City of Greenfield Hazard Mitigation Plan

Adopted by the City of Greenfield on April 16, 2020
Approved by FEMA on April 28, 2020

Prepared by

Greenfield Multi-Hazard Mitigation Plan Update Committee

and

Franklin Regional Council of Governments
12 Olive Street, Suite 2
Greenfield, MA 01301
(413) 774-3167
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This project was funded by grants received from the Massachusetts Emergency Management Agency (MEMA) and the Federal Emergency Management Agency (FEMA).

U.S. Department of Homeland Security
FEMA Region I
99 High Street, Sixth Floor
Boston, MA 02110-2132

FEMA

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 City of Greenfield Hazard Mitigation Plan effective **April 28, 2020** through **April 27, 2025** 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

City of
GREENFIELD, MASSACHUSETTS

OFFICE OF THE MAYOR

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Massachusetts
DEPARTMENT OF ENERGY RESOURCES

CERTIFICATE OF ADOPTION
CITY OF GREENFIELD, MASSACHUSETTS

CITY COUNCIL

A RESOLUTION ADOPTING THE CITY OF GREENFIELD
2020 MULTI-HAZARD MITIGATION PLAN

WHEREAS, the City of Greenfield established a Committee to prepare the 2020 Hazard Mitigation plan; and

WHEREAS, the City of Greenfield Hazard Mitigation Plan contains several potential future projects to mitigate potential impacts from natural hazards in the City of Greenfield, and

WHEREAS, a duly-noticed public meeting was held by the City Council on April 15, 2020, and

WHEREAS, the City of Greenfield authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan, and

NOW, THEREFORE BE IT RESOLVED that the City of Greenfield CITY COUNCIL adopts the 2020 Hazard Mitigation Plan, in accordance with M.G.L. Ch. 40.

ADOPTED AND SIGNED this Date. April 16, 2020

Name(s) Ashley Stempel

Title(s) City Council President

Signature(s) Ashley Stempel

ATTEST A TRUE COPY, ATTEST: Kathryn J. Scott
Kathryn J. Scott
Town Clerk
Greenfield, MA 01301

Acknowledgements

The City of Greenfield extends special thanks to the Greenfield Multi-Hazard Mitigation Plan Update Committee as follows:

Eric Twarog, Director, Department of Planning & Development
Robert Strahan, Emergency Management Director, Fire Department
Mark Holley, Greenfield DPW, Water and Sewer Superintendent
Ian Hodgdon, Greenfield DPW
Carole Collins, Greenfield Energy Department
Rachel Lindsay, Conservation Commission
Ginny DeSorgher, Greenfield Planning, Commission on Disability Access
Nathaniel Hussey, Agricultural Commission

The City of Greenfield offers thanks to the Massachusetts Emergency Management Agency (MEMA) for developing the 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, which served as a resource for this plan and the technical assistance provided by the Franklin Regional Council of Governments' staff.

Franklin Regional Council of Governments

Peggy Sloan, Director of Planning & Development
Kimberly Noake MacPhee, Land Use & Natural Resources Program Manager
Alyssa Larose, Senior Land Use & Natural Resources Planner
Helena Farrell, Land Use & Natural Resources Planner
Allison Gage, Land Use & Natural Resources Planner
Xander Sylvain, Emergency Preparedness Program Assistant
Ryan Clary, Senior GIS Specialist

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1 PLANNING PROCESS

1.1 INTRODUCTION

The Federal Emergency Management Agency (FEMA) and the Massachusetts Emergency Management Agency (MEMA) define Hazard Mitigation as any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards such as flooding, storms, high winds, hurricanes, wildfires, earthquakes, etc. Mitigation efforts undertaken by communities will help to minimize damages to buildings and infrastructure, such as water supplies, sewers, and utility transmission lines, as well as natural, cultural and historic resources.

Planning efforts, like the one undertaken by the City of Greenfield, make mitigation a proactive process. Pre-disaster planning emphasizes actions that can be taken before a natural disaster occurs. Future property damage and loss of life can be reduced or prevented by a mitigation program that addresses the unique geography, demography, economy, and land use of a community within the context of each of the specific potential natural hazards that may threaten a community.

Preparing, and updating a hazard mitigation plan every five years, can save the community money and facilitate post-disaster funding. Costly repairs or replacement of buildings and infrastructure, as well as the high cost of providing emergency services and rescue/recovery operations, can be avoided or significantly lessened if a community implements the mitigation measures detailed in the plan.

FEMA requires that a community adopt a pre-disaster mitigation plan as a condition for mitigation funding. For example, the Hazard Mitigation Grant Program (HMGP), the Flood Mitigation Assistance Program (FMA), and the Pre-Disaster Mitigation Program are programs with this requirement.

1.2 HAZARD MITIGATION COMMITTEE

Updating the City of Greenfield's Hazard Mitigation plan involved a committee comprised of the following members:

Eric Twarog, Director, Department of Planning & Development
Robert Strahan, Emergency Management Director, Chief Greenfield Fire Department
Mark Holley, Water and Sewer Superintendent, Greenfield DPW

Ian Hodgdon, Engineering Technician, Greenfield DPW
Carole Collins, Energy & Sustainability Manager, Greenfield Energy & Sustainability Department
Rachel Lindsay, Member/Volunteer, Greenfield Conservation Commission
Ginny DeSorgher, Member/Volunteer, Greenfield Planning Department, Commission on Disability Access
Nathaniel Hussey, Member/Volunteer, Greenfield Agricultural Commission

The Hazard Mitigation Planning process update for the City included the following tasks:

- Reviewing and incorporating existing plans and other information including changes in development in the years since the City's previous Hazard Mitigation planning process
- Updating the natural hazards that may impact the community from the previous plan
- Conducting a Vulnerability/Risk Assessment to identify the infrastructure and populations at the highest risk for being damaged by the identified natural hazards, particularly flooding
- Identifying and assessing the policies, programs, and regulations the community is currently implementing to protect against future disaster damages
- Identifying deficiencies in the current Hazard Mitigation strategies and establishing goals for updating, revising or adopting new strategies
- Adopting and implementing the final updated Hazard Mitigation Plan

The key product of this Hazard Mitigation Plan Update process is the development of an Action Plan with a Prioritized Implementation Schedule.

Meetings
Meetings of the Multi-Hazard Mitigation Plan Update Committee were held on the dates listed below. Agendas for these meetings are included in Appendix A. All meetings followed Massachusetts Open Meeting Law and were open to the public.

April 16, 2019
Committee members discussed the hazard mitigation plan update project timeline, updated the hazard profiles and past events, and began a discussion of hazard identification and risk assessment.

June 4, 2019
Committee members continued a discussion of hazard identification and risk, and completed the vulnerability assessment. Members identified critical facilities in City, made edits to their

critical facilities and past hazard map, and reviewed existing hazard mitigation strategies.

July 16, 2019
The Committee reviewed the revised vulnerability assessment, and reviewed map of critical facilities and natural hazards. The Committee identified draft mitigation strategies to be included in this plan.

August 27, 2019
Committee members reviewed status of Action Items and Existing Mitigation Measures Tables from 2014 Multi-Hazard Mitigation Plan.

September 19, 2019
The members continued working to update the status of Action Items and Existing Mitigation Measures Tables from 2014 Multi-Hazard Mitigation Plan.

October 15, 2019
Committee members finalized updates to the 2020 Prioritized Action Plan (Table 4-3) that includes items carried forward from the 2014 plan. Members finalized the Completed or Obsolete 2014 Hazard Mitigation Actions (Table 4-4), and finalized Existing Mitigation capabilities (Table 4-1).

October 31, 2019
Committee members discussed 2020 Prioritized Actions and began initial review of the Flooding Hazard profile and problem statements.

November 14, 2019
Committee members finalized the Flooding hazard section and discussed remaining hazard problem statements and discussed the public meeting and comment period.

December 19, 2019
Committee members finalized hazard problem statements and scheduled the public meeting and comment period for the draft plan.

Agendas and sign-in sheets for each meeting can be found in Appendix A. While not all Committee members were able to attend each meeting, all members collaborated on the plan and were updated on progress by fellow members after meetings occurred.

1.3 PARTICIPATION BY STAKEHOLDERS

A variety of stakeholders were provided with an opportunity to be involved in the update of the Greenfield Hazard Mitigation Plan. The different categories of stakeholders that were involved, and the engagement activities that occurred, are described below.

Local and Regional Agencies Involved in Hazard Mitigation Activities
FRCOG regularly engages with the City of Greenfield as part of its regional planning efforts, which include the following:

- River Corridor Management Toolkit, which developed and piloted innovative practices for delineating river corridors using a scientifically defensible mapping protocol. The toolkit also outlines two management tools to accompany the mapping: a River Corridor Protection Overlay Zoning District Bylaw and a River Corridor Easement Restriction.

- Deerfield River Watershed-Based Plan, which outlines evidence-based recommendations to protect watershed health, restore impaired water bodies, and increase the watershed's resiliency to climate change.

- Developing the Sustainable Franklin County Plan, which advocates for sustainable land use throughout the region and consideration of the impact of flooding and other natural hazards on development.

- Developing and implementing the Franklin County Comprehensive Economic Development Strategy, which includes goals and strategies to build the region's economic resilience.

- Developing the Franklin County Regional Transportation Plan, which includes a focus on sustainability and climate resilience, and implementing the Franklin County Transportation Improvement Program to complete transportation improvements in our region.

- FRCOG Emergency Preparedness Program staff work with four regional committees: the Mohawk Area Public Health Coalition, the Franklin County Regional Emergency Planning Committee, the Franklin County Emergency Communications System Oversight Committee, and the Western Mass. Health and Medical Coordinating Coalition. Working with these committees and with local governments, the FRCOG works to provide integrated planning and technical assistance to improve and enhance our communities' ability to prepare for, respond to, and recover from natural and man-made disasters.

All of these FRCOG initiatives consider the impact of natural hazards on the region and strategies for reducing their impact to people and property through hazard mitigation activities. The facilitation of the update of the Greenfield Hazard Mitigation Plan by FRCOG ensured that information from these plans and initiatives were incorporated into the Hazard Mitigation Planning process.

Agencies that Have the Authority to Regulate Development

The Greenfield Planning Board is the primary City agency responsible for regulating development in City. Feedback from the Planning Board was ensured through the participation of the City's Director of Planning & Development and a member of the Planning Board on the Hazard Mitigation Committee. In addition, the Franklin Regional Council of Governments, as a regional planning authority, works with all agencies that regulate development in Greenfield, including the municipal entities listed above and state agencies, such as the Department of Conservation and Recreation and MassDOT. This regular involvement ensured that during the development of the Greenfield Hazard Mitigation Plan, the operational policies and any mitigation strategies or identified hazards from these entities were incorporated into the Hazard Mitigation Plan.

Participation by the Public, Businesses, and Neighboring Communities

The plan update and public meetings were posted on the City's website. A copy of the draft plan was available to the public at the Greenfield Department of Planning & Development, at the Greenfield Public Library, and on the City website at www.greenfield-ma.gov. A public forum was held on January 16, 2020 and provided an opportunity for the public and other stakeholders to provide input on the mitigation strategies and to prioritize action items. Stakeholder letters were sent to City boards, committees, and departments, and to all neighboring communities, inviting them to the public forum and to review the plan and provide comments. The public forum and subsequent comment period was advertised via a press release in the Greenfield Recorder and on the City website. (See Appendix A, Public Participation Process, for copies of all press releases and stakeholder letters mailed to solicit comments on the draft Plan). Comments were reviewed by the Committee and incorporated into the final plan as appropriate.

The Committee and FRCOG staff reviewed and incorporated the following existing plans, studies, reports and technical information, which are cited in footnotes throughout this plan:

- 2014 Sustainable Greenfield Master Plan

- 2017 Watershed-Based Plan for the Deerfield River Watershed
- 2019 A Framework for Resilience: Responding to Climate Change in the Deerfield River Watershed
- 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan
- 2019 River Corridor Toolkit and its Green River Corridor Mapping and Management Report.
- Resilient MA Climate Change Clearinghouse for the Commonwealth
- Additional data sources cited in footnotes throughout this Plan

2 Local Profile and Planning Context

2.1 COMMUNITY SETTING

The City of Greenfield is located in the middle of Franklin County and is bisected by two major transportation routes in the county; Interstate 91 which travels north/south and State Route 2 which travels east/west. Greenfield is the largest community in the county with a recorded population of 17,474 people or approximately 24.6% of the total population for Franklin County.[1] Greenfield's downtown area is densely developed and people from Franklin County and beyond travel to the City to take advantage of the employment opportunities, cultural and recreational offerings, retail shops, and restaurants.

In the late 17th Century, the City of Greenfield was known as the Green River District of the Town of Deerfield, an agricultural community populated by settlers looking for land to farm. However, due to the location of this new settlement at the confluence of three major rivers – the Connecticut, Deerfield and Green Rivers – the community rapidly evolved into a trading hub.

Greenfield was officially incorporated in 1753. In 1811, Greenfield was named the official County Seat in the newly established Franklin County. With its abundant water resources, Greenfield attracted industrial development that could be powered by water-generated electricity. Many mills and factories were built in Greenfield during the Industrial Revolution in clusters along the many large rivers running through the City. The growth of the rest of the city was characterized by a compact downtown area with two- and three-storied brick and wood buildings surrounded by densely developed residential neighborhoods. Interstate 91 and Route 2 are the major transportation corridors running through town. The outer perimeter of the city is characterized by larger residential lots and agricultural uses in the rural areas.

In May 2019, MassGIS released a new land cover/land use dataset. This statewide dataset contains a combination of land cover mapping from 2016 aerial and satellite imagery, LiDAR and other data sources. Land use mapping is derived from standardized assessor parcel information for Massachusetts. This land cover/land use dataset does not conform to the classification schemes or polygon delineation of previous land use data from MassGIS (1951-

[1] 2013-2017 American Community Survey (ACS) 5-Year Estimates

1999; 2005) so comparisons of land use change over time can't be made using this current data.[2]

However, the 2016 land cover/land use dataset shown in Table 2-1 does reveal interesting information about Greenfield that most residents probably already know. For example, most of the *land cover* is forests but the *land use* is primarily residential.

Table 2-1: Greenfield 2016 MassGIS Land Cover and Land Use Data				
Land Cover	**Acres**		**Land Use**	**Acres**
Bare Land	181.42		Agriculture	1074.89
Cultivated	577.62		Commercial	687.55
Deciduous Forest	3696.09		Forest	220.78
Developed Open Space	1691.84		Industrial	143.85
Evergreen Forest	4030.73		Mixed use, other	1144.11
Grassland	482.38		Mised use, primarily commercial	55.64
Impervious	1592.63		Mixed use, primarily residential	931.39
Palustrine Aquatic Bed	5.57		Open land	2348.57
Palustrine Emergent Wetland	95.18		Recreation	186.52
Palustrine Forested Wetland	713.87		Residential - multi-family	945.23
Palustrine Scrub/Shrub Wetland	32.06		Residential - other	125.98
Pasture/Hay	681.81		Residential - single family	3251.58
Scrub/Shrub	50.08		Right-of-way	1392.51
Water	188.72		Tax exempt	1183.05
			Unknown	81.90
			Water	246.45

The River Corridor area of the Green River, which runs through the City, was mapped using a scientific protocol that was developed as part of a MassDEP 319 project completed by the FRCOG, and is detailed in the 2019 *Green River Corridor Mapping and Management Report*. Table 2-2 shows the 2016 land cover and land use totals located within the mapped river corridor. The committee identified the need to use this data in conjunction with the mapped river corridor data to update the vulnerability assessment for flooding and other hazards that create flooding. Since the data just became available in 2019, there was an Action Item created in Table 4-3 to address this need.

[2] https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use

Table 2-2: Greenfield 2016 Land Cover and Land Use Data for the Delineated River Corridor				
Landcover	**Acres**		**Land Use**	**Acres**
Bare Land	13.23		Agriculture	96.06
Cultivated	15.78		Commercial	16.66
Deciduous Forest	315.47		Forest	11.97
Developed Open Space	86.91		Industrial	4.96
Evergreen Forest	118.10		Mixed use, other	163.81
Grassland	35.58		Mixed use, primarily commercial	41.49
Impervious	62.38		Mixed use, primarily residential	37.35
Palustrine Aquatic Bed	2.07		Open land	200.36
Palustrine Emergent Wetland	17.79		Recreation	32.59
Palustrine Forested Wetland	184.36		Residential - multi-family	37.76
Palustrine Scrub/Shrub Wetland	1.74		Residential - single family	85.70
Pasture/Hay	78.51		Right-of-way	62.55
Scrub/Shrub	8.33		Tax exempt	146.98
Water	42.99		Unknown	5.29
			Water	39.70

Population Characteristics

According to the 2010 U.S. Census, there are 17,456 residents in the City and the population decreased by 3.9% between the 2000 and 2010 Census. As of 2017, Greenfield's total population is estimated to be 17,474, a very small increase since the 2010 Census.[3]

Environmental Justice Populations

The State of Massachusetts defines an environmental justice (EJ) community if any of the following conditions are met:

- Block group whose annual median household income is equal to or less than 65 percent of the statewide median ($62,072 in 2010); or
- 25% or more of the residents identifying as minority; or
- 25% or more of households having no one over the age of 14 who speaks English only or very well - Limited English Proficiency (LEP)

According to these criteria, the City of Greenfield has three Census Block Groups that are EJ

[3] U.S. Census Bureau 2013-2017 American Community Survey 5-Year Estimates.

populations based on income. The population in these three EJ block groups is 3,438 or approximately 20% of the City's population.

