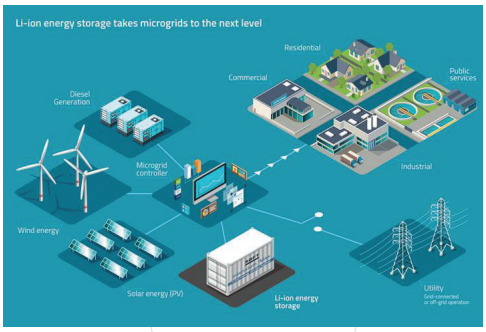
Source: Heat Island Group at Lawrence Berkeley National Laboratory



Source: U.S. Department of Energy Guidelines for Selecting Cool Roofs

COOLING CENTERS

RENEWABLE MICRO-GRIDS



RE-EVALUATE LOCAL REGULATIONS & POLICIES


BROOKLINE MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) ACTION PROJECT

town of brookline, massachusetts

DEFINE COMMUNITY ACTIONS

Photo: Courtesy of the Tewksbury Public Library

IDENTIFY PRIORITY ACTIONS

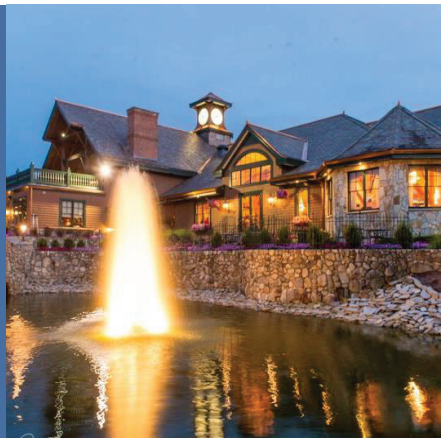


Photo: Tewksbury Country Club. Theknot.com.

15 MINUTE BREAK!

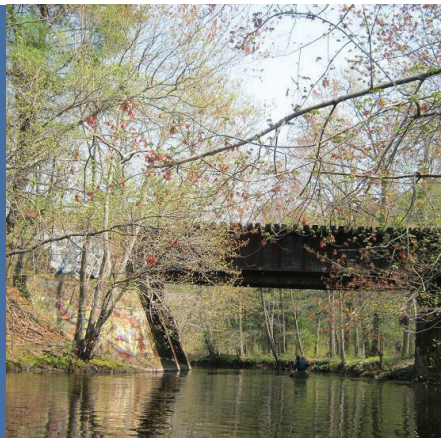


Photo: Merrimack River. Blogspot.com.

WRAP-UP & CLOSING REMARKS

Photo: Tewksbury High School. Patch.com.


Planning Grant
CRB Workshop
Listening Session
MVP-HMP Plan
Action Grant
Summer 2019
Jan 2019
Feb 2019
April 2020
April 2020

THANK YOU

Tewksbury CRB Workshop – 1/22/2020

Favorite things about Tewksbury:

- Sense of community
- Support from upper management
- Variety of nature and forest community
- Support from town staff
- Nice, affordable town, not overdeveloped
- Great work force
- Contribution from residents
- Open communication across town staff
- Natural community
- Access
- People and facilities in town
- Residents want to be involved
- Protected open space

Existing Mitigation Measures Noted During large group discussion:

- EV Charging stations: Town Hall, Library
- Tewksbury has 2 electric cars

Top Hazards in Tewksbury:

1. Heavy Precipitation and flooding
2. Severe thunderstorms, wind, nor'easters, tornados
3. Severe snowstorms, ice storms
4. Wildfires and Drought

Additional notes during large group discussion:

- Grandchildren will be living in a Massachusetts that feels like Georgia
- Attendees did not know if Tewksbury uses to the TP-40 data
    - The Town's related work is aiming to address water quality, quantity, recharge
- Maritime provinces in Canada – a storm dumped 6 ft. of snow (doors were blocked)
    - Bomb cyclone – barometric pressure dropped, moisture was in the air, and storm increased in intensity

TABLE 1 NOTES

- Ames Pond- Downstream POD rose to 100- year
- Tewksbury Friends of Open Space
- South and Bridge St were elevated after 2004 flood
- Resiliency checklist for site plan reviews- recommendations to update bylaws
- Form a commission for study of new development
- Substation – invested tens of millions in last five-years
- Brown and Nikols- three town owned intersection

    - Floods
    - 3rd major road in town
    - Muet – jurisdiction bridge
- Commuter rail
- Shawsheen St – 129 cut through
- Woburn St – exit 37 on 495
- East St. off of Woburn St dev, local businesses potential for large scale warehouse, which would contribute to economic tax base and will need a functional road
- Pump stations- N. St. Development had to work with DPW
    - Would impact economy if not functional
    - Should be solar powered- new battery technology
- Lowell agreed to accept Tewksbury sewage
- Portions of 38 need to be updated by the State
- Police Station borders wetlands
- Natural gas facility owned by National Grid needs a backup
- Elementary school is in wetlands area
- National grid has two other large energy facilities in the area

Additional notes from Table 1:

- Environmental
    - Parks & Open Space
        - Town wide/strength
    - Vector borne illness
        - Town wide (vulnerable)
            - *bug boxes (low tec. Options)
    - Rivers and brooks
        - Town wide, town/private
    - Trees
        - Town wide (ownership) vulnerable and strength
        - Town and Grid (tree trimming program)
        - Continue tree trimming program
    - Wetlands/Beaver
        - Private and town owned/state owned
        - Vulnerability and strength
        - Access/permission to private land
        - Education to homeowners
    - Trails – town wide
- Heavy Precip/Flooding
- Infrastructural
    - Dams – Ames Pong (vulnerable)
        - Private 75-acre, 4 ft. depth
        - 1-acre properties
    - Bridges/Roads
        - 495-93

        - Brown/Nichols (3 town-owned intersection)
        - Woburn Street/Shawsheen
            - Impact on wear and tear on vehicles
        - Culvert work on Mill Street?
        - Strategic target locations to raise roads
        - Talk with DPW to get culvert list that town wants to upgrade
    - Pump Stations – 47 pump stations. Generator powered
        - Town wide / town owned
        - Vulnerability and strength
        - Education to public on what can/can't be dumped down drain
        - Economic impact
        - Alternative
            - Solar/battery generators?
            - Capacity?
    - Stormwater
        - Town owned
        - State owned
        - Reuse grey water
        - Storm water regulations
    - Public safety and DPW
        - Town owned
        - Resilient design for DPW building
    - Water treatment/water storage
        - Merrimack Drive
        - Town owned
        - Both vulnerable and strength
        - Increase storamge and capacity
        - Link irrigation system in pd to pumping (storage tank)
        - What is the altnerative water supply
        - Regional approach to increase quality of water
    - National Grid
        - Tree trimming program
        - Ground to sky program (state funded)
- Societal
    - Shelters (town and private)
        - Senior center
        - High school
        - Congregational/police department (warming centers)
        - More transportation
        - Identify other buildings in town for heating or cooling shelter
        - Identify facilities in town for pet friendly
        - Clearly communicate to town residents
        - Public safety for education for the school system
    - Transient (homeless)
        - Identify homeless shelters

        - Counseling for addicts
    - 55+ population units
    - Mental health/sheltering
        - Volunteers, counseling, etc.
        - State hospital (resources)
        - Red cross plan
    - Public health
        - Emergency preparedness education
        - Education children in turn parents will be educated
    - Public Safety
        - Mail merge
        - Tri fold pamphlet of emergency information for the public

TABLE 2 NOTES

Assets

- Sewer
    - pump stations go down for miles
    - pipes are relatively new
    - man holes
    - siphon
    - grinders
    - No treatment plan- 20-year contract with Lowell, in the future capacity could be an issue
- Energy
    - Starting to have underground electric utilities
    - Gas lines would be susceptible to earthquakes
- Water Treatment
    - Earthquake is a threat to pipe system
    - Have a conservation restriction bylaw
    - Water Treatment Plan, Intake on River and 3 Tanks, 2 pump stations
- Drainage
    - Manholes, culverts (undersized)- many are old concrete or metal
    - Bridge St culvert (DEP permit did not go through)
    - Pinnacle—some replaced and more to go
    - Bayberry Detention Ponds
- Housing Authority- they have a database of the people that are vulnerable and live in their units

TABLE 3 NOTES

- Infrastructure Features
    - Sewer /water supply/ Drainage– pump stations, pipers man holes siphon, no treatment facility – must be concerned about capacity, intake pump station, water

quality, river as source, 3 storage tanks, drainage, culverts, 600 culverts mapped, regulatory restrictions, 43 retention ponds.
    - Dams= privately held.
    - Some area in south need drainage issue addressed.
    - Electricity Grid – Power line, substations, high wire, town wide, national grid.
    - Facilities Town - Town Wide,
    - Gas Line
    - Communications
    - Police, fire station, dpw
- Societal Features
    - Get services to elders areas
    - Disabled – need services, isolation.
    - Local business – town wide
    - Youth & schools-
    - Library, cooling heating stations, Public
    - Transportation - strength
- Environment Features
    - Tree Canopy
    - Wetlands & Swamps
    - Agricultural lines
    - Air & water quality
- Infrastructure Actions
    - Sewer – (address pump station via removal in locations that are at risk during high rainstorm (Regina S.)
    - Ensure all pump stations have plug in power access.
    - Water stations – assure the plug-in power access
    - If earthquake - catastrophic water access event.
    - Water restriction rules in place if drought occurs
    - Implement storm water program for flood sites. Town wide assessments of flood vulnerable areas.
    - Rules and regs regarding small development and storm water
    - Regularly update storm and wetland area list
    - Electrical Grid – tree pruning along grid.
    - Town facilities – utilize solar
    - Pumps under police station – due to spring that flows under
    - New DPW building net zero with solar.
    - Study impact of removal of Ames dams
- Societal Actions
    - Warming stations and cooling stations program.
    - Let know that town reaches out to agency that disabled housing agencies know that there are services available.
    - Youth and schools more resources to schools in place.
    - Health assessment with a climate focus
- Environmental Actions
    - Tree canopy – increase street trees or study options.

- Landfill – design and construct road to implement solar farm.
- Wetland – improve wetland bylaws.
- Better standards for conservation restrictions and residential education.

TABLE 4 NOTES:

- Alicia, NMCOG
- Marilyn, Council on Aging
- JoAnne, Chief Assessor
- Chester, Engineering Department
- Stefania, Conservation
- Scott, Tewksbury State Hospital

Features

Infrastructure:

- Schools
- Library
- Senior Center
- Town Hall
- Church
- Brown Street – used to flood at crossing near Billerica, Wilmington. Raised roadway and installed a new culvert to alleviate flooding
- Shawsheen and main (flooding)
- Southern Bridge (flooding)
- Pinnacle Street culvert (flooding)
- Pump stations – 46 in town
- Main Street – Maseli Bridge: Southeast edge of town could be cut off
- Police Department is located near flood zone.
- Utility lines: Southern Tewksbury experiences more power outages than the rest of the Town
- Gas facilities and electric plant
- Tewksbury Hospital – 700 acres in town. Have their own wells. Used to be a fallout shelter. Pump station is low and gets flooded.
- 70% of the town is on sewer
- Communication facilities: Foster, Hospital
- Merrimack River – Water Treatment Sewer goes up to Lowell. Drinking water goes down
- Sub station facilities- protected area, impact Merrimack Valley for power, homeland security monitoring

Societal

- Food and Supply – Market Basket Warehouse
- Daycares
- Vulnerable populations
- Elderly

- Medial health centers
- New regional dispatch (911 headquarters)
- Code Red
- District wide planning team
- Drug epidemic

Environmental

- Shawsheen River Watershed
- Drinking Water comes from the Merrimack River. Used to come from 5(?) wells in Town, they are not used anymore
- Round pond
- Open space (300 acres is conserved).
- Bay circuit trail
- Beavers
- Wetlands and floodplains: water resources
- Trees- every five years National Grid trims for power, state plants more every 1 to 4 years, need policy on when to remove trees/10 feet back and plan for cycle to die out/cost of replacement in drought
- Need more green space next to roads
- Strategy for rights to access culverts

Actions:

- May be building a new police/fire station. This could be an opportunity to reduce vulnerability to these buildings by keeping the out of the flood plain and installing solar on the buildings.
- Need a vulnerability assessment done on existing police station that is close to the flood zone (will it be in flood zone if you look at projected rainfall data?)
- Opportunity for a solar partnership at the Tewksbury State Hospital. They have areas on their property in mind. Could work with town to construct and then it could provide some power for the town.
- How much of the floodplain is protected open space? Can we update bylaws so that all floodplain that is open space is protected from development?
- Assess undeveloped property for acquisitions
- Vulnerability assessment of culverts has been done recently but the culverts are not prioritized?

Additional Notes (unmarked table):

- Has to use climate and incorporate nature-based
- Energy resilience
- Resilient building case + 3'
- Bill S.10
- MA 2050 decarbonization plan
    - 80x50 study
    - 2050 road map

- Absorb effects of climate change
- 25% match requirement – can use ferent (?) and private funding
- Co-benefits – restoration
- NOAA Atlas
- Dams – feature
- Precipitation/flooding
- Fire
- Storms – wind, cold
- Drought – heat
- temperature

Highest High Priorities

- Drainage – Stormwater System
    - Town wide culvert assessment and priority list with a stormwater management plan
    - CIP improvements
    - Roadways/Complete streets with LID (Main Street)
- Communications
- Open Space and Trails—flood mitigation and land acquisition
- Vulnerable Populations
    - Shelter capacity
    - Community rooms
    - Medical needs center
    - List of people
    - Plan in place
    - Messaging and communication
- Facilities
    - Identify opportunities for LID on municipal property
    - Net zero DPW
- Water Treatment Plant/Water Quality
    - Fortify system
    - Reduce pollutants