Current Development Trends

Today, the City's densest development is concentrated in the southeastern part of town and bounded by Interstate 91 and Route 2. Development outside these major transportation corridors is characterized by larger residential lots and agricultural uses in the rural areas. Much of Greenfield's commercial development is in the downtown area. However there are strips of commercial development extending from downtown along main transportation arteries, including the Route 5/10 corridor, the commercially developed area around the Route 2A/2/I-91 interchange, and along Route 2A (High Street). Residential development, some of it relatively dense, surrounds the commercially zoned areas of Greenfield along these corridors. In the northern and western areas of town, the lower density residential lots and agricultural uses result in a more rural character.

The zoning over the years has led to denser residential and commercial development in the urban core and larger residential lots in the rural areas. The density in the downtown core area of Greenfield varies as some parcels are vacant and others are underutilized. This provides opportunities for infill development to support more concentrated and sustainable growth located near transit and services, and relieves the pressure to develop along the outskirts of town where expansion of the infrastructure may be needed.

While Greenfield's population is not expanding (according to 2010 U.S. Census) the City's open land continues to diminish as these areas slowly change use over time. Increasing suburbanization has occurred in these rural areas, with the development of residential frontage lots along rural roadways. This pattern of development is allowed through the Approval-Not-Required (ANR) process, which requires only a sign-off by the Planning Board certifying that the division of land meets the dimensional standards in the Zoning Ordinance. Farmland is gradually reduced through ANR development as farmers sell portions of their farms to people who want to build single-family homes, for example. This type of development has significant impacts on the rural character of the landscape. The changes are slow but constant and, over time, open areas become house-lined streets, one house deep, which is a major contributor to suburban sprawl.[4]

National Flood Insurance Program Status

Greenfield is a participating member of the National Flood Insurance Program. Currently there

[4] 2014 Greenfield Comprehensive Sustainable Master Plan

are 43 flood insurance policies in effect in Greenfield, for a total insurance value of $15,351,000. Forty-one (41) losses have been paid in Greenfield, for a total payout of $2,699,328. The City only has one repetitive loss (RL) property. In February 2020, after discussions with MEMA and FEMA Region 1 staff, the City filed a signed Information Sharing Access Agreement (ISAA) with FEMA Region 1 to request additional information on the RL property to further inform future mitigation strategies and actions that may be undertaken by the City. The ISAA must be executed by FEMA Headquarters and then the information will be released to the City. Once received, the City will update this Plan, as appropriate.

Greenfield's floodplain map is from 1980. In 2018, the Federal Emergency Management Agency (FEMA) initiated a 5-10 year process to update the floodplain maps for Franklin County towns, which will primarily involve using recent LiDAR topographic mapping and limited field surveys to create digital floodplain maps and correcting some anomalies in the 1980 maps (floodplains on the tops of hills) that may be revealed by the LiDAR mapping.

Roads and Highways

Greenfield has a total of approximately 124 miles of roadway within its borders, including the major transportation arteries Interstate 91 and Route 2. Interstate 91 connects Greenfield and Franklin County with Vermont and New Hampshire to the north and to the south, the larger communities of Northampton, Holyoke and Springfield, Massachusetts and the states of Connecticut and New York. Route 2 is the major east-west route in northern Massachusetts. This road links Greenfield and Franklin County with Boston and other metropolitan areas to the east and the Berkshires and New York State to the west.

Rail

Since the 1840's, railroads have moved people and freight through Greenfield. The Boston and Maine Railroad has two important lines that converge in town, one that runs from Boston to New York State and the other that runs from Springfield, Massachusetts in to Vermont.

In August 2019, the Valley Flyer train service began, which runs from Greenfield to New Haven, Connecticut. The service will run seven days a week and allow passengers to travel from Greenfield to New York City and back in a single day. The John W. Olver Regional Transit Center (completed in December of 2011) will serve as the hub of the Valley Flyer service and other public transportation options in and around Greenfield. The expanded train service is expected to improve travel options within the Connecticiut River Valley and provide an economic boost to Franklin County.

Public Transportation

The Franklin Regional Transit Authority (FRTA) has eight fixed bus routes that all originate at the John W. Olver Transit Center in the center of Greenfield. The FRTA also provides demand response services to elderly and other qualifying residents for transportation to medical appointments. These services are vital to many area residents, particularly low income and elderly residents.

Public Drinking Water Supply

Approximately 95% of the City's residents receive their drinking water from the municipal water supply system. The City currently relies on both groundwater pumped from wells and surface waters for its drinking water supply. The three Millbrook wells, which are located in the northeastern section of town near the Bernardston border, provide groundwater. Known as the Leary Wells site, the City has identified a potential well site located in an area between Leyden and Green River Roads. The City currently has a pending application with FEMA's Hazard Mitigation Grant Program to install a backup generator to provide standby power to the Corrosion Control Building and Millbrook Well #2. The project would provide a reliable backup power source for those facilities to ensure that there is no interruption in potable water service and treatment during hazard events that impact the City of Greenfield.

The Leyden Glen Reservoir in Leyden is a 45 million gallon impoundment that supplies approximately 26% of Greenfield's water supply. The Green River also provides drinking water for the City during periods of peak demand in the summer. Water is withdrawn from the river behind the dam off of Eunice Williams Drive.

Sewer Service

Located in the flood plain of the Green River, Greenfield's municipal sewer system services the City's central, urbanized area and approximately 75% of the residential dwelling units in town. One main interceptor and four trunk sewers feed the wastewater treatment plant located on the Green River at the very southern end of town. This facility has been expanded and upgraded to comply with a 1987 DEP Administrative Order. The plant discharges its effluent into the Deerfield River. This facility underwent a $9.2 million dollar upgrade – including flood proofing – in 2000. Then in 2011, Tropical Storm Irene's flood waters reached 142 ½ feet, inundating the the wastewater treatment plant, which was flood-proofed to elevation 140 feet. As a result of this event, another round of upgrades at the plant was completed in 2014 to raise the flood doors 144.3 ft.

Emergency Shelters

Greenfield Middle School is a designated shelter for the City in the event of a storm, hazard event, or emergency. It is also a regional shelter that alternates with Turner Falls High School to provide emergency shelter during events that impact the broader region. Greenfield Middle School has backup power and a limited inventory of emergency supplies. The City has warming and cooling centers to help residents cope with extreme temperatures. Locations include the Senior Center and Library during business hours. The Salvation Army Center for Worship & Service provides heating overnight. The City participates in the Franklin County Regional Emergency Planning Committee (REPC), which works on regional-based sheltering and evacuation planning.

Natural Resources

Greenfield is located in the Connecticut River Valley lowland physiographic region, which is characterized by gently rolling hills and large expanses of flat land bordered by steep, forested hills and ridges. Rocky Mountain, on the City's eastern border, rises to an elevation of 490 feet and separates the center of town from the Connecticut River. To the northeast, the topography is characterized by small, rounded hills with elevations that range from 500 to 550 feet and the steep slopes and flat, narrow valley of the Fall River. The remaining land in the City is open and relatively flat with the exception of the area adjacent to the Green and Deerfield Rivers in the southwestern part of town.

Though more densely populated than other towns in Franklin County, Greenfield has a wealth of natural resources. Four rivers flow through town, namely the Fall, Green, Deerfield, and Connecticut Rivers. The Connecticut River separates Greenfield from the Town of Montague to the east while the Fall River marks the northeastern limits of the City of Greenfield and forms the border with the neighboring Town of Gill. To the south, the Deerfield River separates Greenfield from the Town of Deerfield. The Green River, which flows in a southerly direction through the middle of town, provides both drinking water and recreational opportunities for residents.

The Connecticut River watershed consists of approximately 11,260 square miles and includes portions of Massachusetts, New Hampshire, Vermont and Connecticut. The Connecticut River flows for 410 miles, beginning at the Canadian border and emptying into the Long Island Sound. Approximately 80% of the watershed is forested, 12% is agricultural, 3% is developed and 5% is water. The Connecticut River Conservancy and the Deerfield River Watershed Assocation are located on Bank Row in Greenfield. These organizations advocate for the health and vitality of these important natural resources.

The Deerfield River watershed is a sub-watershed of the Connecticut River watershed and consists of approximately 665 square miles in the Southern Green Mountains in Vermont and the Northern Berkshires in Massachusetts. The Deerfield River flows approximately seventy miles from Stratton Mountain in Vermont to the Berkshire Mountains where it flows into the Connecticut River. Approximately 78% of the basin is forested and about 3% is urbanized.

The Green River is the second largest tributary to the Deerfield River; therefore its watershed is a sub-basin of the Deerfield River watershed. The Green River watershed is comprised of approximately 88.9 square miles; the river begins in Marlboro, Vermont and ends as it flows into the Deerfield River in the City of Greenfield. The Green River travels the entire length of Greenfield, starting in the northwest, continuing between Leyden and Plain Roads until it reaches Greenfield Meadows, an area known for its rich agricultural soils. Traveling south, the river enters into the Municipal Swimming Area where a dam allows a small storage capacity. The river then flows under Route 2A, and parallels Routes 5 and 10, Deerfield Street, before it converges with the Deerfield River.

Greenfield is fortunate to have forested open space/conservation lands located throughout the city. Public forest lands are used for walking, snowshoeing, and nature study along with being an important habitat for wildlife. While forest quality is generally good, it does require ongoing management efforts.

Cultural and Historic Resources

The importance of integrating cultural resource and historic property considerations into hazard mitigation planning is demonstrated by disasters that have occurred, such as the Northridge earthquake in California, Hurricane Katrina in New Orleans, or floods in the Midwest. The effects of a disaster can be extensive—from human casualty to property and crop damage to the disruption of governmental, social, and economic activity. Often not measured, however, are the possibly devastating impacts of disasters on historic properties and cultural resources. Historic structures, artwork, monuments, family heirlooms, and historic documents are often irreplaceable, and may be lost forever in a disaster if not considered in the mitigation planning process. The loss of these resources is all the more painful and ironic considering how often residents rely on their presence after a disaster, to reinforce connections with neighbors and the larger community, and to seek comfort in the aftermath of a disaster.[5]

Historic properties and cultural resources can be important economic assets, often increasing property values and attracting businesses and tourists to a community. While preservation of historic and cultural assets can require funding, it can also stimulate economic development and revitalization. Hazard mitigation planning can help forecast and plan for the protection of historic properties and cultural resources.

[5] Integrating Historic Property and Cultural Resource Considerations Into Hazard Mitigation Planning, State and Local Mitigation Planning How-To Guide, FEMA 386-6 / May 2005.

Cultural and historic resources help define the character of a community and reflect its past. These resources may be vulnerable to natural hazards due to their location in a potential hazard area, such as a river corridor, or because of old or unstable structures. The Massachusetts Cultural Resource Information System (MACRIS)[6] lists a total of 635 areas, buildings, burial grounds, objects, and structures of cultural and/or historic significance in Greenfield. Some of these include Greenfield's Main Street Historic District, Green River Cemetery, Greenfield Tap and Die Plant #1, Beacon Field, and Guiding Star Guild, to name just a few. Designation on this list does not provide any protective measures for the historic resources but designated sites may qualify for Federal and state funding if damaged during a natural or manmade hazard. The Greenfield Historical Commission noted that many of the buildings on the list are located on or in the floodplain or in areas subject to occasional flooding and that much of Greenfield has a high water table, subjected building to – at the minimum – flooding of cellars. Some of these resources may also be located in the mapped River Corridor area for the Green River.

2.2 IMPACTS OF CLIMATE CHANGE

Greater variation and extremes in temperature and weather due to climate change has already begun to impact Greenfield, and must be accounted for in planning for the mitigation of future hazard events. In 2017, the Commonwealth launched the Massachusetts Climate Change Clearinghouse (Resilient MA), an online gateway for policymakers, planners, and the public to identify and access climate data, maps, websites, tools, and documents on climate change adaptation and mitigation. The goal of Resilient MA is to support scientifically sound and cost-effective decision-making, and to enable users to plan and prepare for climate change impacts. Climate projections for Franklin County available through Resilient MA are summarized in this section. Additional information about the data and climate models is available on the resilient MA website: http://resilientma.org

Figure 2-1 identifies primary climate change impacts and how they interact with natural hazards assessed in the State Hazard Mitigation and Climate Adaptation Plan. Following is a summary of the three primary impacts of climate change on Franklin County and Greenfield: rising temperatures, changes in precipitation, and extreme weather. How these impacts affect individual hazards is discussed in more detail within Section 3: Hazard Identification and Risk Assessment.

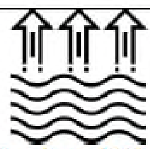
Rising Temperatures

[6] http://mhc-macris.net/Results.aspx

Average global temperatures have risen steadily in the last 50 years, and scientists warn that the trend will continue unless greenhouse gas emissions are significantly reduced. The nine warmest years on record all occurred in the last 20 years (2017, 2016, 2015, 2014, 2013, 2010, 2009, 2005, and 1998), according to the U.S. National Oceanographic and Atmospheric Administration (NOAA).

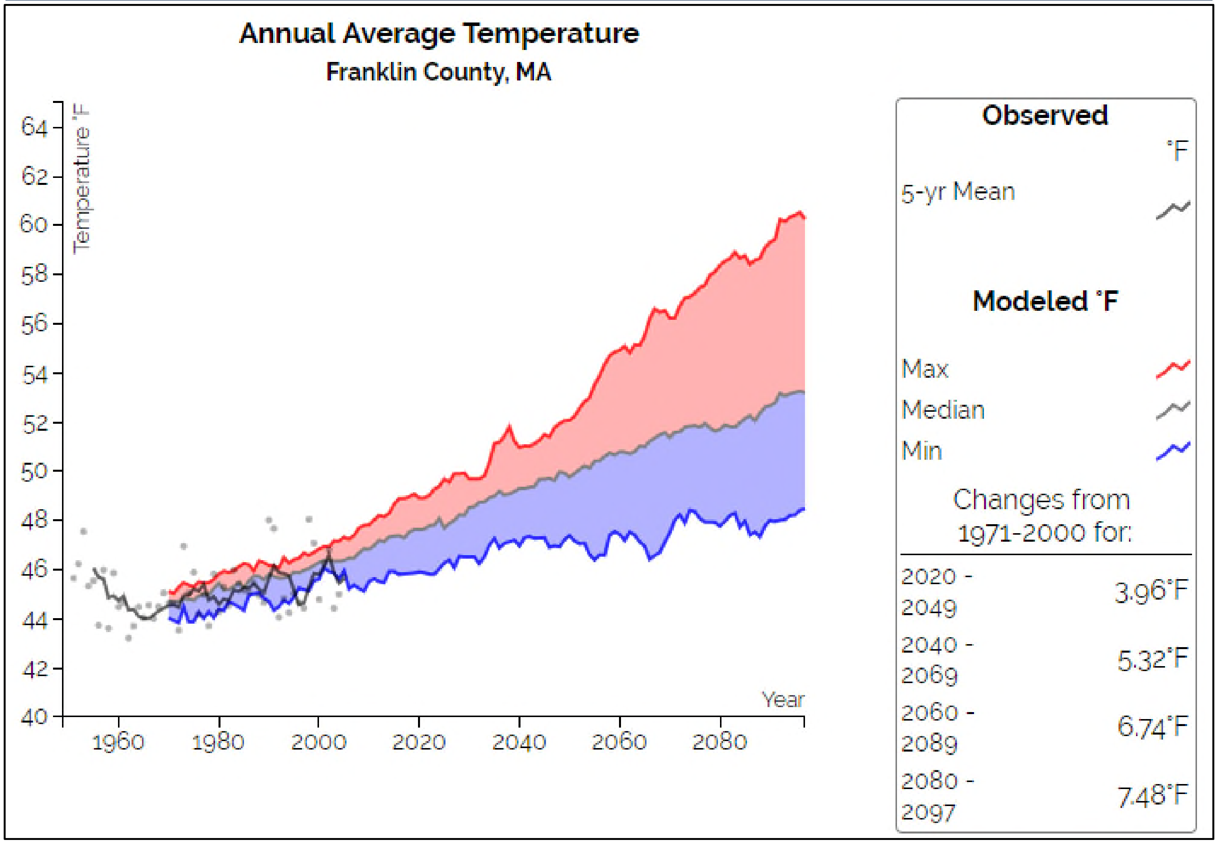
The average, maximum, and minimum temperatures in Franklin County are likely to increase significantly over the next century (resilient MA, 2018). Figure 2-2 displays the projected increase in annual temperature by mid-century and the end of this century, compared to the observed annual average temperature from 1971-2000. The average annual temperature is projected to increase from 45.3 degrees Fahrenheit (°F) to 50.6°F (5.32°F change) by mid-century, and to 52.8°F (7.48°F change) by the end of this century. The variation in the amount of change in temperature shown in Figure 2-2 is due to projections that assume different amounts of future GHG emissions, with greater change occurring under a higher emissions scenario, and less change occurring under a lower emissions scenario. For example, under a high emission scenario, the annual average temperature by the end of the century could be as high as 60°F.