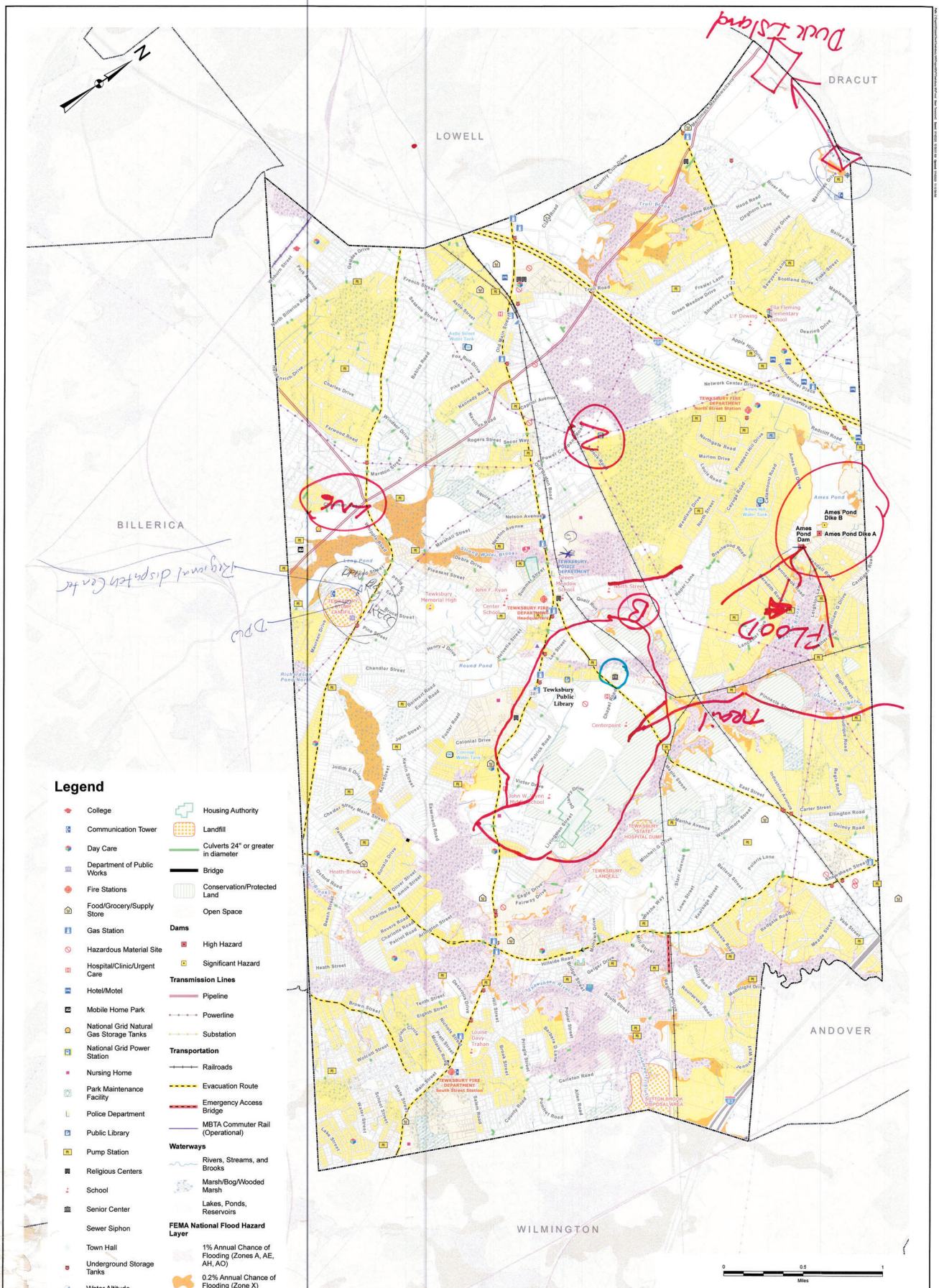


FIGURE 1

TOWN OF TEWKSBURY, MASSACHUSETTS

MUNICIPAL VUNLERABILITY PREPARDNESS HAZARD AND FEATURE MAP

JANUARY 2020 SCALE: NOTED

Weston & Sampson

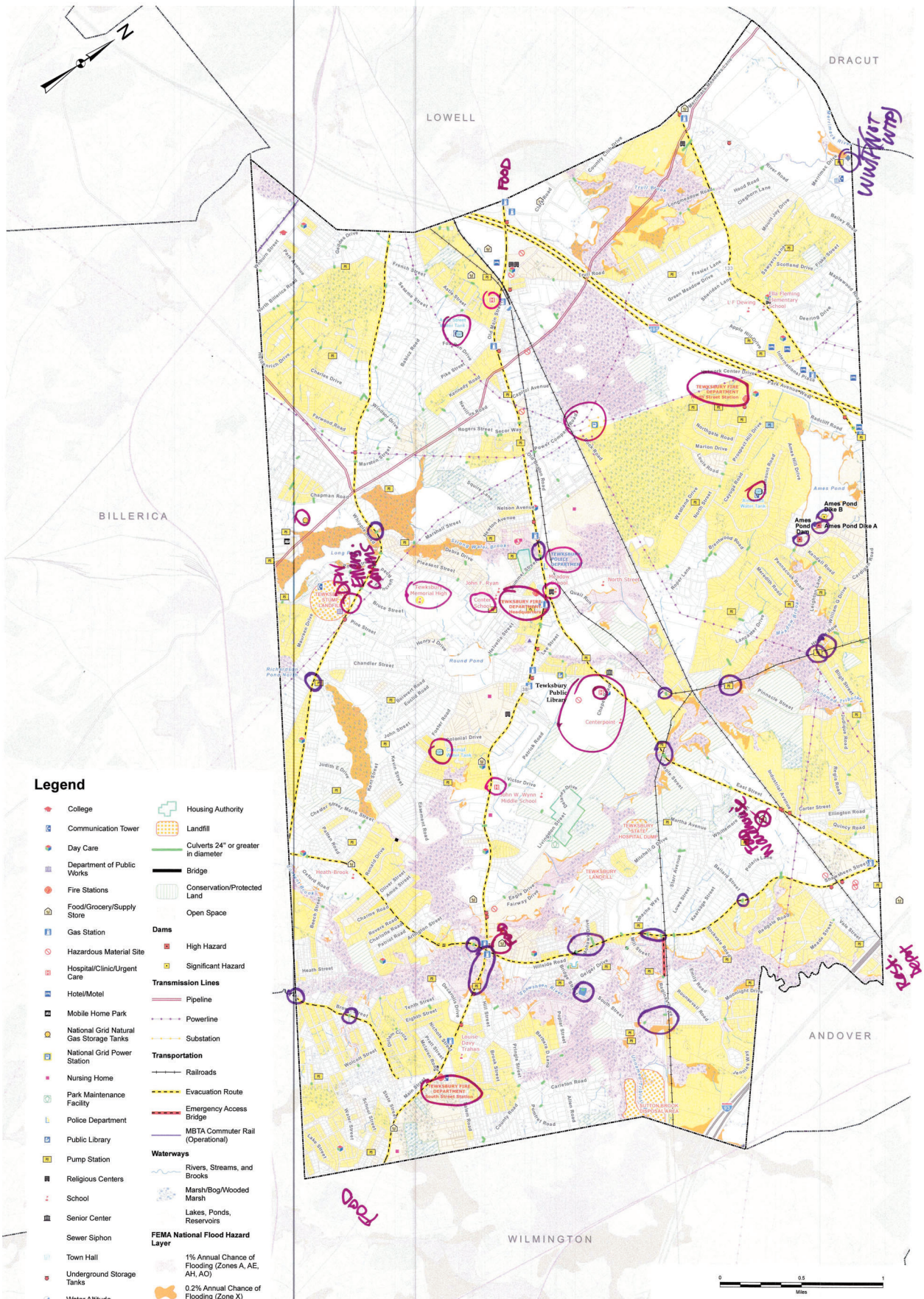


FIGURE 1

TOWN OF TEWKSBURY, MASSACHUSETTS

MUNICIPAL VULNERABILITY PREPAREDNESS
HAZARD AND FEATURE MAP

JANUARY 2020 SCALE: NOTED

Weston & Sampson

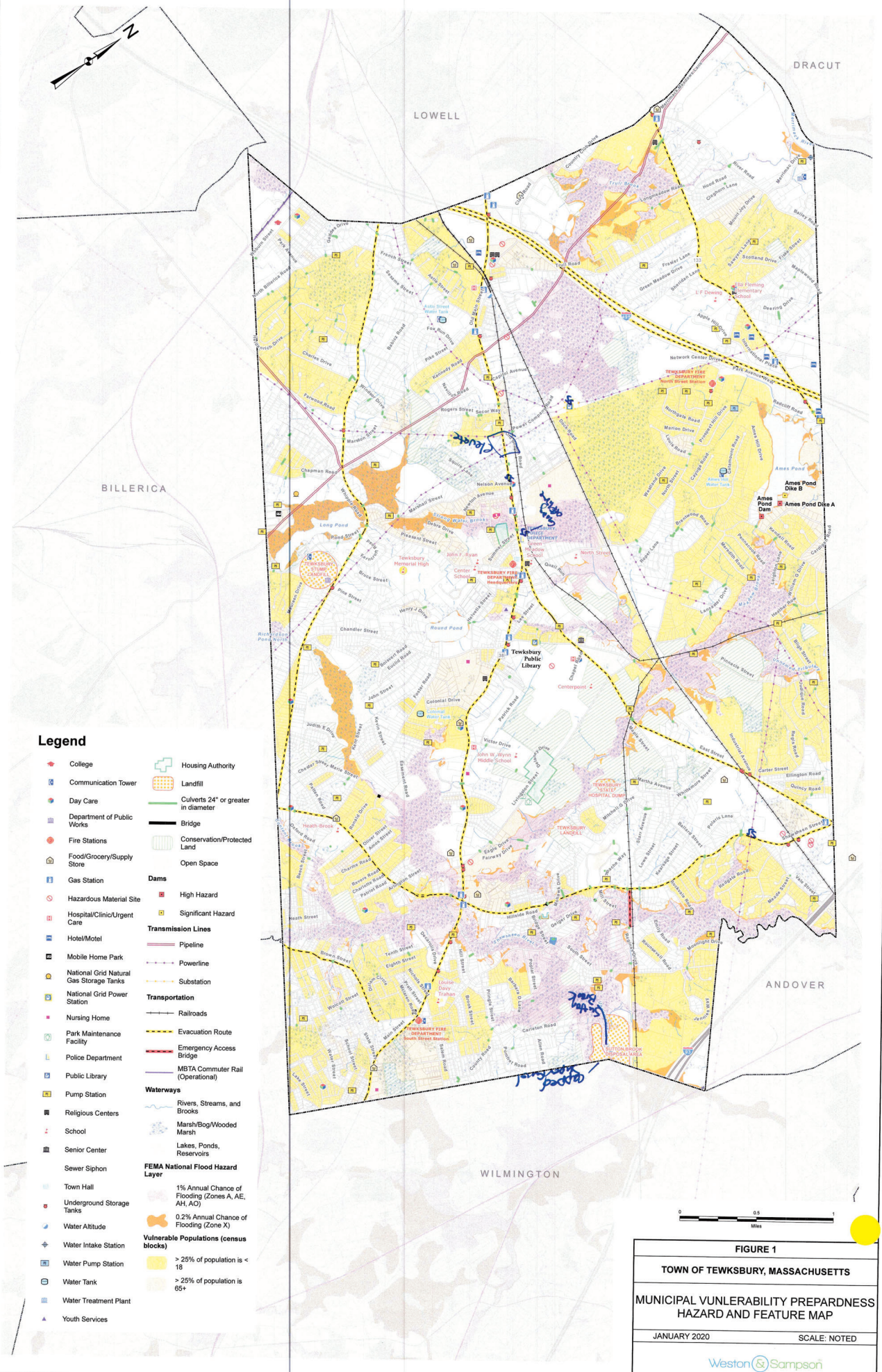


FIGURE 1

TOWN OF TEWKSBURY, MASSACHUSETTS

MUNICIPAL VUNLERABILITY PREPARDNESS HAZARD AND FEATURE MAP

JANUARY 2020 SCALE: NOTED

Weston & Sampson

Community Resilience Building Risk Matrix

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H-M-L priority for action over the **S**hort or **L**ong term (and **O**ngoing)
V = Vulnerability **S** = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	HEAVY PRECIPITATION + FLOODING	SEVERE SNOWSTORMS ICE STORMS + EXTREME COLD	SEVERE THUNDERSTORMS WIND, NOR'EASTER, TORNADO	EXTREME TEMPERATURES, DROUGHT, WILDFIRE	Priority H-M-L	Time Short Long Ongoing
Infrastructural									
DAM	AMES POND	PRIVATE	V	COST BENEFIT ANALYSIS OF LOWERING LEVEL → PUBLIC EDUCATION/OUTREACH TO DOWNSTREAM RESIDENTS; TOWN COORD. WITH OWNER		→ DAM FAILURE ANALYSIS + RISK ASSESSMENT → TOWN OWNERSHIP		M	L
PUMP STATIONS ~~STORMWATER SYSTEMS~~	TOWN WIDE	TOWN	V/S	study power alternatives - solar/battery; resilient installation of generators (elevated if needed); capacity study - buildout for future precipitation levels; education for homeowners re:	what should go down drains.	More hazardous material disposal days with public/private partnerships		M	S
STORMWATER SYSTEM	TOWN WIDE	TOWN + PRIVATE	V/S	* TRASH CANS FOR NEEDLE DISPOSAL + PUBLIC SPACES; coord./mtgs/policy with surrounding towns → incld stormwater detention on site and use of gray water - regulations for new development; incentives for a density bonus, specific design guidelines → PUBLIC EDUCATION TO REDUCE POLLUTANTS IN WATER SUPPLY			H	L
PUBLIC SAFETY + DPW BLDGS (REC)	TOWN WIDE	TOWN	V/S	~~Assess flood risk at fire station~~ Design resilient DPW building + vehicle storage				M	S
WATER TREATMENT PLANT + WATER STORAGE	Wynnmack	TOWN	V/S	increase storage through link irrigation to decommiss regional improvements	gray/green infra. at pond at police station in water quality	study of	study/ID alternative water supply use, gray water for plumbing in homes overall water capacity/needs	H	L
ROADS + BRIDGES 495, 93 38 is a state rd.	TOWN	STATE, LOCAL	V/S	elevate roads at strategic locations, upsize culverts, construct other infrastructure; water detention, underground storage, planting				H	L/O
Societal									
SHELTERS	Town/Lowell	Town → Private	S/V	update inventories of shelters to ID equipment needs - coord with Red Cross to conduct study and address needs for other locations	training for municipal staff. Live full-scale drill; communicate with residents - distribute pamphlets; assess shelter in place model; assess storage capacity/needs	assess shelter plan's ability to service current populations (use dog license data and updated development)	transportation for seniors - senior center has 2 vans; study 9 Town bldgs that could be warming/cooling creation/shelter accessible and pet-friendly shelters equipment: carriers, cages for pets	M	O
TRANSIENT POPULATION (HOMELESS)	Town/Lowell	/	V			partner with Tewksbury/State Hospital	identify homeless shelters + capacity; partner w/ non profit to assist police; provide mental health/substance abuse counseling/referrals	M	O
+55 POPULATION	Town wide	~~Private~~ /	V		Information on shelters - Town website, message board, reverse coord with Senior Center, Town Nurse (visit elderly)	incl. info in Town repos; 911 "Good Neighbor" program; buddy system with young residents; snow removal/home checks	GIS study of existing data to ID elderly/vulnerable resident locations; coord with emergency management etc coord with emergency management at map of hazards at buildings	M	O
Mental Health	Town wide	/	V			coord with State Hospital for resources	provide mental health services at shelters. More staff, volunteers training. coord with Red Cross re: best practices.	H	O
Public Health	Town wide	/	V	emergency preparedness/education, capacity to shelter in place; creative education/outreach strategies; school curriculum - home work for kids + parents				H	S
Public Safety				climate curriculum for students STEM education		"Coffee with cop" events	pamphlet on emergency info incl in water or tax bill; mag/mailer/flyers for other properties; flyers at library, kiosk at grocery store or coffee shops	M	O
Environmental									
TREES	TOWN WIDE	TOWN + NATIONAL GRID	V/S			tree trimming		M	L
WETLANDS + BEAVERS	TOWN WIDE	PRIVATE + PUBLIC TOWN/STATE	V/S	*MAP FUTURE FLOODPLAIN STUDY PRIORITY HABITAT AREAS + BEAVER PROBLEM AREAS	PUBLIC EDUCATION RELATED TO BEAVERS + HABITAT → COORD TO GET TOWN ACCESS TO ~~WETLANDS ON PRIVATE PROP (MAINTENANCE)~~			L	O
PARKS + OPEN SPACE	TOWN WIDE	TOWN	S	land agquisition land donation for tax relief				M	L
VECTOR BORNE ILLNESS	TOWN WIDE	\	V	alternative treatment/remediation				H	O
RIVERS + BROOKS	TOWN WIDE	TOWN + PRIVATE	V	*) COORD FOR TOWN ACCESS FOR MAINTENANCE (REMOVE BLOCKAGES)				M	O
TRAILS	TOWN WIDE	TOWN + PRIVATE	V/S						

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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Heavy Precipitation + Flooding	Severe Thunderstorms, Wind, Nor'easters, Tornado	Severe Snow, Ice, Extreme Cold	Extreme Heat, Drought, Wildfire	Priority H - M - L	Time Short Long Ongoing
Infrastructural				Regina S					
Sewer	Specific + townwide	Town	B	Assess & Street Pump station for removal to reduce risks + look @ others for removal/fortification. Generator @ pump stations (9 generators on HMP Grant ongoing)				M	O
Water Supply 1 - pump station	1	Town	B	or portable plug-ins for H2O too	→ Improve intake flood proofing/assess based on future conditions			M	L
Drainage	Townwide / Lacking - seeing list (South)	Town	V	CIP implementation w/ climate-resilience; Use town-properties for stormwater GI + LID; Action - Plan for Stormwater System + assessment for vulnerability; ↳ Subdivision Regs need LID incentives/requirements		Use Long Pond as example of GI (CPA + 319) ↗	Add culverts to assessment → keep updating	H	S-O-L
Electric Grid (substations, lines)	Townwide	Nat Grid	B		- Reduce impact of vegetation + guidelines on types of trees to plant near lines			L	L
Facilities / ~~Shelters~~ / Operations DPW EOC	Specific locations	Town	S	Resilience features as part of DPW - net zero. Solar as backup on roofs + Car PV ↳ + study (structurally)		Water tight chamber @ police station + running pumps all the time - spring (L)	LC longer term solution	H	S
Communications Radio, new EOC underway, dispatch	Town-wide	Town	S					L	L
Societal DAMS	Specific (4)	Private	V	Study dam removal + impacts downstream					
Seniors - Senior Center (town) → shuttle bus	Census Tract map + specific housing options	Private - Housing Authority	B	Increase communication about how to get folks on list of vulnerable pops + coordination w/ agencies		HA needs generator for community room ←	More cooling + warming centers that are accessible	H	O
Disabled Population - Group Homes	Dispersed	—	V						
Youth + Schools	Census Tract map; Schools specific	Public + Private	B	New elementary as leverage for grant funding + resilience features. More resources to shelter in place				L	O
Local Business / Services	Town-wide	Private	B	Support emergency plans that would lead to more MOUs for food				M-H	S-O
Library + Cooling/Heating Stations Shelters	Specific	Public	S						
Emerging Health Risks / Health Care	Town-wide	—	V	Fix detention basins. Expanded communication	Health assessment w/ climate ch.			H	O
Transportation / Roadways	Town-wide	Public/State Mostly	B pg 38	Main St. green elements for Stormwater (H-S) - need to work w/ MassDOT and private. Rt 38 - Raise roadways				M	O
Environmental									
Tree Canopy	Townwide	Public (some private)	B	Increase street trees (heat) → planting plan to reduce heat island	Tree management + pruning (fire + drought)			M	O
Landfill	Few sites	Town	V	Monitor - Maintain - Bid on Solar but need access rd.			Communicate about cap	H	S
Wetlands + Swamps	Townwide	Public + State Private	B	Improve Wetland Bylaw + education + stormwater Bylaw				H	S
Agricultural Lands / Open Space	Townwide	State Private Public	S	Better standards on conservation restrictions + guidelines for O+M				H	L
Air Quality + Water Quality	Townwide	—	S-now V-future	Improve pollution control on impaired water bodies. EV Infrastructure				M	O
Invasives	Townwide	—	V	Create recommended list of plantings. Invasive removal policies / program + education				L	O

Amanda Kohn to send info on regs w/ LID

isolated

#3

Community Resilience Building Risk Matrix

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H-M-L priority for action over the Short or Long term (and Ongoing)
V = Vulnerability S = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Heavy Precip & Flooding	Severe Thunder storms Wind, Nor'easters Tornado	Severe Snowstorms, Ice Storms, Extreme Cold	Extreme Temps Drought, Wildfire	Priority H-M-L	Time Short Long Ongoing
Infrastructural									
WTP	Merrimac Drive	Town	V/S	Continue to support infrastructure improvements				H	O
Communications	Town-Wide	Town/Private	V	Evaluate comm. systems & facilities Town facilities on fiber optic —				M	O
WW Pump Stations	Town-Wide	Town/private	V		Continue to implement improvements			H	O
Police Station	Main St.	Town	V	Basement pumping - Evaluate PV power, pumping solution - Maintenance				H	O
Ames Dam	Ames Pond	Private	V	Evaluate assets Dam removal				M	O
Roadways, Drainage, Bridges Culverts	Town-Wide	Town	V	Replace culverts Drainage improvements	Bayberry Lane/culvert/bridge repair - Many locations 5 yr cap. improvement plan			H	O
Societal									
Senior Center - warming/cooling	Chandler St	Town	V/S	Update HVAC/roof Evaluate solar	- Evaluate trans during emergencies - Regional solutions - Assess communication to seniors			H/M	O
Library —	Chandler St.	Town	V/S	Evaluate expanding shelter- warming/cooling				M	O
High School	Pleasant St.	Town	V/S	Solar canopy - parking Evaluate GI and MS4 implementation = phosphorus benefits				M	O
Nursing Homes, Assisted living fac. Group Homes	Town-Wide	Private	V	Develop communication plans				M	O
Multi-Lingual Population	Town-Wide	—	V	Develop outreach plan				M	O
Public Housing/Rentals	Town-Wide	—	V	" "	"			M	O
Environmental									
Wetlands + Wildlife	Town-Wide	Town/state private	V	Promote wetlands protection				H	O
Trails + Recreation	Town-Wide	Town/state	V	Expand trail networks Fields improvements - parking & stormwater improvements				H	O
Rivers: Merrimack, Shawsheen, Heath Brook, Stony Water Brook, Sutton Brook	Town-Wide	—	V	Continue to support WQ improvements - stormwater				H	O
Ponds	Town-Wide	Town	V	Assess Long Pond improvements Septic systems				H	O
Recreational Fields	Town-Wide	Town	V	Field improvements - parking & stw improvements - MS4				H	O

GROUP 4

Community Resilience Building Risk Matrix

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Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	HEAVY PRECIPITATION & FLOODING	SEVERE THUNDERSTORMS WIND, NOR'EASTERS, TORNADOS	SNOW STORMS, ICE STORMS, EXTREME COLD	EXTREME TEMPS DROUGHT, WILDFIRE	Priority H-M-L	Time Short Long Ongoing
Infrastructural									
DRAINAGE INFRASTRUCTURE (CULVERTS)	TOWNWIDE	TOWN	V	assessment + upgrades → Brown St.	By-law updates, higher design standards.			H	O
BRIDGES	TOWNWIDE	TOWN/ STATE	V/S	assessment, prioritize + upgrade or work with state. Bridge St Bridge	→			H	O
EMERGENCY FACILITIES (POLICE, FIRE) (POLICE IS NEAR FLOODZONE)	MULTIPLE	TOWN	V/S	Floodproofing Police/Fire New	communication/backup and redundancy	→ backup power/generator?		H	S
ROADWAYS	TOWNWIDE	TOWN/ STATE/PRIV.	V/S	complete streets plan, plant trees (main st.) heat; stormwater; pervious pavement at town buildings	→	keeping roads clear for em. vehicles assess opportunities for snowclearing		M	O
DRINKING & WASTEWATER (PUMP STATIONS)	TOWNWIDE	TOWN	V/S	assessing vulnerability of pump stations & address	→			M	O
EMERGENCY SHELTERS & HOSPITALS	MULTIPLE	TOWN/ STATE	V/S	at hospital Feasibility study for solar on town facilities & shelters, including new elem. school				H	S
Societal									
VULNERABLE POPULATIONS (sick, group homes, autism, low income)	Town Wide		V	updates to social media so people can get information and report emergencies developing medical needs shelter identifying these populations				H	S
ELDERLY			V/S	outreach to elderly population				H	O
COMMUTER POPULATIONS			V/S	inbound commuters: get info to them on best routes in/out of town, emergency shelters; reverse 911. COMMUNICATION to businesses, residences "one call now"				H	O
CHILDREN (Schools & Daycares)			V	communication and outreach to families emergency plan to defend in place or move kids				H	O
FOOD & SUPPLIES			S	working with grocery store to provide food to emergency shelter				M	S
COMMUNICATION & REGIONAL COORDINATION			S/V	District Wide Security Team: include discussion on hazard planning				H	O
Environmental									
Watersheds (4 in Town)	Town Wide		S/V	working with regional groups and	watersheds to address water quality (in process of MS4 updates)			M	O
Open Space & Trails			S	assessment to acquire open space for flood storage + management, as well as connectivity for wildlife corridors				M	O
Drinking Water (Nemmack River)			S/V	working regionally with communities on reducing pollution				H	O
Vector Borne Diseases			V	public outreach: posting info on trails about ticks info on covering standing water to reduce mosquitos				H	S
(Wetlands Resources) Rivers, Streams, Ponds			S/V	treat algae growth in Long Pond Assement to keep rivers clear, reduce flooding				M	L
Flora & Fauna			S/V	beaver management for flooding	invasive species management			M	O

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Infrastructural									
Dam	Ames Pond	Private	V	Cost benefit analysis of lowering level with town coordination and owner, public education and outreach to downstream residents, dam failure analysis and risk assessment; possible seek town ownership				M	L
Pump Stations	Townwide	Town	V/S	capacity study for buildout for future precipitation levels	resilient installation of generators, elevated if needed	Study power alternatives- solar/battery	Education for homeowners; re: what should go down drains, more hazardous material disposal days with public/private partnerships	M	S
Stormwater system	Townwide	Town/Private	V/S	Trash cans for needle disposal and public spaces; coordinate meetings or policy with surrounding towns to increase public education to reduce pollutants in water supply; policy for stormwater detention on site and use of gray water- regulations for new development incentives for a density bonus, specific design guidelines				H	L
public safety, DPW, (RECC) Buildings	Townwide	Town	V/S	Design resilient DPW building and vehicle				M	S
Water Treatment Plant and Water Storage	Merrimack Dr	Town	V/S	Floods: Increase storage through gray/green infrastructure and link irrigation to detainment pond at police station; regional improvements in water quality		Drought: Study or identify alternative water supply; use gray water for plumbing in homes; study overall water capacity/needs		H	L
Roads and Bridges (495, 93, 38 are State Rds)	Townwide	State, Town	V/S	Floods: elevate roads at strategic locations, upsize culverts; construct other infrastructure for water detention, underground storage, and plantings				H	L/O
Societal									
Shelters	Town/Lowell	Town/Private	V/S	Update inventories at shelters to identify equipment needs; coordinate with Red Cross to conduct study and assess needs for other locations; communicate with residents and distribute pamphlets; assess shelter in place model and storage capacity/needs and ability to serve current populations; create transportation for seniors; study town buildings that could be warming/cooling stations; needs to be pet friendly				M	O
Transient Population (Homeless)	Town/Lowell	-	V	identify homeless shelters and capacity; partner with nonprofit to assist police provide mental health/substance abuse counseling/ treatment- work with Tewksbury State Hospital				M	O
55+population	Townwide	-	V	Information on shelters added to Town website, message board, reverse 911, at Senior Center, Town nurse, town reports; develop a "Good Neighbor" program or buddy system with young residents (snow removal, home checks); GIS study of existing data to identify seniors and vulnerable populations;				M	O
Mental health	Townwide	-	V	Provide mental health services at shelters; add staff, develop volunteer training program, coordinate with Red Cross and State Hospital for best practices				H	O
Public health	Townwide	-	V	emergency preparedness/education, capacity to shelter in place, creative education/outreach strategies/ school curriculum for homework for kids and parents				H	S
public safety				Climate curriculum for students; STEM education		"coffee with a cop" events	pamphlet on emergency information including in water or	M	O
Environmental									
Trees	Townwide	Town/National Grid	V/S			tree trimming		M	L
Wetlands and Beavers	Townwide	Town/Private/ State	V/S	Map future floodplain; Study priority habitat areas and beaver problem areas; coordinate town access to wetlands on private property for maintenance; public education				L	O
Parks and open space	Townwide	Town	S	land acquisition/ land donation for tax relief				M	L
Vector Borne Illness	Townwide	-	V	alternative treatment/remediation				H	O
Rivers and Brooks	Townwide	Town/Private	V	Coordinate for Town access for maintenance to remove blockages				M	O
Trails	Townwide	Town/Private	V/S						

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Features	Location	Ownership	V or S	Heavy Precipitation and Flooding	Severe Thunderstorms, Wind, Nor'easters, Tornado	Severe Snow, Ice, Extreme Cold	Extreme Heat, Drought, Wildfire	Priority (H - M - L)	Time (Short Long Ongoing)
Infrastructural									
Sewer	Specific - Pump stations, other - townwide	Town	B	Assess Regina Street Pump Station for removal	Assess all pump stations for risks and options for removal/fortification Purchase generators for pump stations or portable plug-ins			M	O
Water Supply	Specific - Pump stations, other - townwide	Town	B	Improve intake flood proofing and assess based on future conditions				M	L
Drainage	Townwide	Town	V	CIP implementation with climate resilience lens; Use town properties for stormwater green infrastructure/LID; develop an action plan for the stormwater system with vulnerability assessment for stormwater flooding and culvert upsizing; update subdivision regulations with incentives or requirements				H	S-O-L
Electric Grid	Townwide	National Grid	B	Reduce impact of vegetation on powerlines and provide guidelines on the types of trees to plant near lines				L	L
Facilities/Operations	Specific Locations	Town	S	Resilience features as part of the DPW- net zero; Solar as backup on roofs/car PV; need a long-term solution for the flooding at the police station (they are running pumps all the time)-- possibly a water tight chamber.				H	S-O-L
Communications	Townwide	Town	S						
Dams	Specific Locations (4)	Private	V	Study dam removal and impacts downstream				L	L
Societal									
Seniors- Senior Center	Census Tract Info on Map, Specific	Private/ Housing Authority	B	Increase communication about resources; develop a list or database of vulnerable people; increase coordination with social service organizations		Housing authority or other location need community rooms that can serve as cooling/heating centers that are ADA accessible and people have transportation to		H	O
Disabled Population	Townwide	-	V					H	O
Youth and Schools	Census Tract Info on Map, Schools/Childc	Town & Private	B	Build in resilience components to the new elementary school; increase resources for sheltering in place				L	O
Local Businesses/Services		Private	B	Support emergency plans and advocate that businesses have a plan; develop memorandums of understanding for food				M-H	S-O
Library and Cooling/Heating Stations/Shelters	Townwide	Town	S						
Emerging Health Risks/ Health care	Specific Locations	-	V	Fix detention basins with standing water, expand communication, conduct a health assessment/inventory with climate resilience chapter				H	O
Transportation/Roadways	Townwide	Town/State	B	Incorporate climate adaptation strategies into Main St. reconstruction (work with MassDOT); Raise roadway at Rte 38				M	O
Environmental									
Tree Canopy	Townwide	Mostly Town, some private	B	Increase street trees; develop a tree management program and pruning schedule to reduce wildfire vulnerability; develop planting plan to reduce heat island				M	O
Landfill	Few Sites	Town	V	monitor - maintain sites; place solar on top of sites; cap where needed				H	S
Wetlands and Swamps	Townwide	Mostly Town, some private	B	Improve wetland bylaw, stormwater bylaw, and education				H	S
Agricultural Lands/ Open Space	Townwide	State/Town/Private	S	Better standards on conservation restrictions and guidelines of operations and maintenance				H	L
Air Quality and Water Quality	Townwide	-	S-now, V-future	Improve pollution controls on impaired waterbodies; install more EV infrastructure				M	O
Invasives	Townwide	-	V	Create recommended list of plantings; develop invasive removal polices/programs and education				L	O

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.org

H-**M**-**L** priority for action over the **S**hort or **L**ong term (and **O**ngoing)
V = Vulnerability **S** = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Heavy Precipitation and Flooding	Severe Thunderstorms, Wind, Nor'easters, Tornado	Severe Snow, Ice, Extreme Cold	Extreme Heat, Drought, Wildfire	Priority H - M - L	Time Short Long Ongoing
Infrastructural									
Water Treatment Plant	Merrimack Drive	Town	V/S	Continue to support infrastructure improvements				H	O
Communications	Townwide	Town/private	V	Evaluate communication system and facilities (town facilities are on fiber optic)				M	O
Wastewater pumping stations	Townwide	Town/private	V	Continue to implement improvements				H	O
Police Station	Main St.	Town	V	Basement pumping Evaluate PV Power, pumping solution- maintenance				H	O
Ames Dam	Ames Pond	Private	V	Evaluate or assess dam removal				M	O
Roadways, Drainage, Bridges, Culver	Townwide	Town	V	Replace culverts and make drainage improvements (Bay Berry Lane/Culvert Bridge Repair, many others in 5 year capital improvement plan)				H	O
Societal									
Senior Center	Chandler St	Town	V/S	Update HVAC/Roof and evaluate with solar; evaluate transportation during emergencies and communication with seniors; develop a regional approach				H-M	O
Library	Chandler St	Town	V/S	Evaluate expanding shelter- warming and cooling				M	O
High School	Pleasant St	Town	V/S	Solar canopy on parking lot and evaluate GI and MS4 implementation possibilities for phosphorus retrofits				M	O
Nursing Homes, Assisted Living Facilities, Group Homes	Townwide	Private	V	Develop communication and engagement plan				M	O
Multi-lingual population	Townwide		V					M	O
public housing/rentals	Townwide		V					M	O
Environmental									
Wetlands and Wildlife	Townwide	Town/State/Private	V	Promote wetlands protection				H	O
Trails & Recreation	Townwide	Town/State	V	Expand trail network, make field improvements, install parking and stormwater opportunities				H	O
Rivers: Merrimack, Shawsheen, Heath Brook, Strongwater Brook, Sutton Brook	Townwide	-	V	Continue to support water quality improvements through stormwater				H	O
Ponds	Townwide	Town	V	Assess Long Pond improvements and septic systems				H	O
Recreational Fields	Townwide	Town	V	Field improvements- parking and stormwater improvements (MS4)				H	O

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Features	Location	Ownership	V or S	Heavy Precipitation and Flooding	Severe Thunderstorms, Wind, Nor'easters, Tornado	Severe Snow, Ice, Extreme Cold	Extreme Heat, Drought, Wildfire	Priority H - M - L	Time S Short L Long O Ongoing
Infrastructural									
Drainage Infrastructure (Culverts)	Townwide	Town	V	Assessment and upgrades (Brown St.); bylaw updates and higher design standards				H	O
Bridges	Townwide	Town/State	V/S	Assessment, prioritize, upgrade bridges, specifically work with the State on the bridge on Bridge St.				H	O
Emergency Facilities (Police-near flood zone and Fire)	Multiple	Town	V/S	Floodproof new police/fire	Communication with backup or redundancy			H	S
Roadways	Townwide	Town/State/Private	V/S	Complete streets plan; plate trees (Main St); install pervious pavement at Town Buildings		Keep roads clear for emergency vehicles and		M	O
Drinking and Wastewater (Pump Stations)	Townwide	Town	V/S	Assess vulnerability of pump stations and address problem at hospital				M	O
Emergency Shelters and Hospitals	Multiple	Town/State	V/S	Feasibility study for solar on Town facilities and shelters including the new elementary school				H	S
Societal									
Vulnerable Population	Townwide		V	Develop a medical needs shelter; identify populations and build database; put updates on social media so people can get information; need platform for people to report emergencies online				H	S
Elderly	Townwide		V/S	Outreach				H	O
Commuters	Townwide		V/S	Inbound commuters: get info to them on best routes in/out of town, emergency shelter capacity, reverse 911 communication expansion to businesses, residents				H	O
Children (Schools and Daycare)	Townwide		V	Communication and outreach to families	Emergency plan to shelter in place or move kids			H	O
Food and Supplies	Townwide		S	Work with grocery store to provide food to emergency shelter				M	S
Communication and Regional Coordination	Townwide		V/S	District wide security team				H	O
Environmental									
Watersheds (4 in Town)	Townwide		V/S	Work with regional watershed groups to address water quality in concert with MS4 updates				M	O
Open Space and Trails	Townwide		S	Assessment to acquire open space for flood storage and management as well as connectivity for wildlife corridors				M	O
Drinking Water (Merrimack River)	Townwide		V/S	work regionally with communities to reduce pollution				H	O
Vector Borne Diseases	Townwide		V/S	public outreach, posting info on trails about ticks and on covering standing water to reduce mosquitos				H	S
Rivers, Streams, Ponds, Wetland Resources	Townwide		V/S	Treat algae growth in Long Pond; Assessment on how to keep rivers clear, reduce flooding				M	L
Flora and Fauna	Townwide		V/S	Beaver management	Invasive species management			M	O