Figure 2-1: Climate Change and Natural Hazard Interactions from the Massachusetts State Hazard Mitigation and Climate Adaptation Plan

Primary Climate Change Interaction	Natural Hazard	Other Climate Change Interactions	Representative Climate Change Impacts
 Changes in Precipitation	Inland Flooding	Extreme Weather	Flash flooding, urban flooding, drainage system impacts (natural and human-made), lack of groundwater recharge, impacts to drinking water supply, public health impacts from mold and worsened indoor air quality, vector-borne diseases from stagnant water, episodic drought, changes in snow-rain ratios, changes in extent and duration of snow cover, degradation of stream channels and wetland
	Drought	Rising Temperatures, Extreme Weather	
	Landslide	Rising Temperatures, Extreme Weather	
 Sea Level Rise	Coastal Flooding	Extreme Weather	Increase in tidal and coastal floods, storm surge, coastal erosion, marsh migration, inundation of coastal and marine ecosystems, loss and subsidence of wetlands
	Coastal Erosion	Changes in Precipitation, Extreme Precipitation	
	Tsunami	Rising Temperatures	
 Rising Temperatures	Average/Extreme Temperatures	N/A	Shifting in seasons (longer summer, early spring, including earlier timing of spring peak flow), increase in length of growing season, increase of invasive species, ecosystem stress, energy brownouts from higher energy demands, more intense heat waves, public health impacts from high heat exposure and poor outdoor air quality, drying of streams and wetlands, eutrophication of lakes and ponds
	Wildfires	Changes in Precipitation	
	Invasive Species	Changes in Precipitation, Extreme Weather	
 Extreme Weather	Hurricanes/Tropical Storms	Rising Temperatures, Changes in Precipitation	Increase in frequency and intensity of extreme weather events, resulting in greater damage to natural resources, property, and infrastructure, as well as increased potential for loss of life
	Severe Winter Storm / Nor'easter	Rising Temperatures, Changes in Precipitation	
	Tornadoes	Rising Temperatures, Changes in Precipitation	
	Other Severe Weather (Including Strong Wind and Extreme Precipitation)	Rising Temperatures, Changes in Precipitation	
Non-Climate-Influenced Hazards	Earthquake	Not Applicable	There is no established correlation between climate change and this hazard

Source: *Massachusetts State Hazard Mitigation and Climate Adaptation Plan*. September 2018

Figure 2-2: Projected Annual Average Temperature

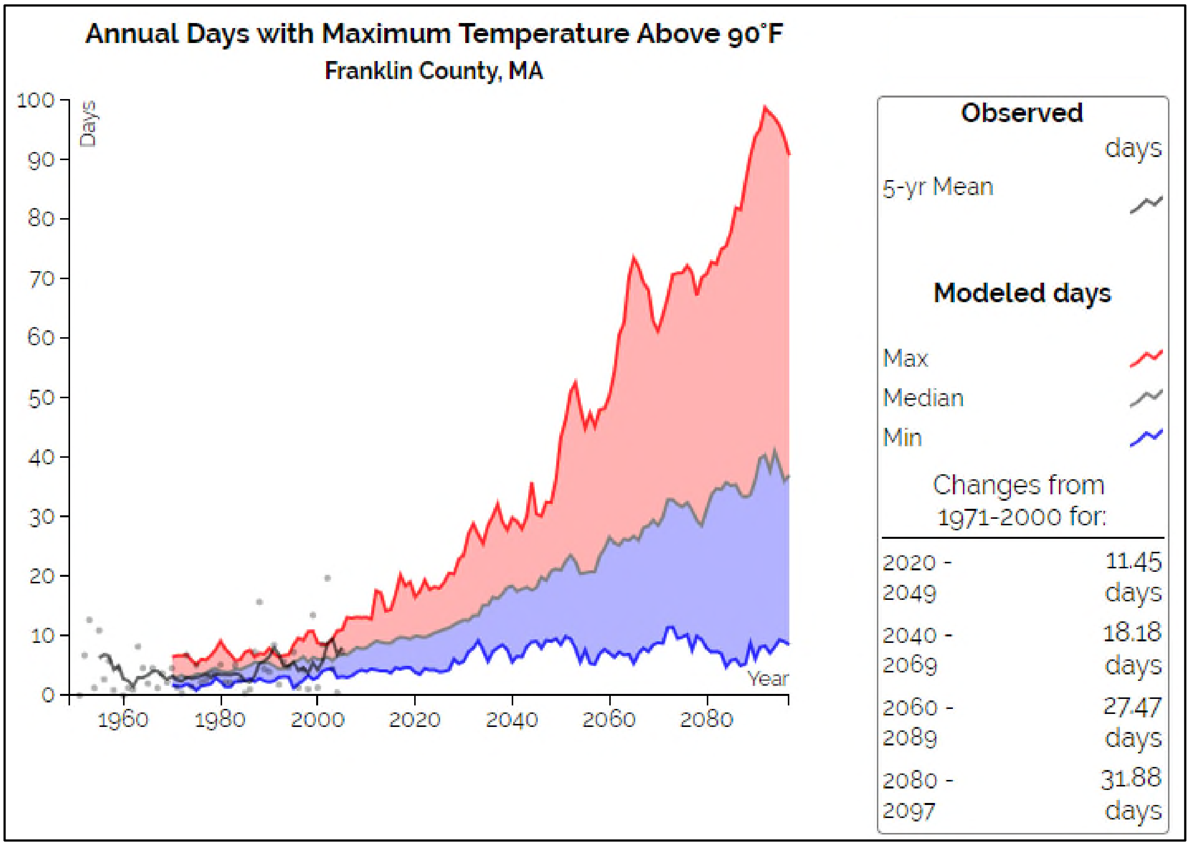


Source: Resilient MA, 2018

Winter temperatures are projected to increase at a greater rate than spring, summer, or fall. Currently Franklin County experiences an average of 169 days per year with a minimum temperature below freezing (32°F). The number of days per year with daily minimum temperatures below freezing is projected to decrease anywhere from 13 to 40 days by the 2050s, and by 15 to as many as 82 days (down to 87 days total) by the 2090s.

Although minimum temperatures are projected to increase at a greater rate than maximum temperatures in all seasons, significant increases in maximum temperatures are anticipated, particularly under a higher GHG emissions scenario. Figure 2-3 displays the projected increase in the number of days per year over 90°F. The number of days per year with daily maximum temperatures over 90°F is projected to increase by 18 days by the 2050s, and by 32 days by the end of the century (for a total of 36 days over 90°F), compared to the average observed range from 1971 to 2000 of 4 days per year. Under a high emissions scenario, however, there could be as many as 100 days with a maximum temperature above 90°F by the end of the century.

Figure 2-3: Projected Annual Days with a Maximum Temperature Above 90°F



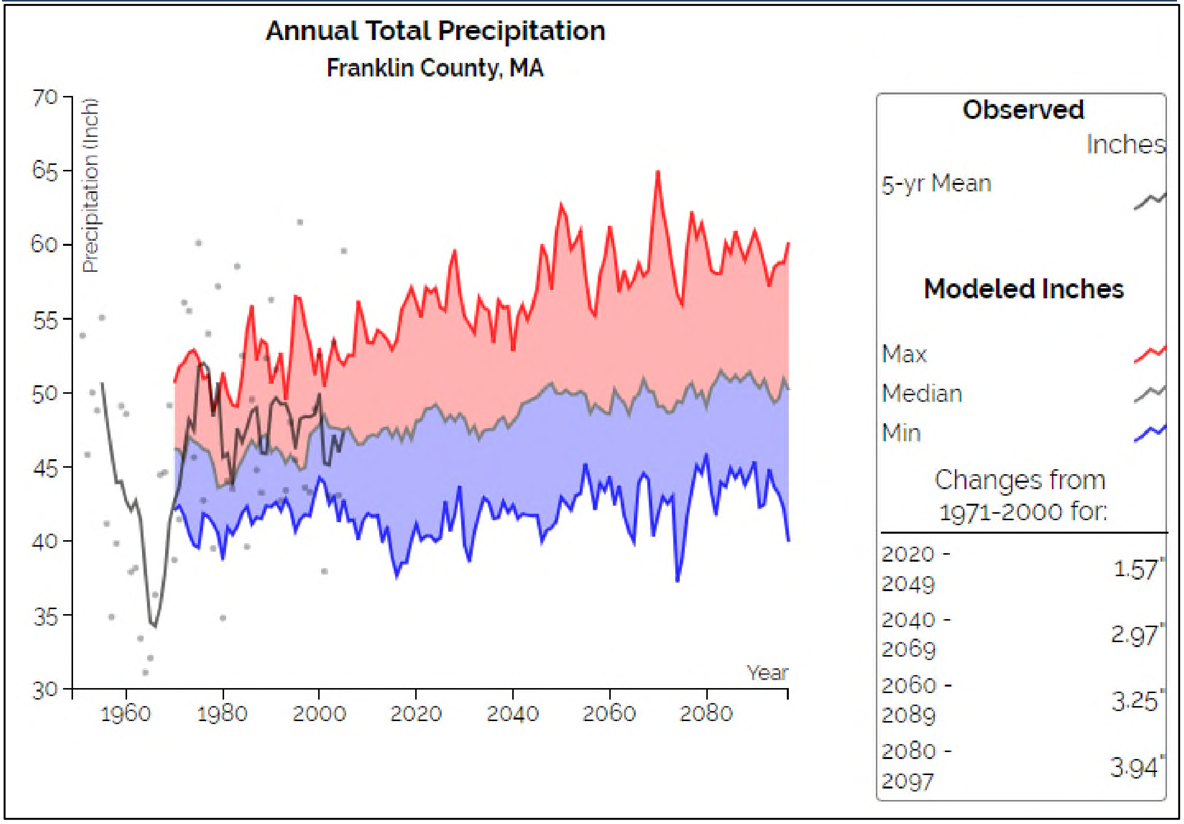
Source: Resilient MA, 2018

Changes in Precipitation

Changes in the amount, frequency, and timing of precipitation—including both rainfall and snowfall—are occurring across the globe as temperatures rise and other climate patterns shift in response. Precipitation is expected to increase over this century in Franklin County. Total annual precipitation is projected to increase by 3 inches by mid-century, and by 4 inches by the end of this century (see Figure 2-4). This will result in up to 52 inches of rain per year, compared to the 1971-2001 average annual precipitation rate of 48 inches per year in Franklin County. Precipitation during winter and spring is expected to increase, while precipitation during summer and fall is expected to decrease over this century. In general precipitation projections are more uncertain than temperature projections.[7]

[7] http://resilientma.org/datagrapher/?c=Temp/county/pcpn/ANN/25011/

Figure 2-4: Projected Annual Total Precipitation (Inches)



Source: Resilient MA, 2018

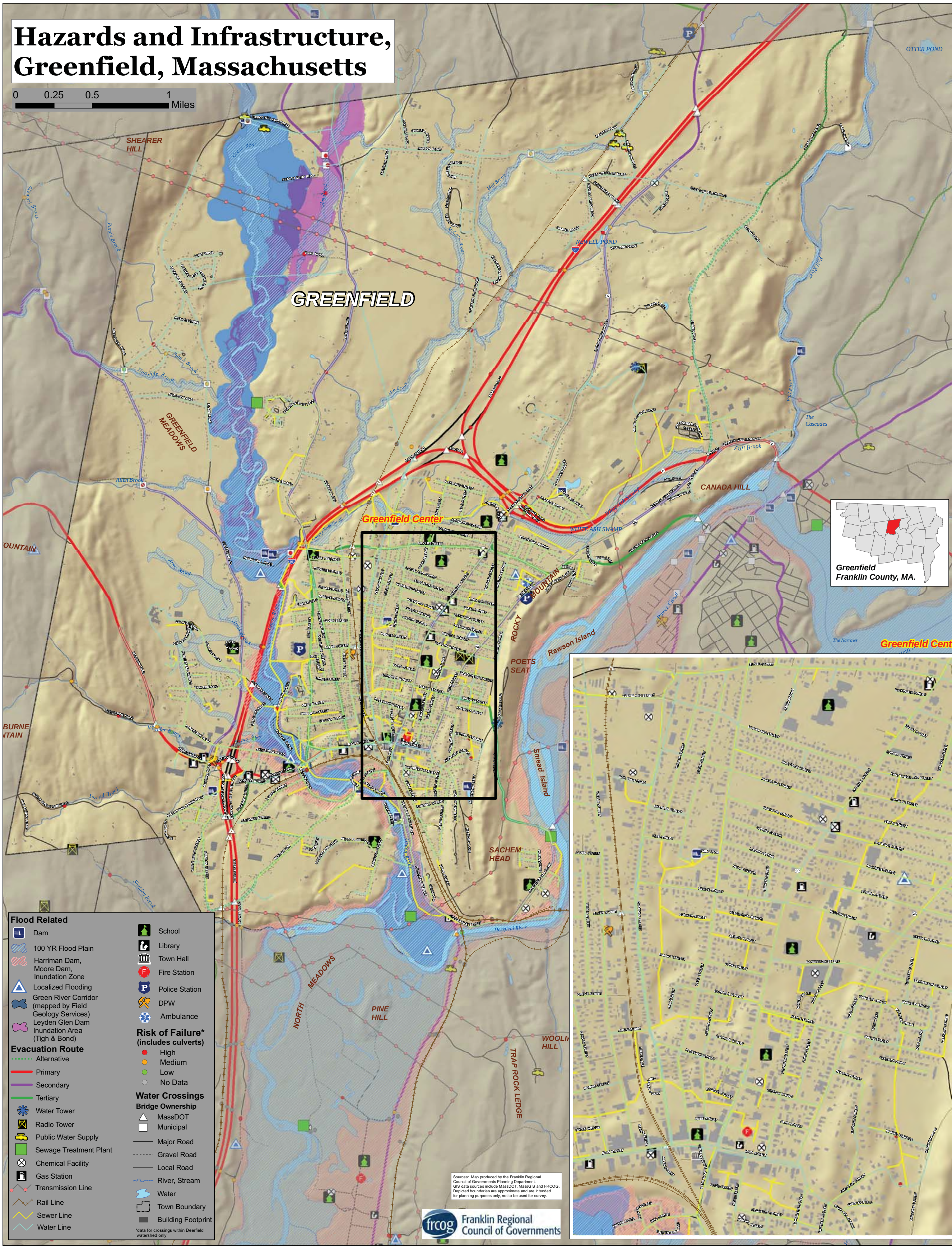
Extreme Weather

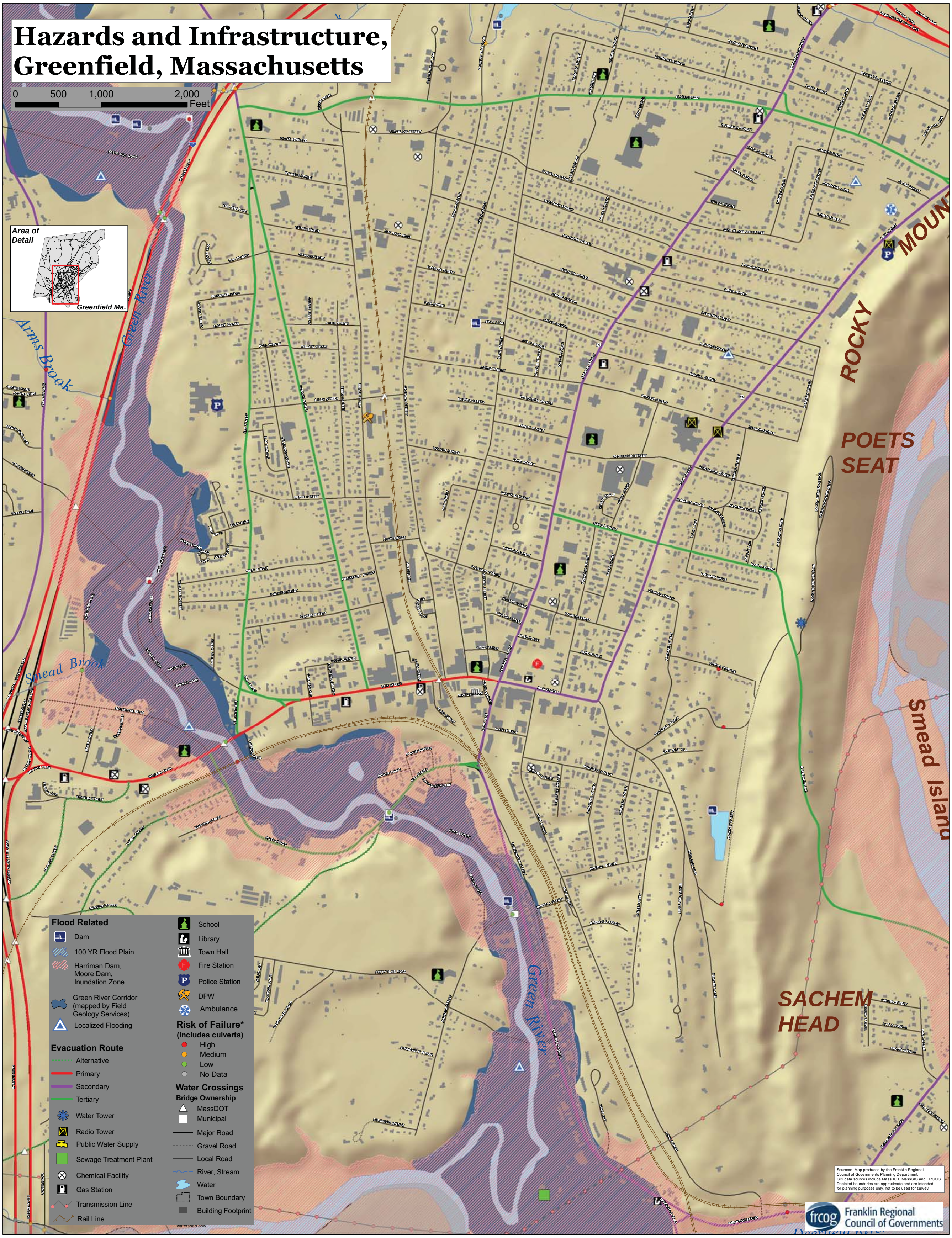
Climate change is expected to increase extreme weather events across the globe, as well as right here in Massachusetts. There is strong evidence that storms—from heavy downpours and blizzards to tropical cyclones and hurricanes—are becoming more intense and damaging, and can lead to devastating impacts for residents across the state. Climate change leads to extreme weather because of warmer air and ocean temperatures and changing air currents. Warmer air leads to more evaporation from large water bodies and holds more moisture, so when clouds release their precipitation, there is more of it. In addition, changes in atmospheric air currents like jet streams and ocean currents can cause changes in the intensity and duration of stormy weather.

In Franklin County, recent events such as Tropical Storm Irene in 2011, and the February tornado in Conway in 2018, are examples of extreme weather events that are projected to become more frequent occurrences due to climate change. While it is difficult to connect one storm to a changing climate, scientists point to the northeastern United States as one of the regions that is most vulnerable to an increase in extreme weather driven by climate change.

Environmental Resources
Greenfield, Massachusetts
0 0.25 0.5 1
Miles
GREENFIELD
Greenfield Center
SHEARER HILL
GREENFIELD MEADOWS
CANADA HILL
ROCKY MOUNTAIN
POETS SEAT
Rawson Island
SACHEM HEAD
ARTHURS SEAT
PINE HILL
TRAP ROCK LEDGE
Greenfield
Franklin County, MA.
Flood Related
Dam
100 YR Flood Plain
Harriman Dam, Moore Dam, Inundation Zone
Localized Flooding
Green River Corridor (mapped by Field Geology Services)
Transmission Line
Rail Line
Sewer Line
Water Line
Evacuation Route
Alternative
Primary
Secondary
Tertiary
Water Crossings
Bridge Ownership
MassDOT
Municipal
Major Road
Gravel Road
Local Road
River, Stream
Water
Town Boundary
Building Footprint
*data for crossings within Deerfield watershed only
Sources: Map produced by the Franklin Regional Council of Governments Planning Department. GIS data sources include MassDOT, MassGIS and FRCOG. Depicted boundaries are approximate and are intended for planning purposes only, not to be used for survey.
Franklin Regional Council of Governments

Hazards and Infrastructure, Greenfield, Massachusetts





Hazards and Infrastructure, Greenfield, Massachusetts
0 500 1,000 2,000 Feet
Area of Detail
Greenfield Ma.
Green River
Arms Brook
Smead Brook
ROCKY MOUNT
POETS SEAT
Smead Island
SACHEM HEAD
Flood Related
Dam
100 YR Flood Plain
Harriman Dam, Moore Dam, Inundation Zone
Green River Corridor (mapped by Field Geology Services)
Localized Flooding
Evacuation Route
Alternative
Primary
Secondary
Tertiary
Water Tower
Radio Tower
Public Water Supply
Sewage Treatment Plant
Chemical Facility
Gas Station
Transmission Line
Rail Line
School
Library
Town Hall
Fire Station
Police Station
DPW
Ambulance
Risk of Failure* (includes culverts)
High
Medium
Low
No Data
Water Crossings
Bridge Ownership
MassDOT
Municipal
Major Road
Gravel Road
Local Road
River, Stream
Water
Town Boundary
Building Footprint
Sources: Map produced by the Franklin Regional Council of Governments Planning Department. GIS data sources include MassDOT, MassGIS and FRCOG. Depicted boundaries are approximate and are intended for planning purposes only, not to be used for survey.
frcog Franklin Regional Council of Governments

3 HAZARD IDENTIFICATION AND RISK ASSESSMENT

The following section includes a summary of disasters that have affected or could affect Greenfield. Historical research, conversations with local officials and emergency management personnel, available hazard mapping and other weather-related databases were used to develop this list.

The Hazard Mitigation Committee referred to the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan* (September 2018) as a starting point for determining the relevant hazards in Greenfield. The table below illustrates a comparison between the relevant hazards in the State plan and in Greenfield's plan.

Massachusetts State Hazard Mitigation and Climate Adaptation Plan (2018)	City of Greenfield Relevance
 Inland Flooding	YES
 Drought	YES
 Landslide	YES
 Coastal Flooding	NO
 Coastal Erosion	NO

Massachusetts State Hazard Mitigation and Climate Adaptation Plan (2018)	City of Greenfield Relevance
 Tsunami	NO
 Average/Extreme Temperatures	YES
 Wildfires	YES
 Invasive Species	YES
 Hurricanes/Tropical Storms	YES
 Severe Winter Storm	YES
 Tornadoes	YES
 Other Severe Weather	YES
 Earthquake	YES

3.1 NATURAL HAZARD RISK ASSESSMENT METHODOLOGY

This chapter examines the hazards in the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan* which are identified as likely to affect Greenfield. The analysis is organized into the following sections: Hazard Description, Location, Extent, Previous Occurrences, Probability of Future Events, Impact, and Vulnerability. A description of each of these analysis categories is provided below.

Hazard Description

The natural hazards identified for Greenfield are: severe winter storms, flooding (including dam failure), hurricanes/tropical storms, severe thunderstorms/tornados/microbursts, earthquakes, landslides, average/extreme temperatures, drought, wildfire, and manmade hazards. Many of these hazards result in similar impacts to a community. For example, hurricanes, tornados and severe snowstorms may cause wind-related damage.

Location

Location refers to the geographic areas within the planning area that are affected by the hazard. Some hazards affect the entire planning area universally, while others apply to a specific portion, such as a floodplain or area that is susceptible to wild fires. Classifications are based on the area that would potentially be affected by the hazard, on the following scale:

Table 3-1: Location of Occurrence Rating Scale	
Classification	**Percentage of City Impacted**
Large	More than 50% of the City affected
Medium	10 to 50% of the City affected
Isolated	Less than 10% of the City affected

Extent

Extent describes the strength or magnitude of a hazard. Where appropriate, extent is described using an established scientific scale or measurement system. Other descriptions of extent include water depth, wind speed, and duration.

Previous Occurrences

Previous hazard events that have occurred are described. Depending on the nature of the hazard, events listed may have occurred on a local, state-wide, or regional level.

Probability of Future Events

The likelihood of a future event for each natural hazard was classified according to the following scale:

Table 3-2: Probability of Occurrence Rating Scale	
Classification	**Probability of Future Events**
Very High	Events that occur at least once each 1-2 years (50%-100% probability in the next year)
High	Events that occur from once in 2 years to once in 4 years (25%-50% probability in the next year)
Moderate	Events that occur from once in 5 years to once in 50 years (2%-25% probability in the next year)
Low	Events that occur from once in 50 years to once in 100 years (1-2% probability in the next year)
Very Low	Events that occur less frequently than once in 100 years (less than 1% probability in the next year)

Impact

Impact refers to the effect that a hazard may have on the people and property in the community, based on the assessment of extent described previously. Impacts are classified according to the following scale:

Table 3-3: Probability of Occurrence Rating Scale	
Classification	**Magnitude of Multiple Impacts**
Catastrophic	Multiple deaths and injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of facilities for 30 days or more.
Critical	Multiple injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of facilities for more than 1 week.
Limited	Minor injuries only. More than 10% of property in affected area damaged or destroyed. Complete shutdown of facilities for more than 1 day.
Minor	Very few injuries, if any. Only minor property damage and minimal disruption of quality of life. Temporary shutdown of facilities.

Vulnerability

Based on the above metrics, a hazard vulnerability rating was determined for each hazard. The hazard vulnerability ratings are based on a scale of 1 through 3 as follows:

1 – High risk
2 – Medium risk
3 – Low risk

The ranking is qualitative and is based, in part, on local knowledge of past experiences with each type of hazard, review of available data, and the work of the Committee. The size and impacts of a natural hazard can be unpredictable. However, many of the mitigation strategies currently in place and many of those proposed for implementation can be applied to the expected natural hazards, regardless of their unpredictability.

Table 3-4: Greenfield Hazard Identification and Risk Analysis

Type of Hazard	Location of Occurrence	Probability of Future Events	Impact	Overall Hazard Vulnerability Rating
Severe Winter Storms	Large	Very High	Limited	1
Flooding	Large	Very High	Catastrophic	1
Tornadoes	Medium	Very High	Catastrophic	2
Dam Failure *Leyden Glen and FERC High Hazard Dams*	Medium	Very Low	Catastrophic	3
Dam Failure *All other dams*	Medium	Moderate	Critical	3
Hurricanes / Tropical Storms	Large	Very High	Catastrophic	1
Severe Thunderstorms / Wind / Microbursts	Large	Very High	Critical	1
Extreme Temperatures	Large	Very High	Limited-Critical	2
Earthquakes	Large	Moderate	Minor-Catastrophic	3
Landslides	Isolated	High	Limited	2

Table 3-4: Greenfield Hazard Identification and Risk Analysis				
Type of Hazard	**Location of Occurrence**	**Probability of Future Events**	**Impact**	**Overall Hazard Vulnerability Rating**
Drought	Large	Very High	Limited	2
Wildfires	Medium	Moderate	Limited	2
Invasive Species	Large	Very High	Critical	1

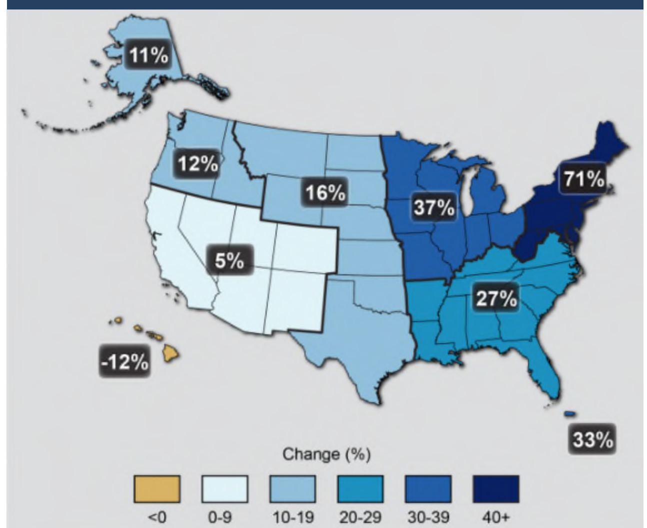
The Committee developed problem statements and/or a list of key issues for each hazard to summarize the vulnerability of Greenfield's structures, systems, populations and other community assets identified as vulnerable to damage and loss from a hazard event. These problem statements were used to identify the City's greatest vulnerabilities that will be addressed in the mitigation strategy (Section 4).

3.3 FLOODING

Potential Effects of Climate Change

In Massachusetts, annual precipitation amounts have increased at a rate of over 1 inch per decade since the late 1800s, and are projected to continue to increase largely due to more intense precipitation events. The Northeast has experienced a greater increase in extreme precipitation events than the rest of the U.S. in the past several decades (Figure 3-1). Although overall precipitation is expected to increase as the climate warms, it will occur more in heavy, short intervals, with a greater potential for dry, drought conditions in between.

Figure 3-1: Observed Change in Very Heavy Precipitation



The northeast has seen a greater increase in heavy precipitation events than the rest of the country. *Source: updated from Karl et al. 2009, Global Climate Change Impacts in the United States.*

Observed average annual precipitation in Massachusetts between 1971-2000 was 47 inches. Total annual precipitation in Massachusetts is expected to increase between 2% to 13% by 2050, or by roughly 1 to 6 inches.

The Climate Data Grapher tool on the resilientMA website contains down-scaled climate data for Franklin County (discussed in Section 2) and for the Deerfield River Watershed, which includes the City of Greenfield. Observed annual precipitation over the last several decades (1970-2005) is approximately 47 inches. By 2050, the model predicts that 45 inches per year would be the minimum annual precipitation; the mean (middle value of the model predictions) could be 52 inches/year with a maximum of 66 inches per year. In general, precipitation projections are more uncertain than temperature projections. [8]

An increase in stronger storms leads to more flooding and erosion. A shift to winter rains instead of snow will lead to more runoff, flooding, and greater storm damage along with less spring groundwater recharge. More frequent heavy precipitation events also lead to an increased risk for people who live along rivers or in their floodplains. Furthermore, residents who live outside the current flood zone could find themselves within it as the century

[8] http://resilientma.org/datagrapher/?c=Temp/basin/pcpn/ANN/Deerfield/

progresses. Figure 3-2 shows potential effects of climate change on flooding from the Massachusetts State Hazard Mitigation and Climate Adaptation Plan.

Figure 3-2: Effects of Climate Change on Flooding

Potential Effects of Climate Change		
	CHANGES IN PRECIPITATION ➔ MORE INTENSE AND FREQUENT DOWNPOURS	More intense downpours often lead to inland flooding as soils become saturated and stop absorbing more water, river flows rise, and urban stormwater systems become overwhelmed. Flooding may occur as a result of heavy rainfall, snowmelt or coastal flooding associated with high wind and storm surge.
	EXTREME WEATHER ➔ MORE FREQUENT SEVERE STORMS	Climate change is expected to result in an increased frequency of severe storm events. This would directly increase the frequency of flooding events, and could increase the chance that subsequent precipitation will cause flooding if water stages are still elevated.
	CHANGES IN PRECIPITATION ➔ EPISODIC DROUGHTS	Vegetated ground cover has been shown to significantly reduce runoff. If drought causes vegetation to die off, this flood-mitigating capacity is diminished.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

Nationally, inland flooding causes more damage annually than any other severe weather event (U.S. Climate Resilience Toolkit, 2017). Between 2007 and 2014, the average annual cost of flood damages in Massachusetts was more than $9.1 million (NOAA, 2014). Flooding is the result of moderate precipitation over several days, intense precipitation over a short period, or melting snowpack (U.S. Climate Resilience Toolkit, 2017). Developed, impervious areas can contribute to and exacerbate flooding by concentrating and channeling stormwater runoff into nearby waterbodies. Increases in precipitation and extreme storm events from climate change are already resulting in increased flooding. Common types of flooding are described in the following subsections.