Table 1: All Recommended Hazard Mitigation Measures

Mitigation Action	Time Frame	Priority
1. Conduct a feasibility study for solar energy on Town facilities and shelters, including the new elementary school	Short-term	High
2. Assist vulnerable populations with a shelter that can address medical needs, building a database of vulnerable residents, using social media to provide emergency alerts, and providing an online platform for residents to report emergencies	Short-term	High
3. Conduct outreach to elderly residents	Ongoing	High
4. Provide commuters with information on safe routes and emergency shelter capacity. Expend the reverse 911 communication system to reach commuters	Ongoing	High
5. Protect children at schools and daycares by conducting outreach to families and having emergency plans to shelter-in-place or evacuate children.	Ongoing	High
6. Work with a grocery store to provide food to emergency shelters	Short-term	Medium
7. Improve regional communication and coordination by forming a district-wide team	Ongoing	High
8. Support infrastructure improvements at the Water Treatment Plant	Ongoing	High
9. Evaluate communication system and facilities	Ongoing	Medium
10. Continue to implement improvements at wastewater pumping stations	Ongoing	High
11. Update HVAC and roof at the Senior Center. Evaluate options for solar energy. Evaluate transportation and communication systems during emergencies	Ongoing	High
12. Install a solar canopy over the parking lot at the high school and evaluate green infrastructure and MS4 implementation possibilities for phosphorus retrofits	Ongoing	Medium
13. Develop a communications and engagement plan with multi-lingual populations	Ongoing	Medium
14. Expand the trail network, install parking and stormwater management near trails	Ongoing	High
15. Implement the capital improvement plan with a climate resilience lens	Ongoing	Highest High
16. Update subdivision regulations with incentives or requirements	Ongoing	Highest High
17. Include resilient features as part of the DPW and its vehicle storage. Evaluate options for net zero energy, solar backup on the roof, and PV panels over the parking lot	Short-term	Medium

Mitigation Action	Time Frame	Priority
18. Increase communication about resources with seniors and disabled residents. Increase coordination with social service organizations.	Ongoing	High
19. Support the development of emergency plans for local businesses.	Short-term	Medium
20. Conduct a public health assessment or inventory with a climate resilience chapter. Expand communication with residents about the public health impacts of climate change	Ongoing	High
21. Install more electric vehicle infrastructure	Ongoing	Medium
22. Provide education for homeowners regarding materials that cannot go down drains. Include more hazardous materials disposal days with public/private partnerships	Short-term	Medium
23. Increase creative emergency preparedness education and outreach strategies. Develop climate curriculum and homework for kids and parents.	Short-term	Medium
24. Discuss emergency preparedness at a “coffee with a cop” event	Ongoing	Medium
25. Increase public education and outreach by sharing pamphlets on emergency information in the water or tax bill. Provide email, mailer, or flyers. Hold events at the library. Host a kiosk at the grocery store and coffee shops.	Ongoing	Medium
26. Study power alternatives for pump stations, including solar and battery	Short-term	Medium
27. Assess and upgrade drainage infrastructure. Replace culverts and make drainage improvements along roadways including Bay Berry Lane, Bridge Street, and many others in the 5-year capital improvement plan	Ongoing	Highest High
28. Update bylaws, including the wetland and stormwater bylaw. Develop policies for stormwater detention on-site and the use of gray water.	Ongoing	Highest High
29. Develop regulations for new development, incentives for a density bonus, and specific design guidelines. Require higher design standards.	Long-term	Highest High
30. Conduct an assessment to acquire open space for flood storage and wildlife corridors. Pursue land acquisition in flood risk areas and land donation for tax relief.	Long-term	Medium
31. Map the future floodplain.	Ongoing	Low
32. Study priority habitat areas and beaver problem areas. Increase public education related to beavers and their impact.	Ongoing	Low
33. Increase flood storage through gray and green infrastructure and link irrigation to detainment pond at the police station.	Long-term	Highest High

Mitigation Action	Time Frame	Priority
34. Improve public education about wetlands and promote wetlands protection	Short-term	High
35. Increase trash cans for needle disposal in public spaces.	Long-term	Highest High
36. Use town properties for stormwater management, green infrastructure, and low impact development.	Long-term	Highest High
37. Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.	Long-term	Highest High
38. Follow the Complete Streets concept, plant trees on Main Street, and install pervious pavement at Town Buildings	Ongoing	Medium
39. Assess, prioritize, and upgrade bridges. Work with the State on the Bridge Street bridge	Ongoing	High
40. Assess flood vulnerability of pump stations and address the pump station problem at the hospital	Ongoing	Medium
41. Work regionally with communities and watershed groups to reduce pollution in waterbodies and drinking water, including the Merrimack River, Shawsheen, Health Brook, Strongwater Brook, and Sutton Brook. Address water quality in concert with MS4 updates. Coordinate meetings or policy with surrounding towns to increase public education and reduce pollutants in the water supply.	Ongoing	High
42. Conduct an assessment on how to keep rivers clear and reduce flooding	Long-term	Medium
43. Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience	Ongoing	High
44. Conduct a cost-benefit analysis of lowering the dam level. Increase coordination between the Town and dam owners. Increase public education and outreach to downstream residents. Conduct a dam failure analysis and risk assessment. Evaluate or assess dam removal and downstream impacts at the Ames Dam. Consider seeking town ownership of private dams.	Long-term	Medium
45. Conduct a capacity study for pump station buildout using future precipitation levels.	Short-term	Medium
46. Assess Long Pond improvements and septic systems. Treat algae growth in Long Pond.	Ongoing	High
47. Improve recreational fields through parking, stormwater management, and MS4 work	Ongoing	High
48. Assess all pump stations for risks and options for removal or fortification, including Regina Street pump station.	Ongoing	Medium
49. Improve water supply intake flood proofing and assess based on future conditions	Long-term	Medium

Mitigation Action	Time Frame	Priority
50. Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.	Long-term	High
51. Coordinate with property owners to provide Town access for maintenance of wetlands, rivers, and brooks; and to remove blockages	Ongoing	Medium
52. Construct infrastructure for water detention and underground storage	Long-term	High
53. Improve emergency response and communication system with backups and redundancy	Short-term	High
54. Reduce the impact of vegetation on power lines through tree trimming	Long-term	Medium
55. Provide guidelines on the types of trees to plant near power lines	Long-term	Low
56. Identify locations for the resilient installation of generators at pump stations, elevated if needed. Purchase generators or portable plug-ins for pump stations	Short-term	Medium
57. Keep roads clear for emergency vehicles and assess opportunities for more snow clearing	Ongoing	Medium
58. Evaluate expanding the shelter at the library, including both warming and cooling stations	Ongoing	Medium
59. Provide community rooms at Housing Authority properties that can serve as cooling and heating centers, are ADA accessible, and have transportation connections	Ongoing	High
60. Update inventories at shelters. Coordinate with Red Cross to assess capacity and needs. Communicate with residents and distribute pamphlets. Create transportation plan for seniors. Study town buildings that could become warming or cooling stations. Provide pet-friendly shelters.	Ongoing	Highest High
61. Identify homeless shelters and their capacity. Partner with nonprofits, Tewksbury State Hospital, and police department. Provide mental health and substance abuse counseling and treatment at shelters.	Ongoing	Medium
62. Add staff and develop volunteer training program for shelters. Coordinate with Red Cross and State Hospital for best practices.	Ongoing	High

Mitigation Action	Time Frame	Priority
63. Reach elderly residents by adding information on shelters to the Town website, message board, reverse 911. Distribute information at the Senior Center, through the Town nurse, and through town reports. Develop a "Good Neighbor" program or buddy system with young residents to assist with snow removal and house checks. Conduct a GIS study of existing data to identify seniors and vulnerable populations. Coordinate with emergency management mapping efforts.	Ongoing	Medium
64. Conduct public outreach related to vector-borne diseases and post information on trails about ticks	Short-term	High
65. Explore alternative treatment and remediation strategies for vector-borne illness	Ongoing	High
66. Protect flora and fauna through invasive species management	Ongoing	Medium
67. Improve standards on water conservation and water restrictions for agricultural land. Provide guidelines for operations and maintenance	Long-term	High
68. Address Town-owned detention basins with standing water to minimize mosquito populations	Ongoing	High
69. Create a recommended list of native plantings. Develop invasive removal policies, programs, and education	Ongoing	Low
70. Increase street trees and develop a planting plan to reduce heat island. Develop a tree management program and pruning schedule to reduce wildfire vulnerability.	Ongoing	Medium
71. Study overall water capacity and needs and assess options for recycling gray water or improving water conservation practices.	Long-term	Highest High

Stakeholders Invited to Attend Tewksbury's Community Resilience Building Workshop

Attend	Name	Title	Affiliation
		Core Team	
√	Anna McGinty	Town Planner	Planning Department
√	Steve Sadwick	Assistant Town Manager	Administration
√	Brian Gilbert	Director	DPW
√	Kevin Hardiman	Town Engineer	Engineering Department
√	Stefania Gallo	Conservation Agent	Conservation
√	Vinnie Bomal	Facilities Manager	Facilities
√	Melissa Maniscalco	Executive Director	Housing Authority
√	Lt. Scott Gaynor	Lieutenant	Police Department
√	Chester Cheng	GIS Project Manager	Engineering Division
√	Al Vasas	Deputy	Fire Department
	Eva Durkin	Chair	Open Space & Rec. Plan Committee
		Local	
	Richard Montuori	Town Manager	Administration
	Edward Johnson	CBO Building Commissioner	Building Department
	Jami Bent		Computer Services
√	Scott Brinch	Assistant Director, Utilities	DPW
	Randy Burly	Project Manager	DPW
	Jon Marchand	Public Schools Facilities	Tewksbury Public Schools
√	Joanne Foley	MAA Chair	Assessor's Office
√	Nicole Hutcheon	Director	Council on Aging
√	Marilyn Murphy	Chair	Council on Aging
	Joan Hatem Roy		Elderly Services (Merrimack Valley)
√	Susan Sawyer	Director	Health Department
	Diane Giarrusso	Director	Tewksbury Public Library
	Brian Dorrington	Director	Telemedia Department
	Kevin Lessard	NMRECC Executive Director	Tewksbury/Dracut RECC
	Vinny Fratalia	Board Member/Volunteer	Planning Board/Tewksbury Habitat Build
√	Raymond Barry	Chair	Board of Health
	Jay J. Kelly	Elected Board Member, Chair	Board of Selectmen/ Tewksbury North & Trahan School Reuse Committee
	John W. Deputat	Chair	Community Preservation Committee
	Patrick Holland	Chair	Conservation Commission
	Mark Kratman	Chair	Economic Development Committee

	Marc A. Difruscia	Treasurer	Housing Authority
	Thomas Churchill	Chair	Historical Commission
	Keith M. Sullivan	Chairman	School Committee
	Robert A. Kocsmiersky	Chair	Finance Committee
	Christopher Malone	Superintendent of Schools	Tewksbury Public Schools
	Thomas Cooke		Green Committee
√	David Lochiatto		Green Committee
	Lisa Downey	Veteran Service Operator	Veterans Services
	Doug Sears	President	Tewksbury Historical Society
	Anne Marie Stronach	Chair	Elemententary School Building Committee
	Nancy Reed	Chair	Local Housing Partnership
	Christian Panasuk	Chair	Cultural Council
	Stephen Johnson, Jr.	Chair	Planning Board
√	Paige Impink	Chair	Beautification Committee
	Richard Cuoco	Consultant/Local Business Owner	Woodland Design
	Matt Hamor	Consultant/Local Business Owner	Landplex
	Jim Andella	Developer	
	Jim Hanley	Consultant/Developer	Civil Design Consultants
	Marc Ginsburg	Developer/ Local Business Owner	Tewksbury Country Club
	Michael Saccone (Christina Saccone)	Developer/ Local Business Owner	MDR
	R.J. Buckley	President	Tewksbury Community Pantry
	Ray Bowden	Volunteer	Tewksbury Community Pantry
	Joyce Hamlyn/ Gina Allard	Troop Leader	Tewksbury Girls Scouts
	Debbie Deputat		Tewksbury Sons of Italy
	David Cyr / Dennis Gray	Volunteer / Pack Leader	Tewksbury Boys Scouts
	Janice Higgins		Tewksbury-Wilmington Elks
	Loretta Ryan	Member	Tewksbury Lions Club
√	Jackie Stone	Volunteer	Tewksbury Friends of Open Space
	Amanda Corella	Pastor	Tewksbury United Methodist Church
	Simeon Damas	Pastor	First Baptist Church ABC
	Rev. Paul Conway	Reverend	Lowell Assembly of God Church (Tewksbury)

	Carol Sturtevant		Tewksbury 1st Congregational Church
	Rev. James Kumankomah	Reverend	Royalhouse Chapel Massachusetts
	Rev. Dr. William Manseau	Reverend	Ecumenical Catholic Diocese of America
	Rev. Quilin Bouzi	Pastor	St. William's Catholic Church
	Jim Duffy		Resident, former Green Communities member
	Jim Carter	Controller, Real Estate	Market Basket
	Patricia Lelos	President	Wilmington-Tewksbury Chamber of Commerce; Tewksbury Rotary Club
	Melody Anoli	Market Manager	Salem Five Bank
	Alison Kalman	VP	Lowell Five Bank
	Maria Antonioni		Lowell Five Bank
√	Tom Hosey	VP & Risk Officer	Lowell Five Bank
	Wayne Freitag	President	Tewksbury Youth Baseball
	Chelsea Holmes		AAA Northeast
State and Regional			
	Barry Finegold Rep	State Senator, 2nd District	Massachusetts Senate
	David Allen Robertson	State Representative, 19th Middlesex District	Massachusetts House of Representatives
	Tram Nguyen	State Representative, 19th Essex District	Massachusetts House of Representatives
√	Alicia Geilen	Environmental Planner	NMCOG
	Justin Howard	Transportation Program Manager	NMCOG
	Melanie Hagman	Interim Superintendent/Director	Shawsheen Valley Technical High School
√	Richard Harrington	Board Member and Treasurer	Merrimack River Watershed Council
	Dan Graovac	President	Merrimack River Watershed Council
	Christina Eckert	Interim Director	Merrimack River Watershed Council
	Laurie Hartwick	Co-President	Shawsheen River Watershed Association
√	Michelle Rowan	MVP Regional Coordinator	EEA
√	Scott Consaul	Facilities Manager/ Emergency Manager	Tewksbury State Hospital
	Elise Simons	Environmental Protection Specialist	U.S. Environmental Protection Agency
	Eric Worrall	Northeast Regional Director	MA Department of Environmental Protection

	Beth Lambert	Director	Division of Ecological Restoration
	Christine Berry	Land Protection Specialist	DCR
√	Jeffrey Zukowski	Hazard Mitigation Unit	MEMA
	Priscilla Geigis or Dan Driscoll	Deputy Commissioner for Conservation and Resource Stewardship	DCR
√	Heather Tecce	Region 1 Manager	MEMA - Region 1 Office
	Paul Sneeringer		Army Corps of Engineers
√	Susan Griffin		National Grid- Natural Gas / Electric
Adjacent Municipalities			
	Paul Materazzo	Director of Planning	Town of Andover
	Jacki Byerley	Town Planner	Town of Andover
	Christopher Samaras	Director, Community Development	City of Lowell
	Chris Reilly - Replacement?	Director, Planning	Town of Billerica
	Valerie Gingrinch	Director, Planning & Conservation	Town of Wilmington
	Evan Belansky	Director, Community Development	Town of Chelmsford
	Besty Ware	Director, Community Development	Town of Dracut

Legend: √ indicates invitee attended the Workshop

Critical Facilities in Tewksbury

Category 1 - Emergency Response Facilities	
Police and Fire Department	
Police Department	918 Main Street
Fire Department Headquarters	21 Town Hall Ave
North Street Station	830 North Street
South Street Station	2342 Main Street
Town Facilities	
Department of Public Work	999 Whipple Road
Tewksbury Community Pantry	999 Whipple Road
Communication Infrastructure	Astile Street/ Watertower Road
	2342 Main Street
	134 Catamount Road
	120 Pond Street
	71 Merrimac Drive
Airport	
Private Landing Pad	Near Tewksbury Country Club
Emergency Shelters	
Senior Center	175 Chandler Street
Tewksbury Memorial High School	320 Pleasant Street
Tewksbury Congregational Church (*warming station*)	10 East Street
Police Station (*warming station*)	918 Main Street
Hospitals and Urgent Care	
Tewksbury State Hospital	365 East Street
Carewell Urgent Care	345 Main Street
Circle Health Urgent Care	1574 Main Street
Primary Evacuation Routes	
	I-495
	Main Street (Route 38)
	Andover Street (Route 133)
	Shawsheen Street
	Whipple Road
	East Street
	Brown Street
Critical Bridges, Intersections, and Sites	
Strong Water Brook	East Street
Bridge	Main Street
Critical intersection	South Street and Bridge Street
Trestle Bridge	Near the Upper South Street Neighborhood
Category 2 – Non-Emergency Response Facilities	

Water and Sewer Infrastructure	
Water Tank/Communications Hub	Water Tower Road
Water Tank	134 Catamount Road
Water Tank	100 Colonial Drive
Water Altitude Valve	Old Main Street
Water Pump Station	Ames Hill
Sewer Syphon	Bridge Street
Water Intake Station	Merrimac Drive
Sewer Pump Stations	

Geiger Drive, Riverdale Ave, Martha Ave, Rockvale Road, Vale Street, Bemis Circle, Serenity Drive, Regina S Drive, Sunset Circle, Eastgate Road, North Street, Florence Ave East Street, Newton Ave, Robinson Ave, Davis Road, North Billerica Road, Westland Drive, Hill Street, Pinnacle Street, Leighton Lane, Heather Row, Cinnamon Circle, Munro Circle, East Street (large), Cemetery (smaller), Meredith Road, Dunvegan Road, Joanne Drive, Merrimac Drive, Andover Street, Germano Drive, Devonshire Rd, Chandler Street, Grasshopper Lane, John Street, Otis Street, Wamesit, Sycamore Drive, Sawyer Lane, Country Club Drive, DeCarolis Drive, Frasier Lane, Louis Road, Marshall Street, New Jersey Road, Champion Street, River Road