Riverine Flooding

Riverine flooding often occurs after heavy rain. Areas with high slopes and minimal soil cover (such as found in many areas of Greenfield and Franklin County) are particularly susceptible to flash flooding caused by rapid runoff that occurs in heavy precipitation events and in combination with spring snowmelt, which can contribute to riverine flooding. Frozen ground conditions can also contribute to low rainfall infiltration and high runoff events that may result in riverine flooding. Some of the worst riverine flooding in Massachusetts' history occurred as a result of strong nor'easters and tropical storms in which snowmelt was not a factor. Tropical storms can produce very high rainfall rates and volumes of rain that can generate high runoff when soil infiltration rates are exceeded. Inland flooding in Massachusetts is forecast and classified by the National Weather Service's (NWS) Northeast River Forecast Center as minor, moderate, or severe based upon the types of impacts that occur. Minor flooding is considered a "nuisance only" degree of flooding that causes impacts such as road closures and flooding of recreational areas and farmland. Moderate flooding can involve land with structures becoming inundated. Major flooding is a widespread, life-threatening event. River forecasts are made at many locations in the state where there are United States Geological Survey (USGS) river gauges that have established flood elevations and levels corresponding to each of the degrees of flooding.

- Overbank flooding occurs when water in rivers and streams flows into the surrounding floodplain or into "any area of land susceptible to being inundated by floodwaters from any source," according to FEMA.

- Flash floods are characterized by "rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level," according to FEMA.

Fluvial Erosion

Fluvial erosion is the process by which the river undercuts a bank, usually on the outside bend of a meander, causing sloughing and collapse of the riverbank. Fluvial erosion can also include scouring and down-cutting of the stream bottom, which can be a problem around bridge piers and abutments. In hillier terrain where streams may lack a floodplain, such as in many areas of Franklin County and some areas in the northern portion of Greenfield, fluvial erosion may cause more property damage than inundation. Furthermore, fluvial erosion can often occur in areas within or outside of the 100- or 500-year floodplain.

While erosion is a natural process, the rate of erosion is affected by human alterations of river channels or land as well as a changing climate. Sometimes buildings and roads are located too close to river banks and areas of active river processes, placing them at risk to erosive forces while at the same time increasing the rate of erosion within the river corridor due to loss of flood storage in the floodplain. The most severe fluvial erosion events in recent years have resulted from heavy rain, such as Tropical Storm Irene in 2011, which washed out roads and destroyed several buildings across Franklin County.

<u>River Corridor Mapping and Management</u>

Fluvial erosion hazard (FEH) zones are mapped areas along rivers and streams that are susceptible to bank erosion caused by flash flooding. Any area within a mapped FEH zone is considered susceptible to bank erosion during a single severe flood or after many years of slow channel migration. As noted above, while the areas of the FEH zones often overlap with areas mapped within the 100-year floodplain on Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) or Flood Hazard Boundary Maps (FHBMs), the FIRMs or FHBMs only show areas that are likely to be inundated by floodwaters that overtop the riverbanks during a severe flood. However, much flood-related property damage and injuries is the result of bank erosion that can undermine roads, bridges, building foundations and other infrastructure. Consequently, FEH zones are sometimes outside of the 100-year floodplain shown on FIRMs or FHBMs. FEH zones can be mapped using fluvial geomorphic assessment data as well as historic data on past flood events. Both the FIRMs and FEH maps should be used in concert to understand and avoid both inundation and erosion hazards, respectively.[9] As mentioned in

With funding from the MassDEP's 319 program, the Franklin Regional Council of Governments (FRCOG) created a River Corridor Management Toolkit (2019). The Toolkit includes a river corridor mapping protocol and river corridor management tools (Model River Corridor Protection Overlay Zoning District and a Model River Corridor Easement Restriction) that communities can use to avoid and mitigate flooding and fluvial erosion hazards. The Toolkit also includes examples of landscape-scale management strategies and projects that restore and protect river corridors and floodplains, promote climate resilient land uses, and reduce the harm to land, water, habitat, people, and infrastructure caused by increasingly severe and frequent flood events. The River Corridor area and fluvial erosion hazard (FEH) zones for the Green River, which runs through the City, were mapped using the scientific protocol that was developed as part of Toolkit project. These areas are described in the 2019 *Green River Corridor Mapping and Management Report* and shown on the maps in Section 2 of this plan.

Urban Drainage Flooding

Urban drainage flooding entails floods caused by increased water runoff due to urban development and drainage systems that are not capable of conveying high flows. Drainage systems are designed to remove surface water from developed areas as quickly as possible to prevent localized flooding on streets and other urban areas. They make use of a closed conveyance system that channels water away from an urban area to surrounding streams, bypassing natural processes of water infiltration into the ground, groundwater storage, and evapotranspiration (plant water uptake and respiration). Since drainage systems reduce the amount of time the surface water takes to reach surrounding streams, flooding can occur more quickly and reach greater depths than if there were no urban development at all. In urban areas, basement, roadway, and infrastructure flooding can result in significant damage due to poor or insufficient stormwater drainage.

[9] *Ammonoosuc River Fluvial Erosion Hazard Map for Littleton, NH*. Field Geology Services, 2010.

Ground Failures

Flooding and flood-related erosion can result from various types of ground failures, which include mud floods and mudflows, and to a much lesser degree, subsidence, liquefaction, and fluvial erosion (discussed above).

Mud floods are floods that carry large amounts of sediment, which can at times exceed 50 percent of the mass of the flood, and often occur in drainage channels and adjacent to mountainous areas. Mudflows are a specific type of landslide that contains large amounts of water and can carry debris as large as boulders. Both mudflows and mud floods result from rain falling on exposed terrain, such as terrain impacted by wildfires or logging. Mud floods and mudflows can lead to large sediment deposits in drainage channels. In addition to causing damage, these events can exacerbate subsequent flooding by filling in rivers and streams.

Subsidence is the process where the ground surface is lowered from natural processes, such as consolidation of subsurface materials and movements in the Earth's crust, or from manmade activities, such as mining, inadequate fill after construction activity, and oil or water extraction. When ground subsides, it can lead to flooding by exposing low-lying areas to groundwater, tides, storm surges, and areas with a high likelihood of overbank flooding.

Liquefaction, or when water-laden sediment behaves like a liquid during an earthquake, can result in floods of saturated soil, debris, and water if it occurs on slopes. Floods from liquefaction are especially common near very steep slopes.

Ice Jam

An ice jam is an accumulation of ice that acts as a natural dam and restricts the flow of a body of water. There are two types of ice jams: a freeze-up jam and a breakup jam. A freeze-up jam usually occurs in early winter to midwinter during extremely cold weather when super-cooled water and ice formations extend to nearly the entire depth of the river channel. This type of jam can act as a dam and begin to back up the flowing water behind it. The second type, a breakup jam, forms as a result of the breakup of the ice cover at ice-out, causing large pieces of ice to move downstream, potentially piling up at culverts, around bridge abutments, and at curves in river channels. Breakup ice jams occur when warm temperatures and heavy rains cause rapid snowmelt. The melting snow, combined with the heavy rain, causes frozen rivers to swell. The rising water breaks the ice layers into large chunks, which float downstream and often pile up near narrow passages and obstructions (bridges and dams). Ice jams may build up to a thickness great enough to raise the water level and cause flooding upstream of the obstruction. The Ice Jam Database, maintained by the Ice Engineering Group at the U.S. Army

Corps of Engineers (USACE) Cold Regions Research and Engineering Laboratory currently consists of more than 18,000 records from across the U.S.

Dam Failure

A dam is an artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water. There are two primary types of dam failure: catastrophic failure, characterized by the sudden, rapid, and uncontrolled release of impounded water, or design failure, which occurs as a result of minor overflow events. Dam overtopping is caused by floods that exceed the capacity of the dam, and it can occur as a result of inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors. Overtopping accounts for 34 percent of all dam failures in the U.S.

There are a number of ways in which climate change could alter the flow behavior of a river, causing conditions to deviate from what the dam was designed to handle. For example, more extreme precipitation events could increase the frequency of intentional discharges. Many other climate impacts—including shifts in seasonal and geographic rainfall patterns—could also cause the flow behavior of rivers to deviate from previous hydrographs. When flows are greater than expected, spillway overflow events (often referred to as “design failures”) can occur. These overflows result in increased discharges downstream and increased flooding potential. Therefore, although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures. Impacts and Greenfield’s vulnerability to dam failure is discussed in more detail in the Dam Failure section of this plan.

Additional Causes of Flooding

Additional causes of flooding include beaver dams or levee failure. Beaver dams obstruct the flow of water and cause water levels to rise. Significant downstream flooding can occur if beaver dams break.

Floodplains

Floodplains by nature are vulnerable to inland flooding. Floodplains are the low, flat, and periodically flooded lands adjacent to rivers, lakes, and oceans. These areas are subject to geomorphic (land-shaping) and hydrologic (water flow) processes. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon. These areas form a complex physical and biological system that not only supports a variety of natural resources, but also provides natural flood storage and erosion control. When a river is separated from its floodplain by levees and other flood control facilities, these natural benefits are lost, altered, or significantly reduced. When floodwaters recede after a flood event, they leave behind layers of rock and mud. These gradually build up to create a new floor of the floodplain. Floodplains generally contain unconsolidated sediments known as alluvium (accumulations of sand, gravel, loam, silt, and/or clay), often extending below the bed of the stream. These sediments provide a natural filtering system, with water percolating back into the ground and replenishing groundwater supplies.

Flooding is a natural and important part of wetland ecosystems that form along rivers and streams. Floodplains can support ecosystems that are rich in plant and animal species. Wetting the floodplain soil releases an immediate surge of nutrients from the rapid decomposition of organic matter that has accumulated over time. When this occurs, microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly fish or birds) often utilize the increased food supply. The production of nutrients peaks and falls away quickly, but the surge of new growth that results endures for some time. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees (trees that grow in floodplains) tend to be very tolerant of root disturbance and grow quickly in comparison to non-riparian trees.

One river prone to flooding in Greenfield, the Green River, rushes past low-lying structures on River Street.

Location

A floodplain is the relatively flat, lowland area adjacent to a river, lake or stream. Floodplains serve an important function, acting like large “sponges” to absorb and slowly release floodwaters back to surface waters and groundwater. Over time, sediments that are deposited in floodplains develop into fertile, productive farmland like that found in the Connecticut River valley. In the past, floodplain areas were also often seen as prime locations for development. Industries were located on the banks of rivers for access to hydropower. Residential and commercial development occurred in floodplains because of their scenic qualities and proximity to the water, and because these areas were easier to develop than the hilly, rocky terrain characteristic of many communities in Franklin County. Although periodic flooding of a floodplain area is a natural occurrence, past and current development and alteration of these areas can result in flooding that is a costly and frequent hazard.

Development in and around floodplains are susceptible to inundation by floodwater. Riverside Drive and the nearby Greenfield Garden Apartments, which includes 6 apartment buildings, are specific areas of the City that are vulnerable to flooding by the Green River. This neighborhood has been evacuated in the past. If residents do not evacuate in time, they may become stranded when floodwater isolate the neighborhood. Ice jams on a nearby bridge have also caused water to backup near homes.

The total land area of Greenfield is 14,016 acres. The 100-year floodplain covers approximately 1,449 total acres, or approximately 10.34% percent of the City. Of those acres, 63 acres are developed land, including an estimated 43 acres of developed residential land and 38 dwellings. Greenfield municipal water supply wells, under districts jurisdiction, are located close to rivers and need flood proofing. The wastewater treatment plant in Greenfield is located in the 100-year floodplain of the Green and Deerfield Rivers. Dams and flood control measures upstream on the Green, Deerfield, and Connecticut Rivers may provide some level of protection to the City during high flow events. The following areas have been designated by FEMA as floodways in Greenfield:

- Arms Brook;
- Cherry Rum Brook;
- Punch Brook;
- Glen Brook;
- Allen Brook;
- Mill Brook;
- McCard Brook;
- Smead Brook;
- Wheeler Brook;
- Fall River;
- Deerfield River;
- Green River; and
- Connecticut River.

Many of the feeder brooks in Greenfield, including Arms Brook, Cherry Rum Brook, Punch Brook, and Wheeler Brook, have the potential to cause localized and / or chronic flooding. The Green and Deerfield Rivers have the potential to cause extensive flooding in the City during major events.

In addition to the 100-year floodplain, areas upstream from major rivers play an important role in flood mitigation. Upland areas and the small tributary streams that drain them are particularly vulnerable to impacts from development, which can increase the amount of flooding downstream. These areas are critical for absorbing, infiltrating, and slowing the flow of stormwater. When these areas are left in a natural vegetated state (forested or forested floodplain), they act as "green infrastructure," providing flood storage and mitigation through natural processes.

Fragmentation and development in upland areas, including roads which commonly were built along stream and river corridors, can alter this natural process and result in increased amounts of stormwater runoff into streams. For example, the channels of many of these streams were altered centuries ago as a result of widespread deforestation for agriculture and lumber. The many small mills that used to dot the landscape built dams on the streams to generate power. Many of these streams are still unstable and flashy during storm events, generating high volumes of runoff and transporting sediment to the lower, flatter reaches of the watershed.

In addition, stressors to forests such as drought, extreme weather, and invasive species, can result in the loss of forest cover in upland areas. In particular, cold water streams shaded by dense hemlock stands are particularly vulnerable due to the hemlock woolly adelgid that is causing widespread mortality of these trees in the region.

Areas of chronic localized flooding include:

- Green River Cemetery, where water has periodically pooled and caused mudslides
- Factory Hollow Road along the Fall River has chronic flooding
- Nash's Mill Road floods annually
- The Meadow's Golf Course floods annually
- Hastings, Haywood and Riddell Streets neighborhoods flood during heavy rain events when the Maple Brook Culvert backs up
- Green River Park floods every few years
- Green and Cooke Streets and Greenway Lane – this neighborhood floods during heavy rain events
- Thayer Road, Keegan Lane, Sunset Avenue, Homestead Avenue

- Riddell Street
- Maddison Circle
- Spring Terrace
- Arch Street and Chapman Street neighborhood

City Roads, Bridges and Culverts

Major and ongoing flooding of Greenfield's waterways, especially in the past decade, have caused severe erosion on riverbanks and cut new channels through adjacent land. As a result of these significant, dynamic changes in the rivers, some of the City's roads, bridges, and culverts have become more prone to flooding and fluvial erosion hazards. This is known to be impacting roads near Wheeler and Hinsdale Brooks. Also vulnerable are Colrain and Shelburne Roads, Leyden Road, Nash's Mill Road, and on Scout Road where erosion on the Fall River exposed a buried water main.

The City also faces challenges related to streams and smaller tributaries located in and around densely developed areas and involve numerous road crossings and extensive lengths of aging infrastructure containing a buried stream. Culvert upsizing, replacements and maintenance are needed on Spring Terrace, Crescent Street, Medicine Circle, Green and Cooke Streets and Greenway Lane, and Hastings, Haywood and Riddell Streets neighborhoods where the Maple Brook Culvert backs up during heavy rain events, including near #34 Riddell Street, which is the proposed location of the new Fire Station. Greenfield also has several bridges that are vulnerable to flooding, and under-performing bridges are a focus of replacement and upgrade efforts. Bridges on Silver Street, Colrain Street, and Meridian Street have been identified by the committee as requiring assessment and possible improvements or replacement.

According to the Greenfield City Engineer, the Maple Brook culvert is the primary drainage system for 1,000 acres of the City's most urbanized area. The culvert was built in the 1930's. The culvert is in poor condition and studies have shown that it is significantly undersized for the current flows. The City of Greenfield has a Capital Project on the books to replace or rehabilitate the culvert. Estimated project cost as of the 2005 Plan was $1,750,000. City Planning Director Eric Twarog indicated the cost of the project would need to be re-estimated given how long it has been since it was initially estimated.

Beaver Dams

Beavers are actively creating impoundments and altering the landscape in multiple areas in the City. Beaver activity is known to be occurring and having an impact on Montague City Road, Cherry Rum Plaza, and along the south side of Route 2A. Regular monitoring of beaver dams and their condition is important for mitigating the risk of downstream flooding should a beaver dam fail.

Dam Failure

There are six major upstream dams on the Deerfield River with the potential to impact Greenfield by dam failure. These include Somerset, Harriman, Sherman, Fife Brook, and Bear Swamp Dams. On the Connecticut River, a dam failure at Moore Dam near Littleton, New Hampshire is a concern due to the potential to trigger cascading dam failures at the eight additional dams along the Connecticut still upstream of the City. There are four dams on the Green River within City limits, plus additional impoundments upstream where a dam failure would have a major impacts, including at Leyden Glen Reservoir Dam. Leyden Glen Reservoir is one of the City's water supply sources, which could be impacted by an upstream dam failure in addition to the retention area and dam structures there, which are needed to help buffer and control flood flows further downstream. A number of small, privately owned dams are located within the City and could impact surrounding neighborhoods if their impoundments failed.