Town Facilities	
Town Hall	1009 Main Street
Town Hall Annex	11 Town Hall Ave
Tewksbury Public Library	300 Chandler Street
Park's Maintenance facilities	255 Livingston Street, 288 Livingston Street
Rec Center	286 Livingston Street
Water Treatment Plant	71 Merrimac Drive
State Facilities	
MA DPW Tewksbury Maintenance Depot	Clark St & Route 38 & Route 495
Natural Resources	
Round Pond	
Long Pond	
Strong Water Brook	
Shawsheen River	
Merrimack River	
Ames Pond	
Meadow Brook	
Open Space & Conservation Land	
Trail Systems	
Frasca Field Soccer Complex	295 North Street
Livingston Street Complex	
Religious Centers	
St. William's Catholic Church	1351 Main Street
Glory2Glory Center	170 Main Street
Tewksbury United Methodist Church	2335 Main Street

Lowell Assembly of God	995 Andover Street
First Baptist Church AMB	1500 Andover Street
Royalhouse Chapel Massachusetts	170 Main Street, G9

Bus Lines

Category 3 – Dangerous/Hazardous Materials and Facilities

Dams

Ames Pond Dam	
Ames Pond Dike A	
Ames Pond Dike B	

Landfill

Rocco Landfill	1069 South Street
Tewksbury State Hospital Dump	Maple/Livingston Streets
Sutton Brook Solar Farm	71 Serenity Drive/Behind 1057 South Street/Behind Sutton Brook Landfill

Power Station

National Grid	357 Old Boston Road

Underground Storage Tanks

National Grid	Chapman Road
Maclellan Oil Co	1187 Main Street
Holt & Bugee Co.	Shawsheen Street
Charter #2420	Andover Street
Mobil Oil	Main Street
Shell Oil	Main Street
Citgo	Main Street

Gas Stations

2 Main Street
270 Main Street
365 Main Street
883 Main Street
1040 Main Street
1049 Main Street
1220 Main Street
1860 Main Street
1975 Main Street
1992 Main Street
2221 Main Street
1700 Shawsheen Street
1920 Andover Street
1795 Andover Street
940 Andover Street

Sewer Siphons

On the north side of Bridge Street under the

Shawsheen River	
At the former police station site at 935 Main Street	
Hazardous Materials Sites	
Astro Circuits Corp	540 Main Street
Liquid Carbonic	1685 Shawsheen Street
Tewksbury State Hospital Power Plant	30 East Street
AT&T	637 Clark Road
Ashland Chemical Co	400 Main Street
Williamsburg Park Near Main St	170 Old Main Street
National Grid gas facility	50 Chapman Road, Tewksbury

Category 4 – Vulnerable Populations and Community Facilities

Housing Authority	
Carnation Drive	
Livingston Street	Delaney Drive (units 1-50)
	Saunders Circle
	Roy Way
	Corinne Way
Pond View Lane	
Schools/Daycare	
Loiuse Davy Trahan Elementary	12 Salem Street
Heath-Brook Elementary	165 Shawsheen Street
North Street Elementary	133 North Street
L F Dewing Elementary	1469 Andover Street
John W. Wynn Middle	1 Griffin Way
John F. Ryan Elementary	135 Pleasant Street
Centerpoint	365 East Street
Baby Bear Family Daycare	65 Parker Ave
Children of America Tewksbury	1497 Main Street
Pattikakes' A Place to Grow	365 East Street
Milestones Children's Center Inc.	1721 Main Street
The Learning Experience	1593 Andover Street
Tewksbury Kindercare	847 North Street
Kreative Kids Child Care	10 Wamesit Road
Tewksbury Knowledge Beginnings	200 Old Main Street
Rising Stars Academy	1500 Andover Street
Stellas Family Childcare	36 Shawsheen Street
Creative Learning Academy	778 Main Street
Brenda's Day Care Inc	1 Sharon Street
Just Like Home Daycare	11 Greenwood Ave
Family Daycare	10 Wamesit Road
Tiny Owl Day Care	1321 Whipple Road
Grocery and Supplies Stores	
Market Basket	10 Main Street
Market Basket	1900 Main Street
Walmart Supercenter	333 Main Street

Spicindya Indian Grocery	1487 Main Street
Hobart's Country Store	2514 Main Street
Tewksbury Market	160 Shawsheen Street
White Dove Pantry	910 Andover Street
Aubuchon Hardware	1777 Main Street
The Home Depot	85 Main Street
Market Basket Distribution Center	East Street
Restaurant Depot	Andover, close to Town line

Youth Services

Children Services – Roxbury	1147 Main Street

Assisted Living/Nursing Home

Blair House at Tewksbury	10 Erlin Terrace
Isle at Emerald Court	2000 Emerald Court
Pines of Tewksbury	2580 Main Street
Wood Haven Senior Living	2580 Main Street
Group Homes	Throughout Town
Heatherwood Gracious Retirement Living	1624 Main Street

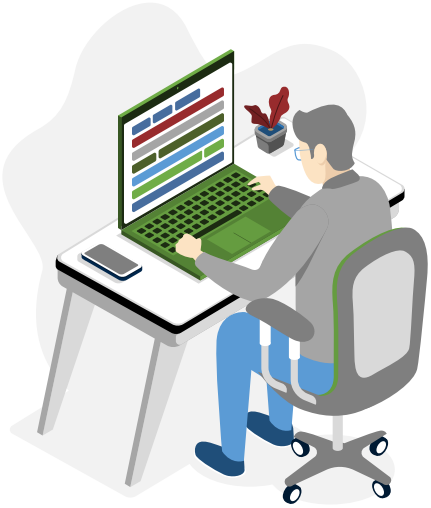
Appendix D

Listening Session

HAZARD MITIGATION & CLIMATE ADAPTATION

WEBINAR, REPORT, AND SURVEY

AVAILABLE APRIL 7TH – APRIL 21ST



The Town of Tewksbury is seeking community input as part of their hazard mitigation and climate adaptation planning process.

This online engagement format includes a summary webinar, draft report, and online survey to record comments and feedback.

Watch the webinar at:
tinyurl.com/TewksburyMVPWebinar

Review the report at:
tinyurl.com/TewksburyMVPReport

Take the survey at:
tinyurl.com/TewksburyMVPSurvey

Please reach out if you have barriers to participating.

Adria Boynton | Resiliency Specialist, Weston & Sampson
(978) 278-3592 | boyntona@wseinc.com

TOWN OF TEWKSBURY

LISTENING SESSION WEBINAR

April 7 – April 21, 2020

Weston & Sampson℠

Photo: Town Hall in Tewksbury, MA. Town of Tewksbury website.

WEBINAR LOGISTICS

WEBINAR

REPORT

SURVEY

WEBINAR LOGISTICS

- The **webinar** was pre-recorded
- The **webinar** will be available on the Town's YouTube page and via a link on the Town's website
- The **webinar** presents information related to Tewksbury's draft **HMP-MVP report**
- A **survey** will be available online from **April 7-April 20, 2020**
  - The **survey** provides an opportunity for public comments and feedback related to the webinar and the draft **HMP-MVP report**
  - A link to the **survey** is included at the end of the presentation

WEBINAR OUTLINE

PRESENTATION:

- Overview of MVP and HMP
  - HMP-MVP Draft Report Available Online
- Overview of Climate Change
- Strengths and Vulnerabilities
- Priority Action Items
- Next Steps
  - Online Survey for Public Feedback

Photo: Tewksbury Town Common. Photo by The Town of Tewksbury.

MVP & HMP OVERVIEW

Photo: Merrimack River. Blogspot.com.

MVP Principles

A community-led, accessible process that

- Employs local knowledge and buy-in
- Utilizes partnerships and leverages existing efforts
- Is based in best available climate projections and data
- Incorporates principles of nature-based solutions
- Demonstrates pilot potential and is proactive
- Reaches and responds to risks faced by EJ communities and vulnerable populations

Why nature-based?

Where appropriate, nature-based solutions can be more cost-effective, protect water quality and quantity, sustain lands that provide food and recreation opportunities, reduce erosion, and minimize temperature increases associated with developed areas and climate change.

MVP Process/ Grant Types

COMMUNITY RESILIENCE BUILDING WORKSHOP(S)

- Define and characterize hazards using latest science and data
- Identify existing and future community vulnerabilities and strengths
- Develop and prioritize community adaptation actions
- Determine overall priority actions
- Receive MVP designation

MVP Planning Grant

MVP Action Grant

Implement priority adaptation actions identified through planning process

MVP Action Grants: Project Types

- Vulnerability and Risk Assessment
- Community Outreach and Education
- Local Bylaws, Ordinances, Plans, and Other Management Measures
- Redesigns and Retrofits
- Nature-Based Flood Protection, Drought Mitigation, Water Quality, and Water Infiltration Techniques
- Nature-Based, Infrastructure and Technology Solutions to Reduce Vulnerability to Extreme Heat and Poor Air Quality
- Nature-Based Solutions to Reduce Vulnerability to other Climate Change Impacts
- Ecological Restoration and Habitat Management to Increase Resiliency
- Energy Resilience
- Chemical Safety
- Land Acquisition for Resilience
- Subsidized Low-Income Housing Resilience Strategies
- Mosquito Control Districts

Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA)

Municipal Vulnerability Preparedness (MVP)

community resilience building workshop

abbreviated time frame

less competitive grants

Overlap

municipal leadership

core team

regional collaboration

listening session

community engagement

review existing information

climate change hazards and projections

hazard impacts and vulnerability

opportunities to improve

existing policies/programs

risk matrix

prioritize climate adaptation actions

identify strengths, vulnerabilities, and potential actions

summary of findings

report

state action grants

grant funding

United States Federal Emergency Management Agency (FEMA)

Hazard Mitigation Planning (HMP)

planning committee

public input events

provide updates on development changes

natural hazards and in-depth hazard profile

document NFIP participation and compliance

document existing

define the future update process

background research

implementation plan for hazard mitigation

address repetitively damaged structures

hazard mitigation plan

federal grants

document formal plan adoption

Weston & Sampson

PROJECT TIMELINE

COMMUNITY RESILIENCE BUILDING WORKSHOP

Focused on Four Hazards

Identified:

- Vulnerabilities
- Strengths
- Priority Action Items

Across Three Categories:

- Infrastructure
- Societal
- Environmental

CLIMATE HAZARDS

Photo: Tewksbury Public Library, Tewksbury Twitter.

TOP FOUR HAZARDS IN TEWKSBURY

Heavy Precipitation and Flooding

Severe Snowstorms, Ice Storms, Extreme Cold

Severe Thunderstorms, Wind, Nor'easters, Tornado

Extreme Temperatures, Drought, Wildfire

EXTREME TEMPERATURES

WARMER ANNUAL AIR TEMPERATURES

UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS

UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

EXTREME TEMPERATURES
IN MASSACHUSETTS

DAYS WITH TEMPERATURES ABOVE 90°F

2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE
6	24	35

DAYS WITH TEMPERATURES BELOW 32°F

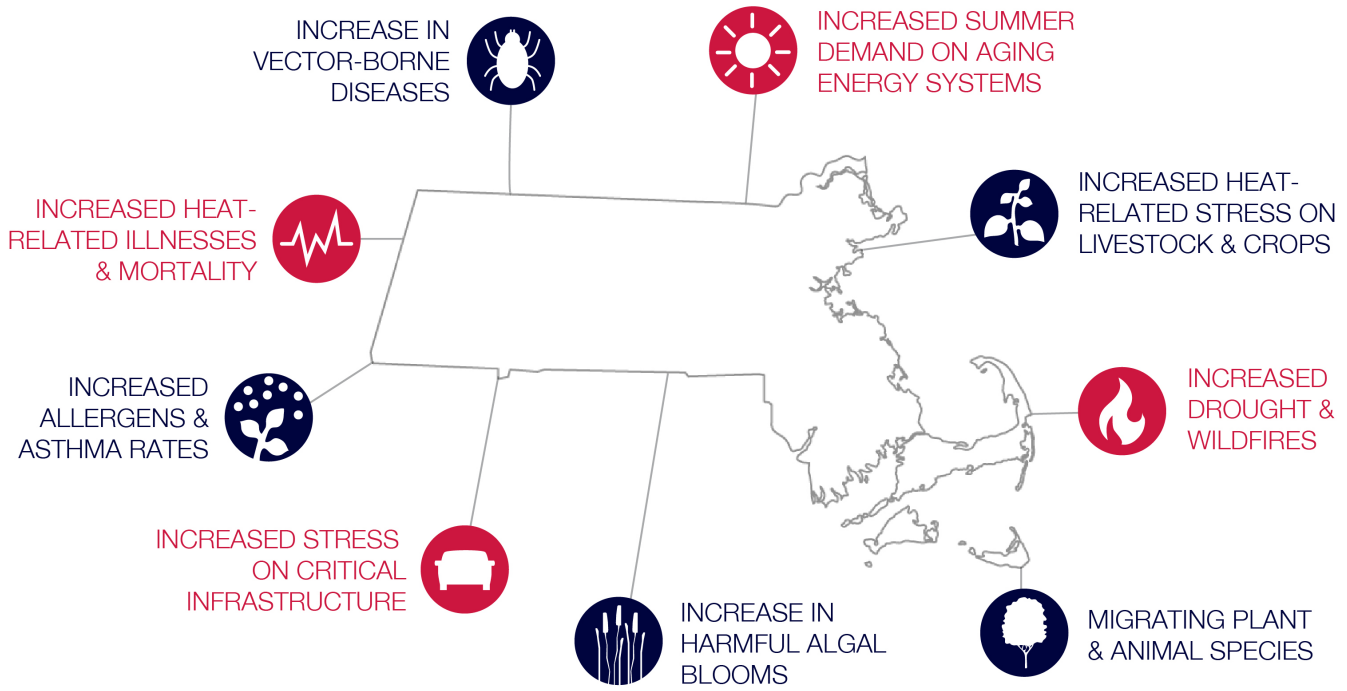
2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE
145	114	101

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "ResilientMA Datagrapher." Massachusetts Climate Change Clearinghouse. Resilientma.org/datagrapher/?c=Temp/state/tx90/ANN/MA/
Notes: Mid-century projected annual averages use a 2040-2069 time range. End-of-century project annual averages use a 2080-2097 time range.

IMPACTS OF **RISING TEMPERATURES**

WARMER ANNUAL AIR TEMPERATURES
UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Rising Temperatures." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/rising-temperatures

Tewksbury Health Department Alerts Residents after Mosquitos in Neighboring Communities Test Positive for EEE

POSTED ON: AUGUST 26, 2019 - 3:04PM

Source: Tewksbury Website, News

PRECIPITATION DURING
HEAVY EVENTS IN THE
NORTHEAST

INCREASED
BY MORE THAN
70%

BETWEEN 1958-2010

"Areas in south and east Tewksbury have experienced substantial flooding, septic system failures and nutrient loading resulting from development in close proximity to wetlands."

–Tewksbury 2016 Master Plan

Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. Resilientma.org/changes/changes-in-precipitation

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events in the northeastern U.S. by midcentury

13%

Increase in extreme precipitation events in the northeastern U.S. by 2100

LOCALLY IDENTIFIED AREAS OF FLOODING

Main Street near the Police Station

Shawsheen Street near Main Street, Mohawk Drive, Algonquin Drive, and the bridge

Brown Street near Nichols Road and Whipple Road

Bridge Street near South Street

Pinnacle Street

Pond Street

Bonnie Lane

Sutton Street

Lake Street

Pupkis Road near Heath Street

Starr Ave near Mitchell G. Drive

Veranda Street

Photo: Pupkis Road Flooding

Water Street at Adelaide Road

Greenwood Ave near Woburn Street

Vernon Street

Cayuga Road

Wolcott Street at Tewmac Terrace

Van Buren Road at Marston Street

Dewey Street at Town Hall Ave

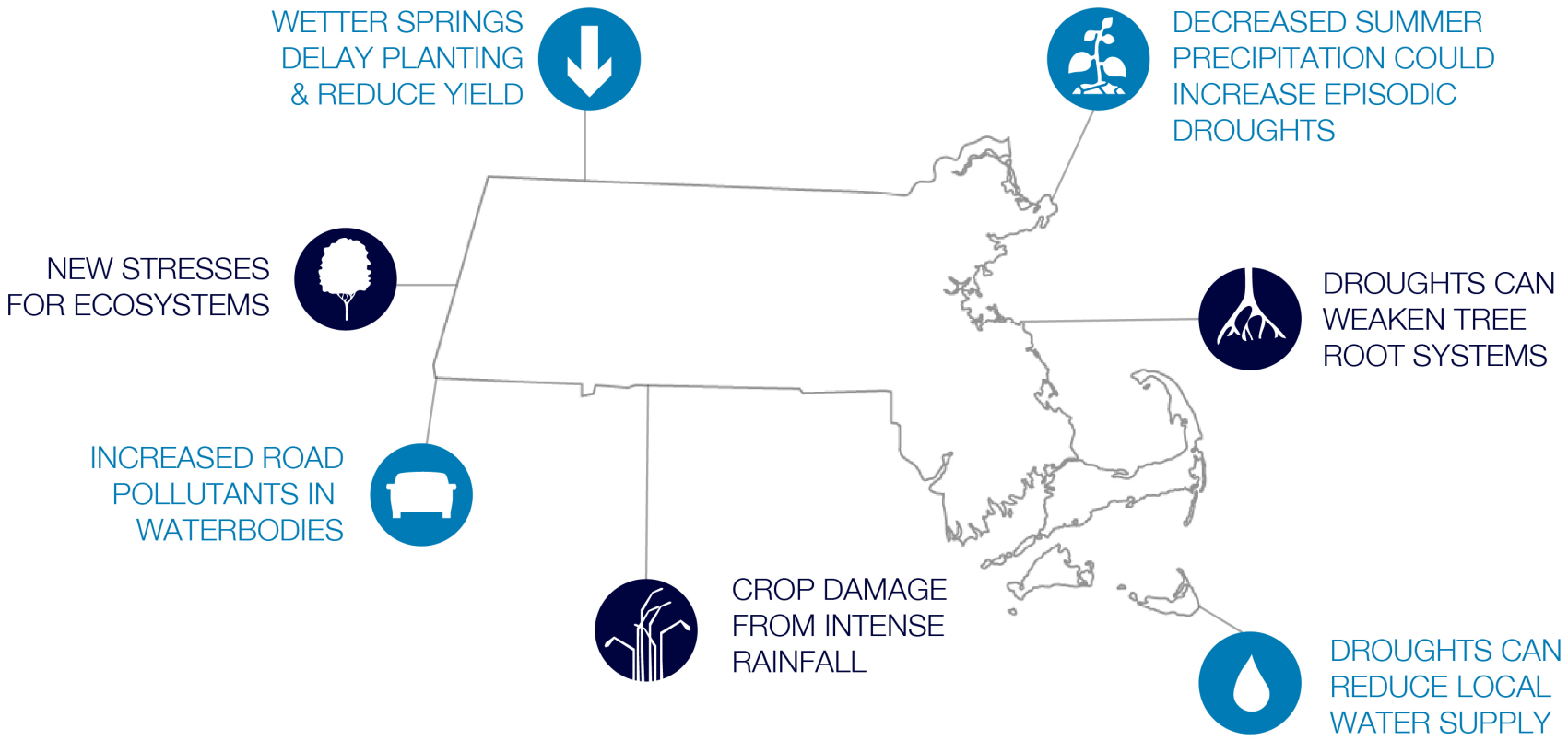
Whipple Road at Chandler Street

Claire Street at Marie Street

IMPACTS OF CHANGING **PRECIPITATION**

HIGHER AVERAGE ANNUAL PRECIPITATION

INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Changes in Precipitation." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/changes-in-precipitation

SEVERE WINTER WEATHER

The blizzard of 2013 left nearly **400,000 Massachusetts residents without power**

Rain, Warmth Close Outdoor Rink In Tewksbury

The town said in a notice on its Website that the rink would be closed "until further notice."