Based on these locations, flooding has a "Large" area of occurrence, with more than 50% percent of the City affected.

Extent

The principal factors affecting the strength and magnitude of flood damage are flood depth and velocity. The deeper and faster that flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high-velocity flows and transporting debris and sediment.

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge (discussed further in the following subsection) has a 1 percent chance of being equaled or exceeded in any given year. The "annual flood" is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river. Floods can be classified as one of two types: flash floods and general floods.

Flash Floods

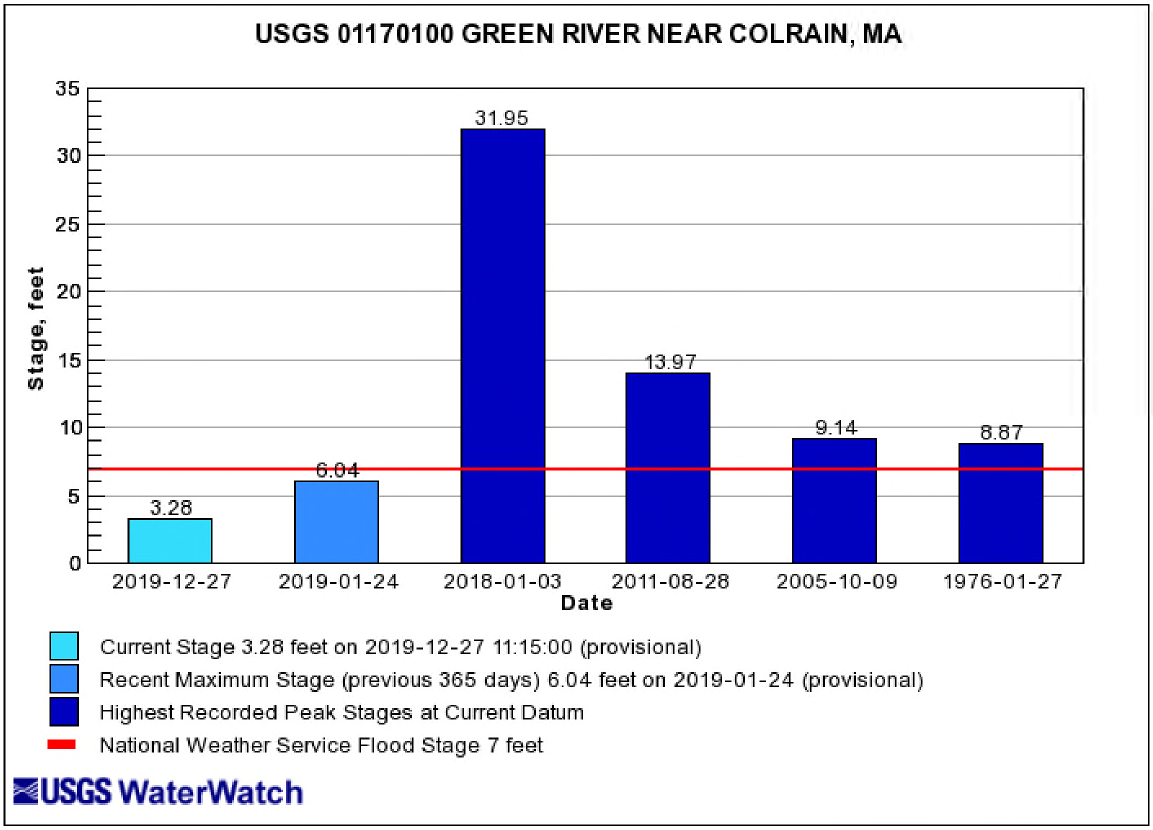
Flash floods are the product of heavy, localized precipitation in a short time period over a given location. Flash flooding events typically occur within minutes or hours after a period of heavy precipitation, after a dam or levee failure, or from a sudden release of water from an ice jam. Most often, flash flooding is the result of a slow-moving thunderstorm or the heavy rains from a hurricane. In rural areas, flash flooding often occurs when small streams spill over their banks. However, in urbanized areas, flash flooding is often the result of clogged storm drains (leaves and other debris) and the higher amount of impervious surface area (roadways, parking lots, roof tops).

General Floods

General flooding may last for several days or weeks and are caused by precipitation over a longer time period in a particular river basin. Excessive precipitation within a watershed of a stream or river can result in flooding particularly when development in the floodplain has obstructed the natural flow of the water and/or decreased the natural ability of the groundcover to absorb and retain surface water runoff (e.g., the loss of wetlands and the higher amounts of impervious surface area in urban areas).

Flood flows in Massachusetts are measured at numerous USGS stream gauges. The gauges operate routinely, but particular care is taken to measure flows during flood events to calibrate the stage-discharge relationships at each location and to document actual flood conditions. In the aftermath of a flood event, the USGS will typically determine the recurrence interval of the event using data from a gauge's period of historical record. Figure 3-3 shows the four highest recorded peak flooding events on the Green River in Colrain (upstream of Greenfield), as well as the highest flow event in the last 365 days.

Figure 3-3: Highest Recorded Flood Events on the Green River Near Colrain, MA



Source: USGS WaterWatch https://waterwatch.usgs.gov/?id=wwchart_ftc&site_no=01170000.

The 100-Year Flood

The 100-year flood is the flood that has a 1 percent chance of being equaled or exceeded each year. In the 1960's, the 100-year flood became the standard used by most federal and state agencies. For example, it is used by the National Flood Insurance Program (NFIP) to guide floodplain management and determine the need for flood insurance.

The extent of flooding associated with a 1 percent annual probability of occurrence (the base flood or 100-year flood) is called the 100-year floodplain, which is used as the regulatory boundary by many agencies. Also referred to as the Special Flood Hazard Area (SFHA), this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. This extent generally includes both the stream channel and the flood fringe, which is the stream-adjacent area that will be inundated during a 100-year (or 1 percent annual chance) flood event but does not effectively convey floodwaters.

The 500-Year Flood

The term "500-year flood" is the flood that has a 0.2 percent chance of being equaled or exceeded each year. Flood insurance purchases are not required by the Federal Government in the 500-year floodplain, but could be required by individual lenders.

Secondary Hazards

The most problematic secondary hazards for flooding are fluvial erosion, river bank erosion, and landslides affecting infrastructure and other assets (e.g., agricultural fields) built within historic floodplains. Without the space required along river corridors for natural physical adjustment, such changes in rivers after flood events can be more harmful than the actual flooding. For instance, fluvial erosion attributed to Hurricane Irene caused an excess of $23 million in damages along Route 2. The impacts from these secondary hazards are especially prevalent in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage, but scour the banks, edging buildings, and structures closer to the river channel or cause them to fall in. Landslides can occur following flood events when high flows oversaturate soils on steep slopes, causing them to fail.

These secondary hazards also affect infrastructure. Roadways and bridges are impacted when floods undermine or wash out supporting structures. Railroad tracks may be impacted, potentially causing a train derailment, which could result in the release of hazardous materials into the environment and nearby waterways. Dams may fail or be damaged, compounding the flood hazard for downstream communities. Failure of wastewater treatment plants from overflow or overtopping of hazardous material tanks and the dislodging of hazardous waste containers can occur during floods as well, releasing untreated wastewater or hazardous materials directly into storm sewers, rivers, or the ocean. Flooding can also impact public water supplies and the power grid.

Previous Occurrences

The average annual precipitation for Greenfield and surrounding areas in western Massachusetts is 48 inches. Between 1996 and 2017, 17 flash floods have been reported in Franklin County (Table 3-5), resulting in $3,245,000 in property damages.

Table 3-5: Previous Occurrences of Flash Floods in Franklin County

Year	# of Flash Flood Events	Annual Property Damage	Annual Crop Damage
1996	4	$1,800,000	No Data

Table 3-5: Previous Occurrences of Flash Floods in Franklin County			
Year	**# of Flash Flood Events**	**Annual Property Damage**	**Annual Crop Damage**
1998	1	$75,000	No Data
2000	1	No Data	No Data
2003	1	$10,000	No Data
2004	1	$10,000	No Data
2005	3	$1,235,000	No Data
2013	3	$65,000	No Data
2014	2	$50,000	No Data
2017	1	No Data	No Data
Total	**17**	**$3,245,000**	No Data

Source: National Oceanic and Atmospheric Administration (NOAA) Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

From 1996 to 2018, 44 flood events were reported in Franklin County, resulting in total property damages worth $25,582,000 (Table 3-6). The bulk of these damages ($22,275,000) were from Tropical Storm Irene in August, 2011, which resulted in 274 landslides across the watershed and reportedly caused the most severe erosion of any flood in Massachusetts historical records. The USDA Natural Resources Conservation Service (NRCS) recorded approximately 800 acres of crop loss or damages across the watershed, and almost 2/3 of that (500 acres) was in the neighboring Town of Deerfield.

Table 3-6: Previous Occurrences of Floods in Franklin County			
Year	**# of Flood Events**	**Annual Property Damage**	**Annual Crop Damage**
1996	7	No Data	No Data
1998	3	No Data	No Data
2001	1	No Data	No Data
2004	1	No Data	No Data
2005	2	$2,600,000	No Data
2007	1	$250,000	No Data
2008	3	$38,000	No Data
2010	1	$150,000	No Data
2011	8	$22,375,000	No Data
2012	2	No Data	No Data

Table 3-6: Previous Occurrences of Floods in Franklin County			
Year	**# of Flood Events**	**Annual Property Damage**	**Annual Crop Damage**
2015	10	$31,000	No Data
2017	1	$1,000	No Data
2018	4	$137,000	No Data
Total	**44**	**$25,582,000**	No Data

Source: National Oceanic and Atmospheric Administration (NOAA) Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

Table 3-7 is an inventory of ten flood events with significant impacts to Greenfield including recorded property damages totaling $194,000. This information was taken from NOAA data that is current through 2018. Event details describe extensive street flooding and impassability, road washouts, flooded basements, damaged and destroyed culverts, local stream and riverine flooding, sewage backup, and man-hole covers lifted by stormwater.

Table 3-7: Previous Occurrences of Floods in Franklin County			
Date	**Type**	**Recorded Property Damages**	**Excerpts from storm details for Greenfield only**
8/3/2018	Flood	$30,000	Heavy rain in Greenfield caused flooding of several basements on Franklin Street. Scout Road was flooded and impassable with some basement flooding. Sanderson Road near Kennemetal and the Medical Center was completely flooded. Adams Road was flooded and impassable. Green Street in Greenfield had significant basement flooding.
6/30/2017	Flood	$1,000	Several streets reported flooded and impassable. These included Chapman, Grinnell, and Greenfield Streets.
8/11/2015	Flood	$0	Several streets experienced minor street flooding (less than 6 inches of water flowing over the road), including Deerfield Street south of Meridan Street and Federal Street.
7/7/2015	Flood	$25,000	The intersections of Davis Road and Emily Lane and Chapman and Arch Streets were flooded and impassable. Basements flooded on Norwood Street, Elm Terrace. Part of the road was washed out at the intersection of Phillips and Elm Street. Columbus Avenue was flooded and impassable.
3/7/2011	Flood/	$100,000	A water soaked ridge near the Green River Cemetery

Table 3-7: Previous Occurrences of Floods in Franklin County			
Date	**Type**	**Recorded Property Damages**	**Excerpts from storm details for Greenfield only**
	Landslide		gave way resulting in a mudslide 13 inches deep that slid over Meridan and Water Streets. Three cars were buried and the mud was up to the foundations of three houses. 17 people were evacuated to a shelter run by the American Red Cross and then to family members houses (2 families) and a hotel (1 family) for the night while crews cleaned the mud from their houses. A portion of Meridian Street remained closed through the night of the 7th.
2/13/2008	Flood	$5,000	Several streets in Greenfield were flooded. Widespread two to four inch rainfall amounts resulted in small stream and poor drainage flooding as well as some minor river flooding.
8/7/2008	Flood	$8,000	Several thunderstorms with heavy rain resulted in flooding. Ten basements were flooded and there was some sewage backup on Silver Street.
7/18/2005	Flash Flood	$5,000	Slow moving thunderstorms produced a significant flash flood event in north central Franklin County. Two maximum rainfall totals of 9 inches were reported from Bernardston, where the worst flooding had been reported. The police station experienced flooding; and approximately 50 homes experienced property damage or basement flooding. In addition, 30 roads were either washed out, closed or partially closed, or had culverts blown out due to flooding.
9/18/2004	Flash Flood	$10,000	Heavy rainfall associated with the remains of Ivan caused flash flooding in Franklin and Hampshire Counties. Storm totals of 3 to 5 inches were observed and caused rapid rises on the Deerfield and Green Rivers. The two rivers caused minor flooding of their respective low lying areas. In Hampshire County, a trained spotter reported several small brooks out of their banks which flooded low lying areas and caused minor damage. No injuries were reported.
9/28/2003	Flash Flood	$10,000	Torrential rainfall caused flash flooding in the Connecticut River Valley. In Greenfield, the Green River rose out of its banks and forced the closure of Nash's Mill Road between Colrain and Leyden Roads.

Source: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~ShowEvent~260419

Tropical Storm Irene
The most recent – and dramatic – example of flooding occurred in the area during and after Tropical Storm Irene which struck Franklin County on August 28, 2011. Irene hit Western Massachusetts in a far more dramatic way than was anticipated. Given that the vast majority of damage caused by Irene was as a result of flooding, Irene is included in this section of the Plan.

According to the National Weather Service, up to 9.92 inches of rain fell during the storm, though amounts varied significantly across Franklin County. Rivers, streams and brooks throughout the County and parts of neighboring Hampshire County and Southern Vermont surpassed flood levels and rising water gathered debris that clogged culverts. Roads and bridges were washed out and homes and businesses were flooded and, in some cases, washed away altogether. About 140 Air National Guard members established a base of operations at nearby Mohawk Trail Regional High School in Buckland and were deployed to repair the damage left in Irene's wake. Damage to roads in Hawley was so severe that for several days travel was only possible by helicopter.


Tropical Storm Irene caused flooding to the Green River Swimming and Recreation Area

Two regional shelters were opened including one at Greenfield Middle School. At least 42,000 homes and businesses were initially without power. Governor Duval Patrick declared a state of emergency and President Barack Obama issued disaster decrees for Berkshire and Franklin Counties and FEMA opened disaster recovery assistance offices in two Franklin County towns. Despite the magnitude of damage, no deaths were reported in Massachusetts as a result of Irene.

During flooding from Irene, the Green River's rushing waters cut new channels in the nearby land

Teams assessed damage to the Berkshire Gas Facility (left) and the Meridian Dam on the Green River (right)

Damage to Greenfield was widespread. Descriptions of the damages were included in the 2014 Multi-Hazard Mitigation Plan and are summarized below:

- Flooding caused damage to farm fields such as lost topsoil and contamination through washed up silt and trash.
- Flooding from the Green River impacted the Colrain Street Bridge area.

- Damage due to flooding was caused to the Green River Dam.
- River banks eroded downstream of the Green River Pump Station.
- A concrete retaining wall by the Leyden Glen dam on the Green River above the Eunice Williams Covered Bridge was knocked over and swept aside by flood waters. Water released from behind the wall washed away about 100 feet of the Leyden Road side of Eunice Williams Drive.
- Eunice Williams Covered Bridge knocked from one of its footings and was damaged.
- The drinking water supply pipe drawing from the Green River near Eunice Williams Covered Bridge was broken and the City had to use alternate sources for drinking water. Drinking water quality was not impacted.
- Sewage treatment plant at the south end of Deerfield Street near the confluence of the Green and Deerfield rivers was flooded. Motors powering the pumps in the outlying pump station were destroyed.
- Flooding to Colrain Street included businesses such as Davenport Trucking, whose offices were mud and silt filled. Computers and electrical wiring had to be replaced.
- Riverside and Greenfield Gardens apartments were evacuated and some were deemed uninhabitable due to flooding.
- Interstate 91 southbound was closed in Greenfield, forcing traffic detours through Greenfield via Routes 5 and 10. Greenfield Police Department staffed detours for weeks with the highway reopening on September 5, 2011.
- Damage occurred on Glen Road, an access route to the City's water supply reservoir.
- The Green River Swimming and Recreation Area on Nash's Mill Road was closed for the season due to flooding and damages to buildings and structures including broken fences and a washed out bike path. The picnic areas, pavilions and lawns were covered with silt and sludge.
- Deerfield Street was flooded with sludge with houses and businesses impacted.
- A water impoundment wall on the Green River Dam was breached and was repaired.
- The electric substation and gas district sites on Deerfield Street were sand-bagged to hold back flood waters while operators controlled values by hand in order to avoid total power outages to the City.