By Dave Copeland, Patch Staff
Jan 25, 2019 3:23 pm ET

Source: Patch.com

"Heavy blizzards are among the **most costly and disruptive** weather events for Massachusetts communities."

SEVERE STORMS

Upward trend in North Atlantic hurricane activity since 1970

2012: Hurricane Sandy

2017: Hurricane Jose

2018: Hurricane Florence

2019: Hurricane Dorian

Nor'easters along the Atlantic coast are increasing in frequency and intensity

Jan 3-4, 2018: Winter Storm Grayson

March 2, 2018: Winter Storm Riley

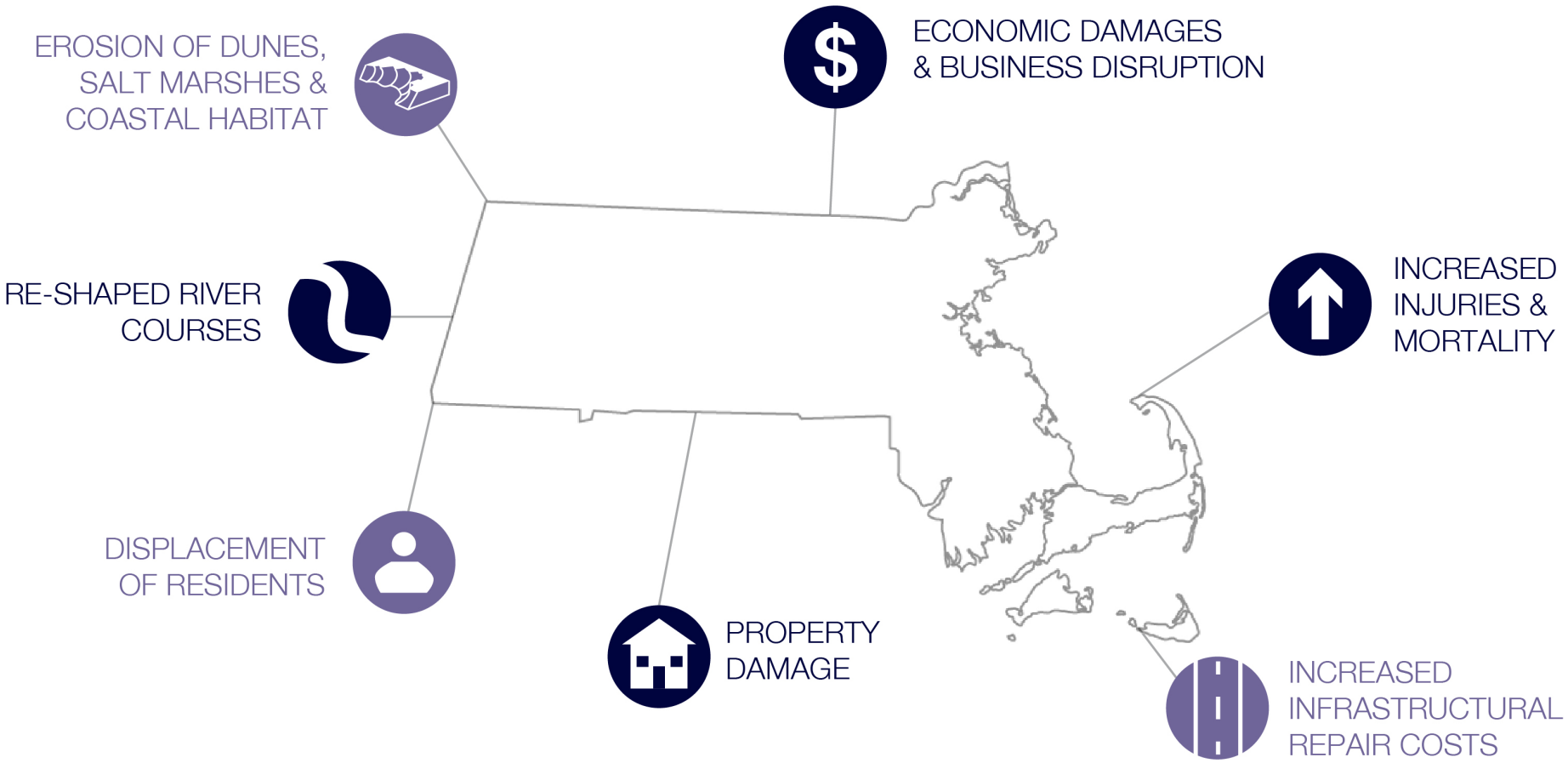
March 8, 2018: Winter Storm Quinn

March 13, 2018: Winter Storm Skylar

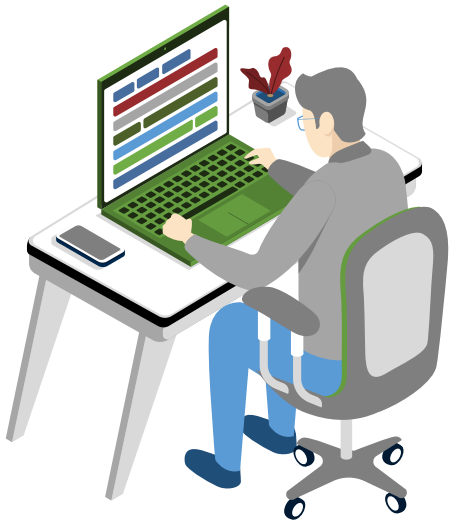
Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)Northern Middlesex

IMPACTS OF **EXTREME WEATHER**

STORMS ARE BECOMING MORE INTENSE AND DAMAGING



Massachusetts Executive Office of Energy & Environmental Affairs. 2019. "Extreme Weather." Massachusetts Climate Change Clearinghouse. http://www.resilientma.org/changes/extreme-weather



Take the online survey to tell us **what hazard most concerns you**

STRENGTHS & VULNERABILITIES

Photo: Tewksbury Congregational Church, 2010.

INFRASTRUCTURE

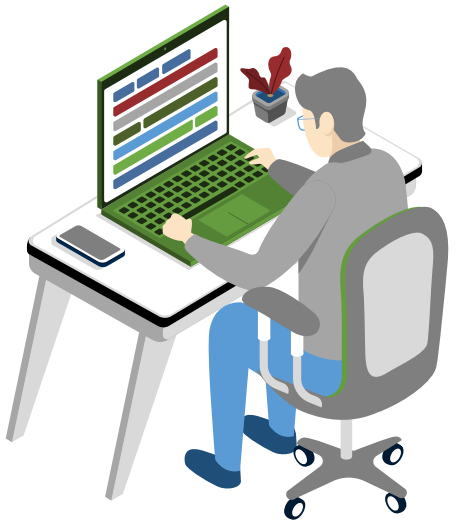
Vulnerabilities	Both Vulnerability and Strength	Strength
• Drainage infrastructure and culverts • Dams, including the Ames dam	• Bridges and roadways • Emergency facilities, including Police, Fire, RECC, and DPW • Water and wastewater pump stations • Water Treatment Plant • Water supply and storage • Emergency shelters and hospitals • Sewer system • Electric grid • Stormwater system • Communications	• Town operations

ENVIRONMENTAL

Vulnerabilities	Both Vulnerability and Strength	Strength
• Wildlife • Recreational fields • Landfill • Invasive species • Vector-borne diseases	• Watersheds, rivers, streams, and ponds • Drinking water (Merrimack River) • Flora and fauna • Tree canopy • Wetlands and swamps • Trails and recreation	• Open space • Agricultural land • Air quality and water quality

SOCIETAL

Vulnerabilities	Both Vulnerability and Strength	Strength
• Homeless population • Mental health • Public health concerns • Disabled population • Emerging health risks/health care • Nursing homes, assisted living facilities, group homes • Multi-lingual population • Public housing/rentals	• Shelters • Elderly residents • Senior Center • Youth and children • Schools and daycares • Local businesses and services • Library • Commuters • Communications and regional coordination	• Cooling and heating stations • Food and supplies



Take the online survey to tell us **more about Tewksbury's vulnerabilities and strengths**

EXISTING HAZARD PROTECTION

- Green Community Designation
- Open Space and Recreation Plan
- Capital Improvement Program
- Emergency Generators
- Reverse 911
- All-Hazard Plan
- Shelters
- Energy Efficiency at Housing Authority properties
- Traffic support and escort
- Electric Vehicle Charging Stations
- NFIP Participation
- CRS Participation
- Floodplain overlay district zoning bylaw
- Discharges to municipal storm sewers bylaw
- Local Wetlands Protection bylaw
- Subdivision regulations
- Street sweeping program, cleaning catch basins and culverts
- Groundwater protection Overlay District
- FMA and HMGP Grants
- Stormwater management and erosion control bylaw
- Manhole maintenance at Housing Authority properties
- Drainage improvement program
- Stormwater management
- Sump pumps at the Police Station
- Repair of the Ames Pond Dam and Dikes
- DPW Forestry Department Tree Maintenance Program
- Snow removal
- Measures to address wildfire risk
- Road maintenance
- Open burning permits
- Fire Department review of proposed development
- Public education
- Statewide Fire Mobilization Plan
- Regional Emergency Planning Committee
- GPS Units for Fire Hydrants
- Housing Authority Water Use
- Tree planting
- Backup water supply
- Cold Weather Alerts
- MA building code for earthquake loads

Source: 2015 HMP, Expert Interviews, CRB Workshop, Core Team

HIGHEST HIGH PRIORITIES

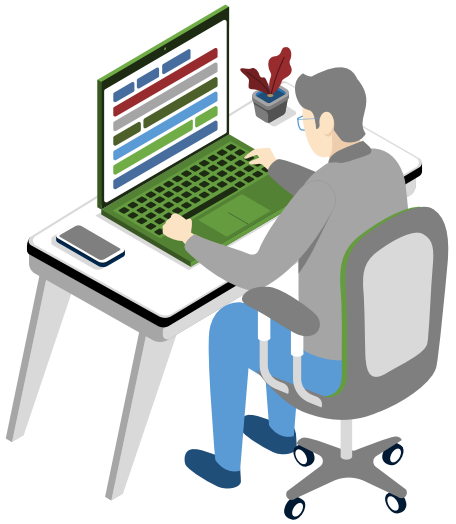
- Assess and upgrade drainage infrastructure. Replace culverts and make drainage improvements along roadways including Bay Berry Lane, Bridge Street, and many others in the 5-year Capital Improvement Plan (CIP)
- Increase flood storage through gray and green infrastructure.
- Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.
- Use town properties for stormwater management, green infrastructure, and low impact development.
- Implement the capital improvement plan with a climate resilience lens

HIGHEST HIGH PRIORITIES

- Create transportation plan for seniors
- Update inventories at shelters. Coordinate with Red Cross to assess shelter capacity and needs. Provide pet-friendly shelters.
- Study overall water capacity and needs and assess options for recycling gray water or improving water conservation practices.
- Update subdivision and development regulations with incentives or requirements. Update bylaws, including the wetland and stormwater bylaw. Develop policies for stormwater detention on-site and the use of gray water.
- Develop design guidelines and require higher design standards.

TOP THREE PROJECTS FOR POTENTIAL MVP ACTION GRANT FUNDING

- Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.
- Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.
- Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience



Take the online survey to tell us which of these three items should be a **top priority for MVP Action Grant funding**

SHARE YOUR FEEDBACK!

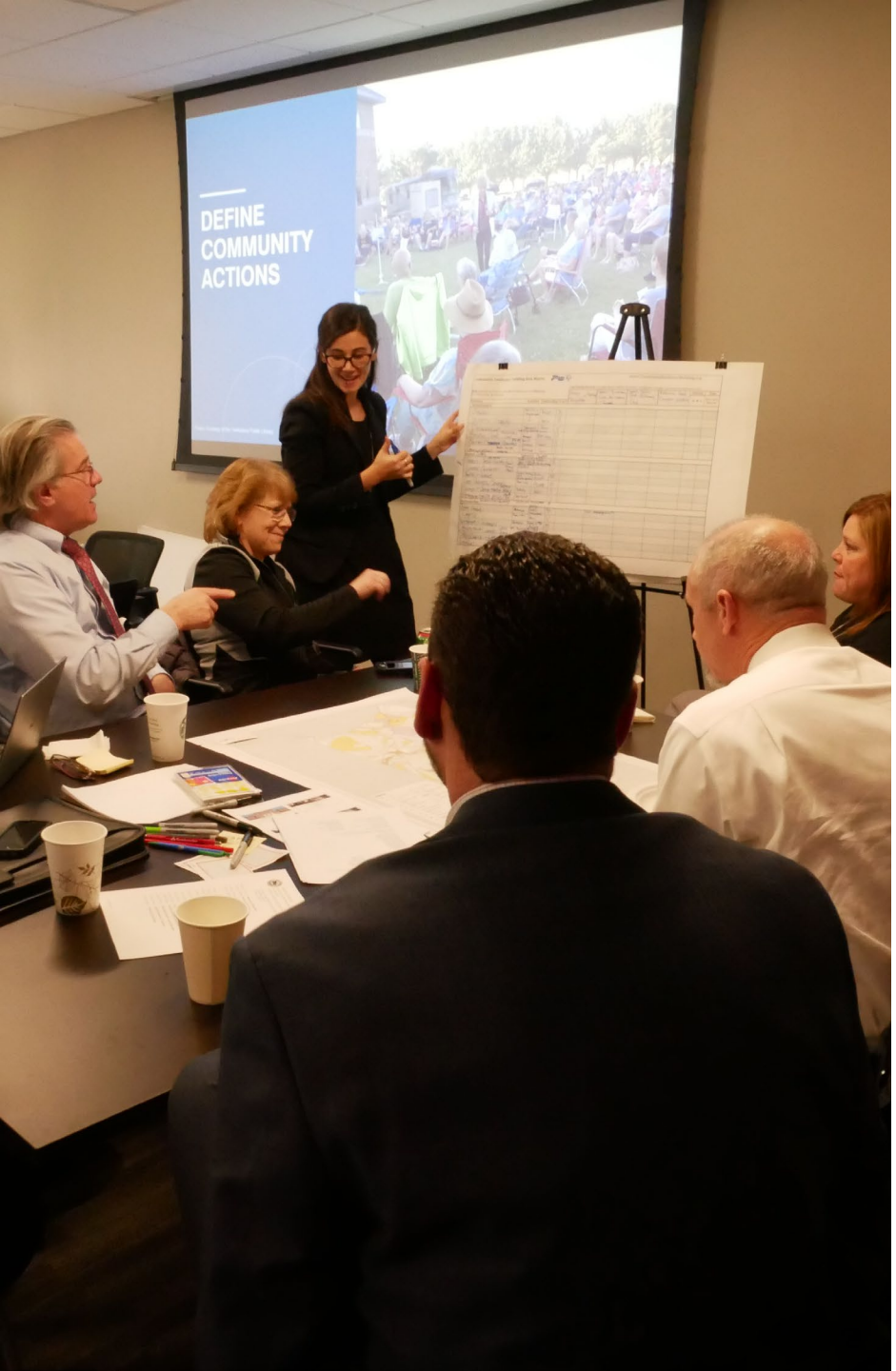
- For more information, review the draft HMP-MVP report online!

  tinyurl.com/TewksburyMVPReport

- Comment on the webinar and report by taking our survey!

  tinyurl.com/TewksburyMVPSurvey

- The survey will be available online from **April 7-April 20, 2020**



THANK YOU

Weston & Sampson℠

Tewksbury MVP Survey

The Town of Tewksbury is seeking community input as part of their hazard mitigation and climate adaptation planning process. This survey captures public feedback related to the Town's draft MVP-HMP report and summary webinar, available at the links below.