Floodwaters from Irene were forceful enough to move large vehicles and structures.

After Irene, floodwaters begin to recede near the Wastewater Treatment Plant and golf course.

The Wastewater Treatment Plant was flood-proofed to elevation 140 feet but Irene’s flooding topped elevation 142 ½ feet.

On September 22, 2011, the Franklin Regional Council of Governments released early estimates on storm damages and costs due to the impacts from Irene. FEMA's preliminary damage assessment totals $27,713,911 for municipal public damage. This number does not include state infrastructure damage.

Greenfield's Department of Public Works provided cost estimates for public works and infrastructure-related projects that resulted from Tropical Storm Irene damage for inclusion in the 2014 Multi-Hazard Mitigation Plan. As shown in Table 3-8, estimated costs as of October 4, 2011 were $12,495,354, with costs potentially rising even higher. In addition to DPW costs, other costs to the City include those for Police and Fire as well as others such as the Board of Health and the building inspector. Action Items in the 2014 Multi-Hazard Mitigation Plan stemming from Irene include fortifying the Wastewater Treatment Plant to withstand a 144 foot elevation flooding (completed in 2014) and repairing Glen Road and its drainage, essential for access to the City's water supply reservoir (updated and carried over to the 2020 Hazard Mitigation Plan). An additional construction project resulting from TS Irene damage included rebuilding the retention area at the Green River Pumping Station Impoundment, which was completed in 2013-2014. Here, the retaining wall, which had been washed away by Irene's floodwaters, was extended and keyed concrete into ledge, and soil on either side of the berm was solidified with a concrete block mat giving it a stronger base. The Committee noted that all projects are now complete.

Table 3-8: Greenfield DPW Irene Cost Estimates/Progress

Project		Fund Source		Status as of 10/4/11	Current Status
Green River Dam	$6,500,000	WF	Tighe & Bond retained 8/29; repair to start with cofferdam installation 10/11	In progress	Completed
Erosion downstream of Green River Pump Station	$80,000	WF	Mitchell Construction apparent low bidder, waiting for quotes for rock	Work to start 10/11	Completed
8 in sewer crossing under Green River @2A bridge breeched	$1,300,000	SF	AECOM (nee Metcalf & Eddy) retained 8/30 ; surveying not complete due to hi water	In progress	Completed

Table 3-8: Greenfield DPW Irene Cost Estimates/Progress					
Project		**Fund Source**		**Status as of 10/4/11**	**Current Status**
Bypass pumping at 2A bridge to stop raw sewage to river	$35,000	SF	Baker Pumps (equipment and setup) Set up & running 9/12/11	In operation	Completed
Maple Brook (akA Solon St) Inceptor repair	$176,354	SF	Davenport Construction retained 8/30; work complete 9/30/11	Completed	Completed
Water Pollution Control Plant	$750,000	SF	CRS, Aaron Assoc, AECOM and Elm Elec retained 8/29	In progress	Completed
Misc road, bike path erosion (including Mead St & Leyden Glen Rd)	$3,500	GF	City doing work	75% completed	Completed
Removal covered bridge from river	$78,000	GF	RFQ issued 9/15/11; Work awarded to Northern Construction 10/4/11	In progress	Completed
Replacement of bridge & road at Eunice Williams Drive	$3,000,000	GF	RFQ for engineering services to be let Nov 2011	In progress	Completed
Remove debris from Petty Plain Foot bridge/repair of bridge	$5,000	GF	Davenport retained 8/29; waiting for quotes on bridge repair	25% completed	Completed
Swimming Pool on Green River-Grounds, fence bldg & bldg contents	$65,000	GF	Elm Elec retained 8/29	In progress	Completed
North and southeasterly retaining walls at Swimming pool	$500,000	GF	Bid will be let in winter for work in spring (water too high now)	In progress	Patched, but not replaced

Table 3-8: Greenfield DPW Irene Cost Estimates/Progress					
Project		**Fund Source**		**Status as of 10/4/11**	**Current Status**
Clean up of Green River Park, reseeding	$2,500	GF	Work will be done by City crews	In progress	Completed
Total	**$12,495,354**				

Prior to Tropical Storm Irene, other recent examples of significant flooding in Greenfield occurred between October 8th and October 15th of 2005. During this time, the Connecticut River Valley received between 12-22 inches of rain from Tropical Storm Tammy and a subtropical depression. Greenfield experienced 100 year flood events in many areas throughout the City. The majority of the flooding occurred along the Green River from Nash's Mill Road south to the mouth of the Deerfield River. The Green River Recreational Swimming Area was severely affected with flood waters damaging the bath house and the public beach.

As noted previously, the City of Greenfield has been severely impacted by major flood events (see Tables 3-7 and 3-8). Chronic flooding is also a problem at a number of feeder brooks in the City, including Wheeler Brook, Arms Brook, Fall River, and Maple Brook. Culvert maintenance is continuously needed, and is done on an ongoing basis. Mapping of all of the City's culverts has been done and data has been digitized.

Probability of Future Events

Based on previous occurrences, the frequency of occurrence of flooding events in Greenfield is "Very High" with a 50-100 percent probability in any given year. Flooding frequencies for the various floodplains in Greenfield are defined by FEMA as the following:

- 10-year floodplain – 10 percent chance of flooding in any given year
- 25-year floodplain – 2.5 percent chance of flooding in any given year
- 100-year floodplain – 1 percent chance of flooding in any given year
- 500-year floodplain – 0.2 percent chance of flooding in any given year

Of all the regions in the United States, the Northeast has seen the most dramatic increase in the intensity of rainfall events. The U.S. National Climate Assessment reports that between 1958 and 2010, the Northeast saw more than a 70% increase in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events). Climate projections for Massachusetts, developed by the University of Massachusetts, suggest that the frequency of high-intensity rainfall events will continue to trend upward, and the result will be an increased risk of flooding. Specifically, the annual frequency of downpours releasing more than two inches of rain per day in Massachusetts may climb from less than 1 day per year to approximately 0.9-1.5 days by 2100. Events which release over one inch during a day could climb to as high as 8-11 days per year by 2100. A single intense downpour can cause flooding and widespread damage to property and critical infrastructure. While the coastal areas in Massachusetts will experience the greatest increase in high-intensity rainfall days, some level of increase will occur in every area of Massachusetts, including Greenfield.[10]

Impact

Flooding can cause a wide range of issues, from minor nuisance roadway flooding and basement flooding to major impacts such as roadway closures. Specific damages associated with flooding events include the following primary concerns:

- Blockages of roadways or bridges vital to travel and emergency response
- Breaching of dams
- Damaged or destroyed buildings and vehicles
- Uprooted trees causing power and utility outages
- Drowning, especially people trapped in cars
- Contamination of drinking water
- Dispersion of hazardous materials
- Interruption of communications and/or transportation systems, including train derailments

The impact of a flood event could be “Catastrophic” in Greenfield, with more than 50% of property in the affected area damaged or destroyed, possible shutdown of facilities (roads, bridges, critical facilities) for more than one week, and multiple deaths and injuries possible.

Vulnerability

Society

The impact of flooding on life, health, and safety is dependent upon several factors, including the severity of the event and whether or not adequate warning time is provided to residents. Populations living in or near floodplain areas may be impacted during a flood event. People traveling in flooded areas and those living in urban areas with poor stormwater drainage may be exposed to floodwater. People may also be impacted when transportation infrastructure is compromised from flooding.

[10] ResilientMA: Climate Change Clearing House for the Commonwealth: http://resilientma.org/changes/changes-in-precipitation. Accessed December 13, 2018.

Of Greenfield's total 14,016 acres, 1,449 total acres, or approximately 10.34% percent of the City lie within the 100-year floodplain. Within the 100-year floodplain, 63 acres are developed land, including an estimated 43 acres of developed residential land and 38 dwellings, according to 2005 MassGIS Land Use data (Table 3-9). Using this number and Greenfield's estimated average household size, it is estimated that 83 people, or 0.48% of Greenfield's total population, reside in the floodplain.

Table 3-9: Estimated Greenfield Population Exposed to a 1 Percent Flood Event

Total Population	# of Dwelling Units in Flood Hazard Area	Average # of People Per Household	Estimated Population in Flood Hazard Area	% of Total Population in Flood Hazard Area
17,474	38	2.19	83	0.48%

Source: 2013-2017 American Community Survey Five-Year Estimates; 2005 MassGIS Land Use data.

Vulnerable Populations

Of the population exposed, the most vulnerable include people with low socioeconomic status, people over the age of 65, young children, people with medical needs, and those with low English language fluency. For example, people with low socioeconomic status are more vulnerable because they are likely to consider the economic impacts of evacuation when deciding whether or not to evacuate. The population over the age of 65 is also more vulnerable because some of these individuals are more likely to seek or need medical attention because they may have more difficulty evacuating or the medical facility may be flooded. Those who have low English language fluency may not receive or understand the warnings to evacuate. Vulnerable populations may also be less likely to have adequate resources to recover from the loss of their homes and jobs.

Table 3-10 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides information to help plan for responding to the needs of Greenfield residents during a flood event.

Table 3-10: Estimated Vulnerable Populations in Greenfield

Vulnerable Population Category	Number	Percent of Total Population*
Population Age 65 Years and Over	3,498	20%

Table 3-10: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Populations that live or work in proximity to facilities that use or store toxic substances are at greater risk of exposure to these substances during a flood event. As the most urban area of Franklin County, Greenfield has several facilities that use, manufacture, treat, transport, or release toxic chemicals into the environment. Some are located near FEMA floodways. Specific facility locations and associated chemicals identified in the EPA's Toxic Release Inventory (TRI) are discussed in more detail in the Manmade Hazards section of this Plan. Greenfield's Water Pollution Control Facility is located within the 100-year floodplain at the confluence of the Green and Deerfield Rivers and has required extensive flood proofing projects since TS Irene inundated the facility in 2011.

In addition, Interstate 91, Route 5&10, and Pan Am Rail System's Connecticut River Main Line and Freight Main Line travel through the City. Each hour, as many as ten trucks carry hazardous materials through Greenfield on I-91 and/or Route 5/10. Meanwhile, the railroads carry between six to ten trains daily, each train typically carrying goods such as plastic pellets, fertilizer, steel reinforcement rods and grain. On the Connecticut River Line an average of two cars per train carry hazardous wastes, while at the Rail Yard and average of between two to five cars per train carry hazardous wastes. Populations living within close proximity to these facilities, roads, railroads, and the East Deerfield Rail Yard are at higher risk of a hazardous material spill. Vulnerability and risk assessment of hazardous material spills in Greenfield are discussed in more detail in the Manmade Hazards section of this plan.

<u>Health Impacts</u>

The total number of injuries and casualties resulting from typical riverine flooding is generally limited due to advance weather forecasting, blockades, and warnings. The historical record from 1996 to 2018 indicates that there have been no fatalities or injuries associated with flooding or flash flooding events in Greenfield. However, flooding can result in direct mortality to individuals in the flood zone. This hazard is particularly dangerous because even a relatively low-level flood can be more hazardous than many residents realize. For example, while 6 inches of moving water can cause adults to fall, 1 foot to 2 feet of water can sweep cars away. Downed powerlines, sharp objects in the water, or fast-moving debris that may be moving in or near the water all present an immediate danger to individuals in the flood zone.

Events that cause loss of electricity and flooding in basements, where heating systems are typically located in Massachusetts homes, increase the risk of carbon monoxide poisoning. Carbon monoxide results from improper location and operation of cooking and heating devices (grills, stoves), damaged chimneys, or generators. According to the U.S. Environmental Protection Agency (EPA), floodwater often contains a wide range of infectious organisms from raw sewage. These organisms include intestinal bacteria, MRSA (methicillin-resistant staphylococcus aureus), strains of hepatitis, and agents of typhoid, paratyphoid, and tetanus (OSHA, 2005). Floodwaters may also contain agricultural or industrial chemicals and hazardous materials swept away from containment areas.

Individuals who evacuate and move to crowded shelters to escape the storm may face the additional risk of contagious disease; however, seeking shelter from storm events when advised is considered far safer than remaining in threatened areas. Individuals with pre-existing health conditions are also at risk if flood events (or related evacuations) render them unable to access medical support. Flooded streets and roadblocks can also make it difficult for emergency vehicles to respond to calls for service, particularly in rural areas.

Flood events can also have significant impacts after the initial event has passed. For example, flooded areas that do not drain properly can become breeding grounds for mosquitos, which can transmit vector-borne diseases. Exposure to mosquitos may also increase if individuals are outside of their homes for longer than usual as a result of power outages or other flood-related conditions. Finally, the growth of mold inside buildings is often widespread after a flood. Investigations following Hurricane Katrina and Superstorm Sandy found mold in the walls of many water-damaged homes and buildings. Mold can result in allergic reactions and can exacerbate existing respiratory diseases, including asthma (CDC, 2004). Property damage and displacement of homes and businesses can lead to loss of livelihood and long-term mental stress for those facing relocation. Individuals may develop post-traumatic stress, anxiety, and depression following major flooding events (Neria et al., 2008).

Economic Impacts

Economic losses due to a flood include, but are not limited to, damages to buildings (and their contents) and infrastructure, agricultural losses, business interruptions (including loss of wages), impacts on tourism, and impacts on the tax base. Flooding can also cause extensive damage to public utilities and disruptions to the delivery of services. Loss of power and communications may occur, and drinking water and wastewater treatment facilities may be temporarily out of operation. Flooding can shut down major roadways and disrupt public transit systems, making it difficult or impossible for people to get to work. Floodwaters can wash out sections of roadway and bridges, and the removal and disposal of debris can also be an enormous cost during the recovery phase of a flood event. Agricultural impacts range from crop and infrastructure damage to loss of livestock. Extreme precipitation events may result in crop failure, inability to harvest, rot, and increases in crop pests and disease. In addition to having a detrimental effect on water quality and soil health and stability, these impacts can result in increased reliance on crop insurance claims.

Damages to buildings can affect a community's economy and tax base; the following section includes an analysis of buildings in Greenfield that are vulnerable to flooding and their associated value.

Infrastructure

Buildings, infrastructure, and other elements of the built environment are vulnerable to inland flooding. At the site scale, buildings that are not elevated or flood-proofed and those located within the floodplain are highly vulnerable to inland flooding. These buildings are likely to become increasingly vulnerable as riverine flooding increases due to climate change (resilient MA, 2018). At a neighborhood to regional scale, highly developed areas and areas with high impervious surface coverage may be most vulnerable to flooding. Even moderate development that results in as little as 3 percent impervious cover can lead to flashier flows and river degradation, including channel deepening, widening, and instability (Vietz and Hawley, 2016).

Additionally, changes in precipitation will threaten key infrastructure assets with flood and water damage. Climate change has the potential to impact public and private services and business operations. Damage associated with flooding to business facilities, large manufacturing areas in river valleys, energy delivery and transmission, and transportation systems has economic implications for business owners as well as the state's economy in general (resilient MA, 2018). Flooding can cause direct damage to City-owned facilities and result in roadblocks and inaccessible streets that impact the ability of public safety and emergency vehicles to respond to calls for service.

Table 3-11 shows the amount of commercial, industrial, and public/institutional land uses located in the City and within Flood Hazard Areas. More than thirteen acres of commercial land and nearly five acres of public/institutional land uses lie within flood hazard areas in Greenfield, accounting for 3 percent of commercial land uses and 2 percent of public/institutional land uses in the City. Nearly two acres of industrial land use is located in the flood hazard area, accounting for one percent of the industrial land in the City.

Table 3-11: Acres of Commercial, Industrial, and Public/Institutional Land Use Within the Flood Hazard Area in Greenfield			
Land Use	**Total acres in City**	**Acres in Flood Hazard Area**	**% of total acres in Flood Hazard Area**
Commercial	403	13.6	3%
Industrial	183	1.9	1%
Public/Institutional	239	4.8	2%

Source: 2005 MassGIS Land Use data.

The River Corridor area of the Green River, which runs through the City, was mapped using a scientific protocol that was developed as part of a MassDEP 319 project completed by The FRCOG, and is detailed in *The Green River Corridor Mapping and Management Report*. Table 3-12 shows the 2016 land cover and land use totals located within the mapped river corridor. The MassGIS land cover and land use data became available in May 2019. The committee identified the need to use this data in conjunction with the mapped river corridor data to update the vulnerability assessment for flooding and other hazards that create flooding. There was an Action Item created in Table 4-3 to address this need.