Draft MVP-HMP report: tinyurl.com/TewksburyMVPReport

Webinar: tinyurl.com/TewksburyMVPWebinar

This survey will be available from April 7-April 21, 2020. If you have additional questions or barriers to participating, please contact Adria Boynton (Resiliency Specialist at Weston & Sampson) at boyntona@wseinc.com or (978) 278-3592.

1. What hazard most concerns you?




	Hazard of most concern	Hazard of significant concern	Hazard of some concern	Hazard of least concern
Heavy precipitation and flooding	○	○	○	○
Severe snowstorms, ice storms, and extreme cold	○	○	○	○
Severe thunderstorms, wind, Nor'easters, and tornado	○	○	○	○
Extreme temperatures, drought, and wildfire	○	○	○	○

2. What memories of climate hazards do you have? These could include impacts from:
    - The heatwave during July 2018
    - The four Nor'easters in March 2018 (Winter Storms Riley, Quinn, Skylar, and Toby)
    - Winter Storm Grayson in January 2018
    - The 2016 drought
    - The blizzard of 2013 Image credits: Town of Tewksbury and Tewksbury Public Library



Image credits: Town of Tewksbury and Tewksbury Public Library

Short answer response:

3. How prepared do you feel the Town is for future extreme events?

- ○ I feel the Town is completely prepared
- ○ I feel the Town is somewhat prepared
- ○ I feel the Town is not prepared
- ○ Other (please specify):

4. What steps have you already taken to prepare for extreme events?

- ☐ I have a kit in case of emergencies (which may include food, water, flashlights, batteries, and other supplies)
- ☐ I receive news, updates, and information about emergency preparedness in Tewksbury
- ☐ I know where the nearest local shelter is
- ☐ Other (please specify):

5. What resources do you need to feel more prepared?

- [ ] More information on areas and infrastructure in town vulnerable to climate impacts
- [ ] More information on evacuation routes and shelters
- [ ] More information on preparing an emergency kit and receiving news updates during an extreme event
- [ ] Other (please specify):

6. What are some of Tewksbury's greatest vulnerabilities?

- ○ Culverts, drainage infrastructure, and stormwater management
- ○ The water treatment plant and water management practices
- ○ Vulnerable populations; including identifying shelter capacity, meeting medical needs, and reaching at-risk residents
- ○ Emergency facilities; including the Police Department, Fire Department, and DPW building
- ○ Other (please specify):

7. What are some of Tewksbury's greatest strengths considering climate resilience?



Image credits: Town of Tewksbury and Tewksbury Public Library

- ○ Public infrastructure; including roads, bridges, the electric grid, and water and wastewater infrastructure and the electric grid
- ○ Emergency facilities; including shelters, hospitals, and the Police and Fire Departments
- ○ Natural features; including open space, trails, trees, wetlands, and rivers
- ○ Public facilities; including the senior center, library, and schools
- ○ Other (please specify):

8. The Town has identified the three projects below for potential MVP Action Grant funding. Which project would you like to see implemented first?

	Most preferable project	Somewhat preferable project	Least preferable project
Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.	○	○	○
Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.	○	○	○
Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience.	○	○	○

9. How can the Town improve its public education and outreach to better share information about existing resiliency projects and actions?

Images: Tewksbury's stakeholder workshop in January 2020.

- ☐ Share information through public events, including virtual webinars
- ☐ Share information through printed media; including reports, fact sheets, or brochures
- ☐ Share information online, including through the Town of Tewksbury website, Twitter, and Facebook pages
- ☐ Strategic outreach to vulnerable populations, such as elderly residents or other groups
- ☐ Other (please specify):

10. Are there any other comments or questions that you would like to share with the project team?

Short answer response:

11. If you are interested in receiving additional updates related to climate initiatives in Tewksbury, please enter your name and email below.

Short answer response:

55 Walkers Brook Drive, Suite 100, Reading, MA 01867
Tel: 978.532.1900

Tewksbury MVP Survey

Summary of Survey Results

Introduction

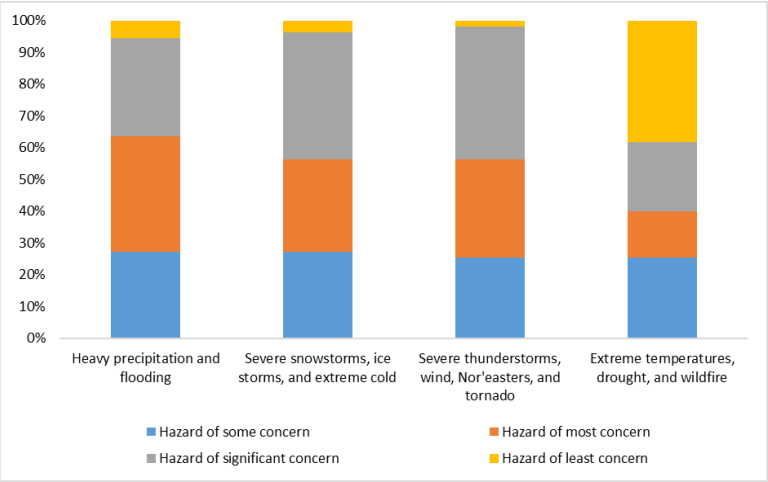
The Town of Tewksbury was awarded a Municipal Vulnerability Preparedness (MVP) Planning Grant to improve the Town's resilience to climate change and to mitigate natural hazards. The MVP Program aims to provide technical and financial support for cities and towns across the Commonwealth to plan for, and mitigate the impacts from, climate change. As part of the virtual Public Listening Session, the project team shared a survey to collect public feedback related to climate hazards, strengths, vulnerabilities, and priority adaptation action items. Key information related to the results of this survey are summarized below:

- The survey was accessible on the Microsoft Forms website from April 7-April 24, 2020. The survey was extended to April 24th to allow time for additional input.
- A link to the online survey was shared on April 7th in a promotional flyer emailed to the stakeholder list and by posting a link on the Town's website and YouTube pages. A link was also shared in a Tewksbury Patch Article on April 8th.
- The Town also distributed one PDF copy to a stakeholder who requested the survey as a document, rather than a webpage.
- The project team received 56 online responses.

The following summary provides an overview of the survey responses, along with key findings and recommendations for using this information.

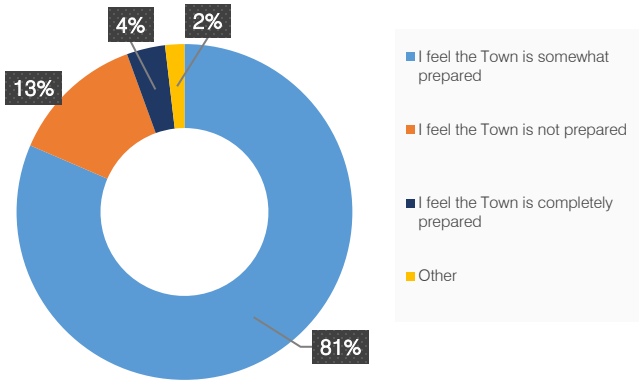
Survey Results

What hazard most concerns you?

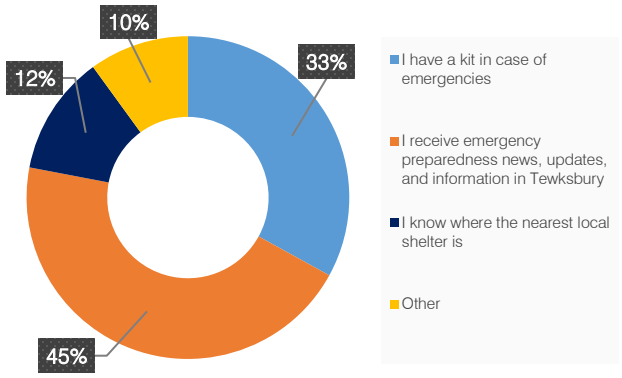


- Survey results suggest that heavy precipitation and flooding are hazards of most concern.
- Extreme temperatures, drought, and wildfire are hazards of least concern for most of the Town's residents.
- Severe snowstorms, ice storms, and extreme cold; and severe thunderstorms, wind, Nor'easters, and tornados are hazards of significant concern.

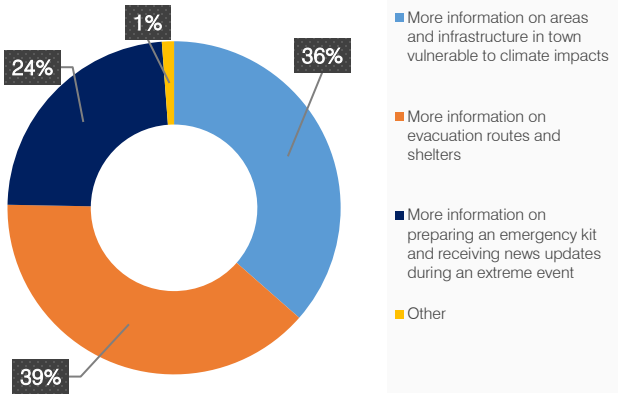
How prepared do you feel the Town is for future extreme events?



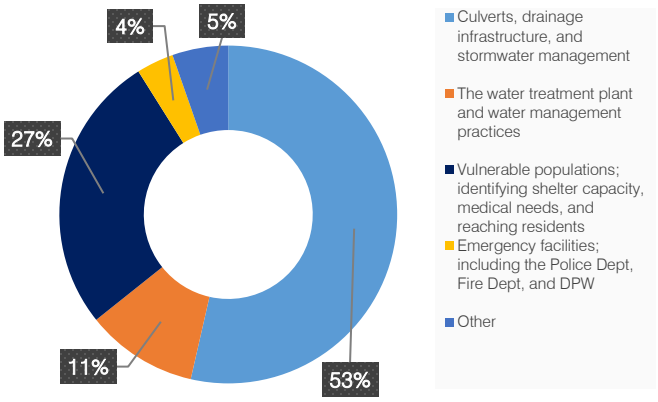
What steps have you already taken to prepare for extreme events?



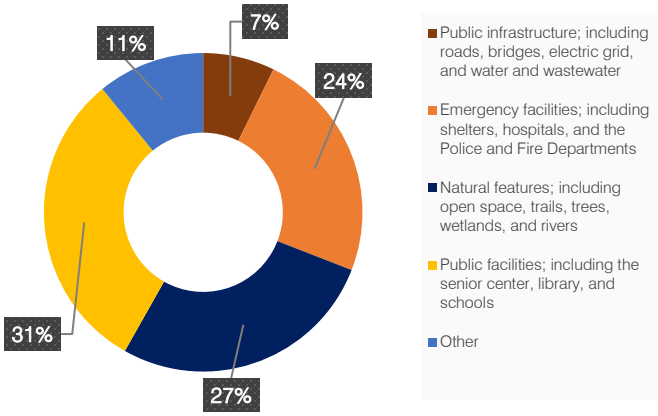
What resources do you need to feel more prepared?



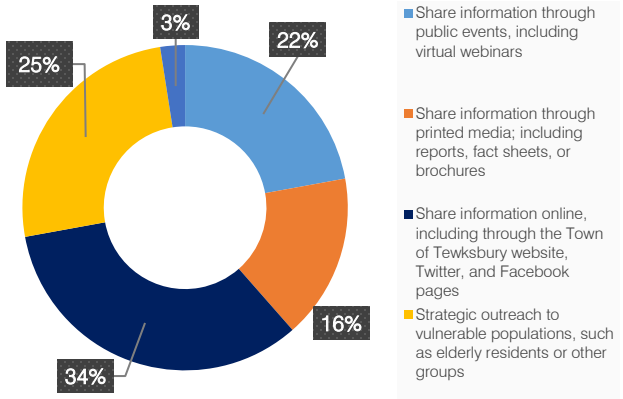
What are some of Tewksbury's greatest vulnerabilities?



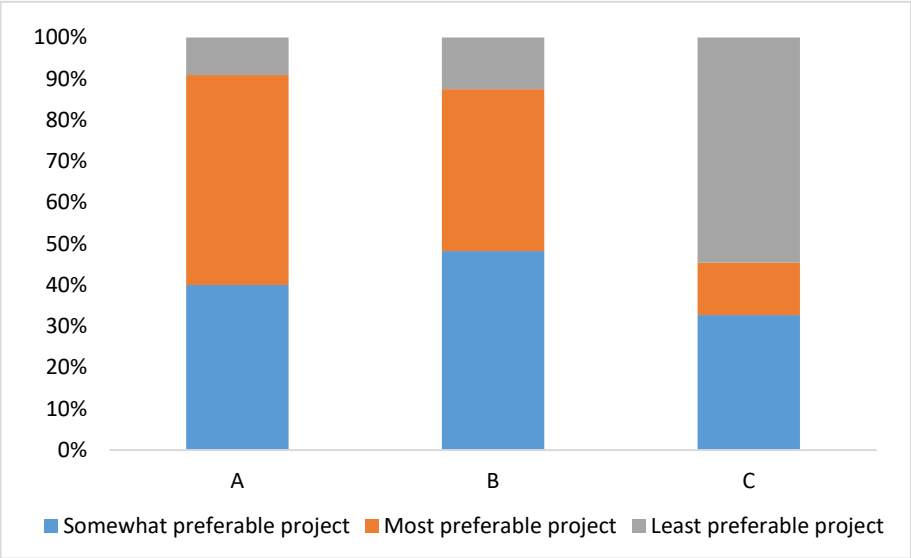
What are some of Tewksbury's greatest strengths considering climate resilience?



How can the Town improve its public education and outreach to better share information about existing resiliency projects and actions?



The Town has identified the three projects below for potential MVP Action Grant funding. Which project would you like to see implemented first?



A: Develop an action plan for the stormwater system with a vulnerability assessment for stormwater flooding and culvert upsizing.
B: Elevate roads at strategic locations, including Route 38, Shawsheen, and local roads leading to 495. Incorporate climate adaptation strategies into the Main Street reconstruction and coordinate with MassDOT.
C: Maintain basement pumping system at the police station and evaluate options for PV power and long-term flood resilience.

Based on responses, developing an action plan for the stormwater system is the most preferred project for potential MVP action grant funding. Maintaining basement pumping system at the Police station and evaluating options for PV power and long-term flood resilience is the least preferred project.

Summary of short-answer responses:

- The most frequently cited climate hazard that caused significant impacts in the Town are four Nor'easters in March 2018 (19 out of 47 responses). People were without power and heat for days. The 2016 drought and the blizzard of 2013 were also mentioned by survey respondents. In general, winter storms, blizzards, and ice storms are of significant concern among residents. Winter storms cause power outages and may keep residents confined to their homes without heat or communication services.
- There was a wide array of additional comments received from the Town's residents. Comments that were repeated by two or more residents included those related to flooding, adjusting Wetland Bylaws to reduce construction in wetland areas, and improving the conditions of roads and sidewalks. Respondents also raised concerns related to beaver management, trash pickup from certain part of town, and the lack of high-water transport vehicles for the Police and Fire departments.

Key Findings & Next Steps

As the pie charts and bar graphs indicate, heavy precipitation and flooding are the main concerns for residents. The responses suggest a need for better drainage infrastructure and stormwater management, along with a more efficient emergency management system. Although the worst

hazards that respondents remember are winter related hazards, one of the short-answer responses also demonstrated concern related to flooding.

The project team should use the findings of this survey to:

- Pursue funding for climate adaptation projects related to heavy precipitation and flooding, including addressing culverts, drainage infrastructure, and stormwater management.
- Share more information with the public related to areas and infrastructure in Town vulnerable to climate hazards, as well as more information on evacuation routes and shelters.
- Share more information online, including through the Town's website and social media platforms.
- Use the email addresses collected to start a climate resilience listserv. Additionally, the next public meeting should be advertised via email to respondents who shared their contact information.

Appendix E

Plan Adoption

BOARD OF SELECTMEN
TOWN OF TEWKSBURY
TOWN HALL
1009 MAIN ST
TEWKSBURY, MASSACHUSETTS 01876

JAY KELLY, CHAIRMAN
BRIAN H. DICK, VICE CHAIRMAN
ANNE MARIE STRONACH, CLERK
MARK KRATMAN
JAYNE E. WELLMAN

(978)-640-4300
FAX (978) 640-4302

CERTIFICATE OF ADOPTION
BOARD OF SELECTMEN

TOWN OF TEWKSBURY, MASSACHUSETTS

A RESOLUTION ADOPTING THE
TOWN OF TEWKSBURY
HAZARD MITIGATION PLAN AND MUNICIPAL VULNERABILITY PREPAREDNESS PLAN
2020

WHEREAS, the Town of Tewksbury established a Committee to prepare the *Town of Tewksbury Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan 2020*; and

WHEREAS, the *Town of Tewksbury Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan 2020* contains several potential future projects to mitigate potential impacts from natural hazards as well as climate change in the Town of Tewksbury, and

WHEREAS, the public provided input through a duly-noticed listening session video, survey, and draft report posted online and advertised by the local Planning Department from April 7th to April 24th and

WHEREAS, the Town of Tewksbury authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan, and

NOW, THEREFORE BE IT RESOLVED that the Town of Tewksbury Board of Selectmen adopts the *Town of Tewksbury Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan 2020*, in accordance with M.G.L. 40 §4 or the charter and bylaws of the Town of Tewksbury.

ADOPTED AND SIGNED this November 17, 2020

Jay Kelly, Chairman Date

Mark Kratman Date

Brian H. Dick, Vice Chairman Date

Jayne E. Wellman Date

Anne Marie Stronach, Clerk Date

LOCAL MITIGATION PLAN REVIEW TOOL - APA
Town of Tewksbury, MA

The *Local Mitigation Plan Review Tool* demonstrates how the Local Mitigation Plan meets the regulation in 44 CFR §201.6 and offers States and FEMA Mitigation Planners an opportunity to provide feedback to the community.

- The Regulation Checklist provides a summary of FEMA's evaluation of whether the Plan has addressed all requirements.
- The Plan Assessment identifies the plan's strengths as well as documents areas for future improvement.
- The Multi-jurisdiction Summary Sheet is an optional worksheet that can be used to document how each jurisdiction met the requirements of each Element of the Plan (Planning Process; Hazard Identification and Risk Assessment; Mitigation Strategy; Plan Review, Evaluation, and Implementation; and Plan Adoption).

The FEMA Mitigation Planner must reference this *Local Mitigation Plan Review Guide* when completing the *Local Mitigation Plan Review Tool*.

Jurisdiction: Town of Tewksbury, MA	**Title of Plan:** Town of Tewksbury Hazard Mitigation Plan (HMP) and Municipal Vulnerability Preparedness (MVP) Plan	**Date of Plan:** May 2020
Single or Multi-jurisdiction plan? Single jurisdiction		**New Plan or Plan Update?** Update
Local Point of Contact: Anna McGinty **Title:** Town Planner **Agency:** Community Development Department **E-Mail:** amcginty@tewksbury-ma.gov **Regional Point of Contact:** N/A		**Address:** 1009 Main Street Tewksbury, MA 01876 **Phone Number:** 978-640-4370 ext. 236

State Reviewer: Marybeth Groff	**Title:** Hazard Mitigation & Climate Adaptation Coordinator	**Date:** 7/17/2020, 10/06/2020

FEMA Reviewer: Jay Neiderbach Brigitte Ndikum-Nyada	**Title:** FEMA Community Planner FEMA Community Planner	**Date:** 7/19/2020 - 7/24/2020 7/19/20 – 7/27/20, 10/7/20;
Date Received in FEMA Region I	7/19/2020, 10/6/2020 &	
Plan Not Approved	7/27/2020	
Plan Approvable Pending Adoption	**10/7/2020**	
Plan Adopted		
Plan Approved		

SECTION 1:
REGULATION CHECKLIST

INSTRUCTIONS: The Regulation Checklist must be completed by FEMA. The purpose of the Checklist is to identify the location of relevant or applicable content in the Plan by Element/sub-element and to determine if each requirement has been 'Met' or 'Not Met.' The 'Required Revisions' summary at the bottom of each Element must be completed by FEMA to provide a clear explanation of the revisions that are required for plan approval. Required revisions must be explained for each plan sub-element that is 'Not Met.' Sub-elements should be referenced in each summary by using the appropriate numbers (A1, B3, etc.), where applicable. Requirements for each Element and sub-element are described in detail in this *Plan Review Guide* in Section 4, Regulation Checklist.

1. REGULATION CHECKLIST Regulation (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
ELEMENT A. PLANNING PROCESS			
A1. Does the Plan document the planning process, including how it was prepared and who was involved in the process for each jurisdiction? (Requirement §201.6(c)(1))	pp. 1-2 through 1-7, 3-2 through 3-10, Appendix A, C, D	X	
A2. Does the Plan document an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, agencies that have the authority to regulate development as well as other interests to be involved in the planning process? (Requirement §201.6(b)(2))	pp. 1-2 through 1-7, 3-2 through 3-10, Appendix A, C	X	
A3. Does the Plan document how the public was involved in the planning process during the drafting stage? (Requirement §201.6(b)(1))	pp. 1-7 through 1-8, Appendix D	X	
A4. Does the Plan describe the review and incorporation of existing plans, studies, reports, and technical information? (Requirement §201.6(b)(3))	pp. 1-5, 9-1 through 9-5	X	
A5. Is there discussion of how the community(ies) will continue public participation in the plan maintenance process? (Requirement §201.6(c)(4)(iii))	pp. 8-1 through 8-2	X	
A6. Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle)? (Requirement §201.6(c)(4)(i))	pp. 8-1 through 8-2	X	
ELEMENT A: REQUIRED REVISIONS			
ELEMENT B. HAZARD IDENTIFICATION AND RISK ASSESSMENT			
B1. Does the Plan include a description of the type, location, and extent of all-natural hazards that can affect each jurisdiction(s)? (Requirement §201.6(c)(2)(i))	pp. 4-1 through 4-50	X	
B2. Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction? (Requirement §201.6(c)(2)(i))	pp. 4-1 through 4-50	X	

1. REGULATION CHECKLIST Regulation (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
B3. Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction? (Requirement §201.6(c)(2)(ii))	pp. 4-1 through 4-50	X	
B4. Does the Plan address NFIP insured structures within the jurisdiction that have been repetitively damaged by floods? (Requirement §201.6(c)(2)(ii))	p. 4-7	X	
ELEMENT B: REQUIRED REVISIONS			
ELEMENT C. MITIGATION STRATEGY			
C1. Does the plan document each jurisdiction's existing authorities, policies, programs and resources and its ability to expand on and improve these existing policies and programs? (Requirement §201.6(c)(3))	pp. 5-1 through 5-12	X	
C2. Does the Plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate? (Requirement §201.6(c)(3)(ii))	pp. 5-8, 5-9	X	
C3. Does the Plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? (Requirement §201.6(c)(3)(i))	p. 2-1	X	
C4. Does the Plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure? (Requirement §201.6(c)(3)(ii))	pp. 7-1 through 7-10	X	
C5. Does the Plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction? (Requirement §201.6(c)(3)(iv)); (Requirement §201.6(c)(3)(iii))	pp. 7-1 through 7-13	X	
C6. Does the Plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate? (Requirement §201.6(c)(4)(ii))	pp. 6-13 through 6-16, 8-2	X	
ELEMENT C: REQUIRED REVISIONS			
ELEMENT D. PLAN REVIEW, EVALUATION, AND IMPLEMENTATION (applicable to plan updates only)			
D1. Was the plan revised to reflect changes in development? (Requirement §201.6(d)(3))	pp. 3-8 through 3-10, 4-13 through 4-15, Appendix B	X	
D2. Was the plan revised to reflect progress in local mitigation efforts? (Requirement §201.6(d)(3))	pp. 6-13 through 6-17	X	
D3. Was the plan revised to reflect changes in priorities? (Requirement §201.6(d)(3))	pp. 6-13 through 6-17, 7-2 through 7-10	X	

1. REGULATION CHECKLIST Regulation (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
ELEMENT D: REQUIRED REVISIONS			
ELEMENT E. PLAN ADOPTION			
E1. Does the Plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval? (Requirement §201.6(c)(5))	Appendix E		
E2. For multi-jurisdictional plans, has each jurisdiction requesting approval of the plan documented formal plan adoption? (Requirement §201.6(c)(5))	N/A		
ELEMENT E: REQUIRED REVISIONS			

SECTION 2:
PLAN ASSESSMENT

A. Plan Strengths and Opportunities for Improvement

This section provides a discussion of the strengths of the plan document and identifies areas where these could be improved beyond minimum requirements.

Recommended Corrections:

- None

Element A: Planning Process

Strengths:

- The Core Team had representation from a variety of Town functions, including the Town Planner, Conservation Agent, Town Engineer, OSRP Committee Chair, and GIS project manager.
- Various methods were used to solicit feedback from stakeholders and the public, with an in-depth workshop held to gather opinions. Public input was effectively captured virtually through an online survey and listening session.
- There is extensive description of the findings from the stakeholder workshop, as well as supporting materials from all the outreach efforts. This information will assist in future updates and evaluation of the plan.
- Combining development of the mitigation and MVP plans, along with incorporation of best practices in community resilience from The Nature Conservancy and information from the State Hazard Mitigation Plan, ensured a thorough and comprehensive planning effort.

Opportunities for Improvement:

- Missing from the executive summary was a brief description of Tewksbury's participation in the 2015 NMCOG Multi-jurisdiction HMP. It is a great accomplishment for the town to successfully complete a single hazard mitigation plan, complimenting with a MVP.

Element B: Hazard Identification and Risk Assessment

Strengths:

- The plan takes into consideration potential future changes to hazard probability and severity.
- A GIS analysis was completed to identify the specific infrastructure and structures located in the floodplain.
- The revised draft HMP was updated with the following information to address repetitive loss properties type: *"There are eight repetitive flood loss buildings in Tewksbury. All eight properties are residential buildings."* Additional information provided also add value to the risk assessment.

Opportunities for Improvement:

- Incorporate existing watershed studies into the risk assessment.
- Incorporate the community's latest Flood Insurance Rate Map (FIRM) into the risk assessment.
- Identify dams in upstream communities that may pose a risk to neighborhoods and assets.

Element C: Mitigation Strategy

Strengths:

- There is a thoughtful assessment of existing mitigation measures, with details about how they relate to risk.
- The revised resubmitted draft HMP included the following to address element C5.c: *"The identification of time frames is not meant to prevent a community from actively seeking out and taking advantage of funding opportunities as they arise. Time frames used include 1-3 years, 3-5 years, and 5-10 years."* It is also implied when funding is available actions will commerce.

Opportunities for Improvement:

- As part of the table of mitigation actions, consider including a column that describes the specific vulnerability that is being addressed. For example, for the mitigation action of, "Assess and upgrade drainage infrastructure," the vulnerability might be described as "undersized drainage infrastructure causes localized flooding at Bay Berry Lane and Bridge Street." Including statements like this will place an emphasis on the specific problems the community is trying to fix and encourage implementation.
- The plan is required to list other plans into which mitigation is already incorporated.
- Ensure that the criteria used to prioritize mitigation actions considers the community's most significant vulnerabilities.
- Great discussion on how the plan will be integrated, which addresses element *C6.c.* However, it is not clearly stated whether the previous hazard mitigation plan was incorporated into other planning mechanisms, (element *C6.d).* An update of a HMP, **must** explain how the jurisdiction **incorporated** the mitigation plan, where appropriate, into other planning mechanisms as demonstration of progress in local mitigation efforts. In the next update, ensure this element is clearly addressed and incorporated.

Element D: Plan Update, Evaluation, and Implementation (*Plan Updates Only*)

Strengths:

- Detailed context is provided regarding the purpose and status of mitigation actions from the previous plan.
- The revised and resubmitted draft HMP incorporated changes addressing, actions from the previous approved HMP, listed as 'On hold' and 'In progress.' Well done.

Opportunities for Improvement:

- Include more information about how recently completed mitigation actions have reduced the Town's vulnerability, in order to highlight successes and build momentum for further implementation efforts.
- Consider mitigation strategy which should help to describe general land use changes in neighboring jurisdictions that may affect the community's risk.
- Clearly state what the changes in priorities are from the previous plan.

B. Resources for Implementing Your Approved Plan

Refer to the Massachusetts Integrated State Hazard Mitigation and Climate Action Plan, Resilient MA Climate Clearinghouse, and State's Climate Action Page to learn about hazards relevant to Massachusetts and the State's efforts and action plan.

Technical Assistance:

FEMA

- FEMA Climate Change: Provides resources that address climate change.
- FEMA Library: FEMA publications can be downloaded from the library website. These resources may be especially useful in public information and outreach programs. Topics include building and construction techniques, NFIP policies, and integrating historic preservation and cultural resource protection with mitigation.
- FEMA RiskMAP: Technical assistance is available through RiskMAP to assist communities in identifying, selecting, and implementing activities to support mitigation planning and risk reduction. Attend RiskMAP discovery meetings that may be scheduled in the state, especially any in neighboring communities with shared watersheds boundaries.

Other Federal

- EPA Resilience and Adaptation in New England (RAINE): A collection of vulnerability, resilience and adaptation reports, plans, and webpages at the state, regional, and community levels. Communities can use the RAINE database to learn from nearby communities about building resiliency and adapting to climate change.
- EPA Soak Up the Rain: Soak Up the Rain is a public outreach campaign focused on stormwater quality and flooding. The website contains helpful resources for public outreach and easy implementation projects for individuals and communities.
- NOAA C-CAP Land Cover Atlas: This interactive mapping tool allows communities to see their land uses, how they have changed over time, and what impact those changes may be having on resilience.
- NOAA Sea Grant: Sea Grant's mission is to provide integrated research, communication, education, extension and legal programs to coastal communities that lead to the responsible use of the nation's ocean, coastal and Great Lakes resources through informed personal, policy and management decisions. Examples of the resources available help communities plan, adapt, and recovery are the Community Resilience Map of Projects and the National Sea Grant Resilience Toolkit
- NOAA Sea Level Rise Viewer and Union for Concerned Scientists Inundation Mapper: These interactive mapping tools help coastal communities understand how their hazard risks may be changing. The "Preparing for Impacts" section of the inundation mapper addresses policy responses to protect communities.
- NOAA U.S. Climate Resilience Toolkit: This resource provides scientific tools, information, and expertise to help manage climate-related risks and improve resilience to extreme events. The "Steps to Resilience" tool may be especially helpful in mitigation planning and implementation.

State

- Massachusetts Emergency Management Agency: The Massachusetts State Hazard Mitigation Officer (SHMO) and State Mitigation Planner(s) can provide guidance regarding grants, technical assistance, available publications, and training opportunities.
- Massachusetts Departments of Conservation and Recreation and Environmental Protection can provide technical assistance and resources to communities seeking to implement their hazard mitigation plans.

- MA Mapping Portal: Interactive mapping tool with downloadable data

Not for Profit

- Kresge Foundation Online Library: Reports and documents on increasing urban resilience, among other topics.
- Naturally Resilient Communities: A collaboration of organizations put together this guide to nature-based solutions and case studies so that communities can learn which nature-based solutions can work for them.
- Rockefeller Foundation Resilient Cities: Helping cities, organizations, and communities better prepare for, respond to, and transform from disruption.

Funding Sources:

- Massachusetts Coastal Resilience Grant Program: Funding for coastal communities to address coastal flooding, erosion, and sea level rise.
- Massachusetts Municipal Vulnerability Preparedness program: Provides support for communities to plan for climate change and resilience and implement priority projects.
- Massachusetts Water Quality Grants: Clean water grants that can be used for river restoration or other kinds of hazard mitigation implementation projects.
- Grants.gov: Lists of grant opportunities from federal agencies (HUD, DOT/FHWA, EPA, etc.) to support rural development, sustainable communities and smart growth, climate change and adaptation, historic preservation, risk analyses, wildfire mitigation, conservation, Federal Highways pilot projects, etc.
- FEMA Hazard Mitigation Assistance (HMA): FEMA's Hazard Mitigation Assistance provides funding for projects under the Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM), and Flood Mitigation Assistance (FMA). States, federally recognized tribes, local governments, and some not for profit organizations are eligible applicants.
- GrantWatch: The website posts current foundation, local, state, and federal grants on one website, making it easy to consider a variety of sources for grants, guidance, and partnerships. Grants listed include The Partnership for Resilient Communities, the Institute for Sustainable Communities, the Rockefeller Foundation Resilience, The Nature Conservancy, The Kresge Climate-Resilient Initiative, the Threshold Foundation's Thriving Resilient Communities funding, the RAND Corporation, and ICLEI Local Governments for Sustainability.
- USDA Natural Resource Conservation Service (NRCS) and Rural Development Grants: NRCS provides conservation technical assistance, financial assistance, and conservation innovation grants. USDA Rural Development operates over fifty financial assistance programs for a variety of rural applications.

Appendix F

FEMA Approval

U.S. Department of Homeland Security
FEMA Region I
99 High Street, Sixth Floor
Boston, MA 02110-2132

FEMA

January 11, 2021

Samantha C. Phillips, Director
Massachusetts Emergency Management Agency
400 Worcester Road
Framingham, Massachusetts 01702-5399

Dear Director Phillips:

The U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA) Region I Mitigation Division has approved the Town of Tewksbury Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan 2020 effective **January 6, 2021** through **January 5, 2026** in accordance with the planning requirements of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended, the National Flood Insurance Act of 1968, as amended, and Title 44 Code of Federal Regulations (CFR) Part 201.

With this plan approval, the jurisdiction is eligible to apply to the Massachusetts Emergency Management Agency for mitigation grants administered by FEMA. Requests for funding will be evaluated according to the eligibility requirements identified for each of these programs. A specific mitigation activity or project identified in this community's plan may not meet the eligibility requirements for FEMA funding; even eligible mitigation activities or projects are not automatically approved.

The plan must be updated and resubmitted to the FEMA Region I Mitigation Division for approval every five years to remain eligible for FEMA mitigation grant funding.

Thank you for your continued commitment and dedication to risk reduction demonstrated by preparing and adopting a strategy for reducing future disaster losses. Should you have any questions, please contact Melissa Surette at (617) 956-7559 or Melissa.Surette@fema.dhs.gov.

Sincerely,

Captain W. Russ Webster, USCG (Ret.), CEM
Regional Administrator
FEMA Region I

WRW:ms

cc: Sarah White, State Hazard Mitigation Officer, MEMA
Jeffrey Zukowski, Hazard Mitigation Planner, MEMA
Beth Dubrawski, Hazard Mitigation Contract Specialist, MEMA