Table 3-12: Greenfield 2016 Land Cover and Land Use Data for the Delineated River Corridor				
Landcover	**Acres**		**Land Use**	**Acres**
Bare Land	13.23		Agriculture	96.06
Cultivated	15.78		Commercial	16.66
Deciduous Forest	315.47		Forest	11.97
Developed Open Space	86.91		Industrial	4.96
Evergreen Forest	118.10		Mixed use, other	163.81
Grassland	35.58		Mixed use, primarily commercial	41.49
Impervious	62.38		Mixed use, primarily residential	37.35
Palustrine Aquatic Bed	2.07		Open land	200.36

Table 3-12: Greenfield 2016 Land Cover and Land Use Data for the Delineated River Corridor				
Landcover	**Acres**		**Land Use**	**Acres**
Palustrine Emergent Wetland	17.79		Recreation	32.59
Palustrine Forested Wetland	184.36		Residential - multi-family	37.76
Palustrine Scrub/Shrub Wetland	1.74		Residential - single family	85.70
Pasture/Hay	78.51		Right-of-way	62.55
Scrub/Shrub	8.33		Tax exempt	146.98
Water	42.99		Unknown	5.29
			Water	39.70

Table 3-13 shows the total value of replacing the structures and contents of buildings located in the flood hazard area in Greenfield. In total, the structures and building contents are valued in excess of $5.7 million. It is evident that catastrophic flooding would cause significant economic, financial and environmental damage.

Table 3-13: Total Building and Contents Value in Flood Hazard Area			
	Building Structure Value	**Building Contents Value**	**Total Building and Contents Value**
Commercial	$243,076,431	100%	$486,152,862
Industrial	$33,819,460	150%	$84,548,650
Public/Institutional	$184,675	150%	$461,688

NFIP data are useful for determining the location of areas vulnerable to flood and severe storm hazards. Table 3-14 summarizes the NFIP policies, claims, repetitive loss (RL) properties, and severe repetitive loss (SRL) properties in Greenfield associated with all flood events as of December 18, 2018. A RL property is a property for which two or more flood insurance claims of more than $1,000 have been paid by the NFIP within any 10-year period since 1978. A SRL property is defined as one that "has incurred flood-related damage for which 4 or more separate claims payments have been paid under flood insurance coverage, with the amount of each claim payment exceeding $5,000 and with cumulative amount of such claims payments exceeding $20,000; or for which at least 2 separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property" (FEMA). Greenfield currently has 43 policies in force, 41 losses have been paid, and there is one (1) repetitive loss property in the City. In February 2020, after discussions with MEMA and FEMA Region 1 staff, the City filed a signed Information Sharing Access Agreement (ISAA) with FEMA Region 1 to request additional information on the RL property to further inform future mitigation strategies and actions that may be undertaken by the City. The ISAA must be executed by FEMA Headquarters and then the information will be released to the City. Once received, the City will update this Plan, as appropriate.

Table 3-14: NFIP Policies, Claims, and Repetitive Loss Statistics for Greenfield						
Number of Housing Units (2017 Estimates)	**Number of Policies in Force**	**Percent of Housing Units**	**Total Insurance in Force**	**Number of Paid Losses**	**Total Losses Paid**	**Number of Repetitive Loss Properties**
8334	43	.5%	$15,351,000	41	$2,699,328	1

Source: National Flood Insurance Program (NFIP), FEMA Region I; U.S. Census Bureau 2013-2017 American Community Survey Five-Year Estimates.

Many dams within the Commonwealth have aged past their design life. As a result, they are less resilient to hazards such as inland flooding and extreme precipitation, and may not provide adequate safety following these disasters. These structures, if impacted by disasters, can affect human health, safety, and economic activity due to increased flooding and loss of infrastructure functions. These dams require termination or restoration to improve their infrastructure and better equip them to withstand the hazards that the Commonwealth will face due to climate change.

As already stated, climate change impacts, including increased frequency of extreme weather events, are expected to raise the risk of damage to transportation systems, energy-related facilities, communication systems, a wide range of structures and buildings, solid and hazardous waste facilities, and water supply and wastewater management systems. A majority of the infrastructure in Massachusetts and throughout the country has been sited and designed based on historic weather and flooding patterns. As a result, infrastructure and facilities may lack the capacity to handle greater volumes of water or the required elevation to reduce vulnerability to flooding. Examples of climate change impacts to sectors of the built environment are summarized below.

<u>Agriculture</u>
Inland flooding is likely to impact the agricultural sector. Increased river flooding is likely to cause soil erosion, soil loss, and crop damage (resilient MA, 2018). In addition, wetter springs may delay planting of crops, resulting in reduced yields.

Energy

Flooding can increase bank erosion and also undermine buried energy infrastructure, such as underground power, gas, and cable infrastructure. Basement flooding can destroy electrical panels and furnaces. This can result in releases of oil and hazardous wastes to floodwaters. Inland flooding can also disrupt delivery of liquid fuels.

Public Health

The impacts to the built environment extend into other sectors. For example, flooding may increase the vulnerability of commercial and residential buildings to toxic mold buildup, leading to health risks, as described in the Populations section of the inland flooding hazard profile. Inland flooding may also lead to contamination of well water and contamination from septic systems (DPH, 2014).

Public Safety

Flash flooding can have a significant impact on public safety. Fast-moving water can sweep up debris, hazardous objects, and vehicles, and carry them toward people and property. Flooding can impact the ability of emergency response personnel to reach stranded or injured people. Drownings may also occur as people attempt to drive through flooded streets or escape to higher ground.

Transportation

Heavy precipitation events may damage roads, bridges, and energy facilities, leading to disruptions in transportation and utility services (resilient MA, 2018). Roads may experience greater ponding, which will further impact transportation. If alternative routes are not available, damage to roads and bridges may dramatically affect commerce and public health and safety.

Water Infrastructure

Stormwater drainage systems and culverts that are not sized to accommodate larger storms are likely to experience flood damage as extreme precipitation events increase (resilient MA, 2018). Both culverts that are currently undersized and culverts that are appropriately sized may be overwhelmed by larger storms. Gravity-fed water and wastewater infrastructure that is located in low lying areas near rivers and reservoirs may experience increased risks. Combined sewer overflows may increase with climate change, resulting in water quality degradation and public health risks (resilient MA, 2018).

Environment

Flooding is part of the natural cycle of a balanced environment. However, severe flood events can also result in substantial damage to the environment and natural resources, particularly in areas where human development has interfered with natural flood-related processes. As described earlier in this section, severe weather events are expected to become more frequent as a result of climate change; therefore, flooding that exceeds the adaptive capacity of natural systems may occur more often.

One common environmental effect of flooding is fluvial erosion (riverbank and soil erosion). Riverbank erosion occurs when high, fast water flows scour the edges of the river, transporting sediment downstream and reshaping the ecosystem. In addition to changing the habitat around the riverbank, this process also results in the deposition of sediment once water velocities slow. This deposition can clog riverbeds and streams, disrupting the water supply to downstream habitats. Soil erosion occurs whenever floodwaters loosen particles of topsoil and then transport them downstream, where they may be redeposited somewhere else or flushed into the ocean. Flooding can also influence soil conditions in areas where floodwaters pool for long periods of time, as continued soil submersion can cause oxygen depletion in the soil, reducing the soil quality and potentially limiting future crop production.

Flooding can also affect the health and well-being of wildlife. Animals can be directly swept away by flooding or lose their habitats to prolonged inundation. Floodwaters can also impact habitats nearby or downstream of agricultural operations by dispersing waste, pollutants, and nutrients from fertilizers. While some of these substances, particularly organic matter and nutrients, can actually increase the fertility of downstream soils, they can also result in severe impacts to aquatic habitats, such as eutrophication.

Vulnerability Summary

Based on the above analysis, Greenfield has a "High" vulnerability to flooding. The following problem statements summarize Greenfield's areas of greatest concern regarding the flood hazard.

Flood Hazard Problem Statements
• FEMA floodplain maps are of primary importance for mitigating the flood inundation hazards but are critically out of date and do not represent present day landform data or climate change models.
• While the chance is low, a catastrophic dam failure at a major facility upstream of Greenfield would resulting in devastating flooding in which roads, buildings and infrastructure would be inundated and evacuations would be needed. There are six major dams of concern on the Deerfield River, including Harriman Dam, where a failure would reach Greenfield in approximately 4 hours. Moore Dam is of concern on the Connecticut

Flood Hazard Problem Statements
River, and Leyden Glen Dam is of concern on the Green River. Maps in this plan include the Dam Inundation Areas for these dams. These maps should be shared with all City departments and coupled with a public outreach effort to inform residents and business located in inundation areas.
• Dam failure notification systems at Great River Hydro dams, Connecticut River Hydro dams, and Leyden Glen dam need to be reestablished and tested, and the City's Standard Operating Procedures (SOPs) for flooding, including managing road closures, evacuation, and sheltering may need to be revised and updated to consider new dam inundation and flood-prone areas in the City. Vulnerable neighborhoods and elderly housing such as The Arbors have a greater need for flood warnings and flood prevention.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Evacuation and sheltering plans may need to be revised and updated to account for flooding on vital evacuation routes including River Street, Mill Street, Deerfield Street, Route 2A, and Shelburne Road. A central communication system should be devised to manage road closures due to flash flooding and to facilitate efficient evacuation. New signage and road closure devices are needed as part of updated evacuation planning.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with current population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stoneleigh Burnham School, and Franklin Medical Center.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
• Leyden Glen Reservoir Access Road is essential to vehicular access to Leyden Glen Reservoir and Dam but is vulnerable to chronic road flooding and erosion hazards.
• The City's aging storm sewer and waste water conveyance infrastructure needs updating

Flood Hazard Problem Statements
to reduce Inflow and Infiltration pressure on municipal wastewater treatment facilities and to reduce the risk of combined waste water and storm water hazard events.
• The City needs additional staff and funding to continue its program to separate domestic sump pump outfall from the municipal sewer system to reduce pressure on municipal wasterwater treatment facilities and to comply with DEP/EPA.
• Funding is needed to prepare final design and cost estimates for climate resiliency projects identified in the *Green River Corridor Mapping and Management Report* (2019) and to expand River Corridor mapping to tributaries of the Green River. Restoration projects that address fluvial erosion on Greenfield's waterways persisting from previous flood events, restore floodplain access, and conserve land identified as attenuation assets should be developed and implemented.
• Beaver activity is occurring in proximity to residential settlement, commercial buildings and facilities, and municipal infrastructure. Continued monitoring and risk assessment is needed to mitigate damage from a potential beaver dam failure.
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• Additional funding and infrastructure is needed to expand existing programming to promote and increase household disaster preparedness City wide, specifically the voluntary removal and safe disposal of hazardous materials.
• Culvert maintenance is continuously needed throughout the City, especially in the Maple Brook Culvert drainage system, to mitigate erosion, debris, and flooding hazards in and around developed areas. Culvert replacements have been prioritized at multiple locations. Green Infrastructure assessments in local flooding hot spots as well as options for daylighting urban streams in key areas are needed to equip the DPW and Planning Departments with alterative strategies to make streets and neighborhoods more flood resilient.
• Abandoned or tax lien properties may be an unrecognized assets in planning for flood resilience and should be assessed for green infrastructure and stormwater engineering options including daylighting streams and creating temporary retention basins to attenuate flood flows, especially in flood-prone areas of the City. This applies to #34 Riddell Street, adjacent to the proposed new fire station, where flooding is a chronic issue, as well as other properties along Maple Brook culvert.

Flood Hazard Problem Statements
• The City needs to consult a hydraulic engineer to develop retrofits and cost estimates for the Wastewater Treatment Plant that would allow the building to be safely inundated by floodwaters as a necessary flood resilience strategy in addition to having raised the flood doors to maximum possible elevation (144.3 ft.) in 2014.
• The City needs to consult a structural engineering consultant to assess the integrity of the concrete retaining walls on the streambanks of the Green River along Deerfield Street and Meridian Streets and to develop feasibility analysis and cost estimates to mitigate risk of structural failures
• An improved process is needed for residents to report situations in which private property is negatively impacted by municipal stormwater infrastructure or flooding issues related to surface drainage and for reports to be handled by the Director of DPW.
• There is are several small, unnamed, privately owned dams in the City that may need to be assessed and/or removed.
• Some municipal facilities and critical infrastructure, including Franklin Medical Hospital and some nursing homes in the City, have natural gas backup generators. However, the electric substation and gas district sites are within the flood hazard area and are vulnerable flood inundation which would result in outages of both gas and electricity for the City. The electric substation and gas district sites on Power Square may need to be elevated.
• Private wells located close to floodways may be vulnerable to flooding.
• Options should be assessed for relocating structures in floodplain and the mapped river corridor.
• An improved process is needed for estimating and tracking local crop damage caused by severe thunderstom, wind, or microburst hazard events.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City's evacuation routes may be impacted by flooding. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a flood.

3.4 SEVERE SNOWSTORMS / ICE STORMS

Potential Effects of Climate Change

Climate projections for Massachusetts indicate that in future decades, winter precipitation could increase annually by as much as 0.4-3.9 inches (an increase of 4-35%), but by the end of the century most of this precipitation is likely to fall as rain instead of snow. There are many human and environmental impacts that could result from this change including reduced snow cover for winter recreation and tourism, less spring snow melt to replenish aquifers and lower spring river flows for aquatic ecosystems. Figure 3-4 shows potential effects of climate change on severe winter storms from the Massachusetts State Hazard Mitigation and Climate Adaptation Plan.

Figure 3-4: Effects of Climate Change on Severe Winter Storms

Potential Effects of Climate Change	
EXTREME WEATHER AND RISING TEMPERATURES ➔ INCREASED SNOWFALL	Increased sea surface temperature in the Atlantic Ocean will cause air moving north over the ocean to hold more moisture. As a result, when these fronts meet cold air systems moving from the north, an even greater amount of snow than normal can be anticipated to fall on Massachusetts.
RISING TEMPERATURES ➔ CHANGING CIRCULATION PATTERNS AND WARMING OCEANS	Research has found that increasing water temperatures and reduced sea ice extent in the Arctic are producing atmospheric circulation patterns that favor the development of winter storms in the eastern U.S. Global warming is increasing the severity of winter storms because warming ocean water allows additional moisture to flow into the storm, which fuels the storm to greater intensity.
EXTREME WEATHER ➔ INCREASE IN FREQUENCY AND INTENSITY	There is evidence suggesting that nor'easters along the Atlantic coast are increasing in frequency and intensity. Future nor'easters may become more concentrated in the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

Severe winter storms include ice storms, nor'easters, heavy snow, blowing snow, and other extreme forms of winter precipitation. A blizzard is a winter snowstorm with sustained or frequent wind gusts to 35 mph or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile (NWS, 2018). 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 definition. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20ºF. 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.

Storm systems powerful enough to cause blizzards usually form when the jet stream dips far to the south, allowing cold air from the north to clash with warm air from the south. Blizzard conditions often develop on the northwest side of an intense storm system. The difference between the lower pressure in the storm and the higher pressure to the west creates a tight pressure gradient, resulting in strong winds and extreme conditions due to the blowing snow. Blowing snow is wind-driven snow that reduces visibility to 6 miles or less, causing significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.

Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects, creating ice buildups of one-fourth of an inch or more. These can cause severe damage. An ice storm warning, which is now included in the criteria for a winter storm warning, is issued when a half inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the pulling down of power lines and trees.

Ice pellets are another form of freezing precipitation, formed when snowflakes melt into raindrops as they pass through a thin layer of warmer air. The raindrops then refreeze into particles of ice when they fall into a layer of subfreezing air near the surface of the earth. Finally, sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. The difference between sleet and hail is that sleet is a wintertime phenomenon whereas hail falls from convective clouds (usually thunderstorms), often during the warm spring and summer months.

Nor'easters

A nor'easter is a storm that occurs along the East Coast of North America with winds from the northeast (NWS, n.d.). A nor'easter is characterized by a large counter-clockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, and rain. A nor'easter gets its name from its continuously strong northeasterly winds blowing in from the ocean ahead of the storm and over the coastal areas.

Nor'easters are among winter's most ferocious storms. These winter weather events are notorious for producing heavy snow, rain, and oversized waves that crash onto Atlantic beaches, often causing beach erosion and structural damage. These storms occur most often in late fall and early winter. The storm radius is often as much as 100 miles, and nor'easters often sit stationary for several days, affecting multiple tide cycles and causing extended heavy precipitation. Sustained wind speeds of 20 to 40 mph are common during a nor'easter, with short-term wind speeds gusting up to 50 to 60 mph. Nor'easters are commonly accompanied with a storm surge equal to or greater than 2.0 feet.

Nor'easters begin as strong areas of low pressure either in the Gulf of Mexico or off the East Coast in the Atlantic Ocean. The low will then either move up the East Coast into New England and the Atlantic provinces of Canada, or out to sea. The level of damage in a strong hurricane is often more severe than a nor'easter, but historically Massachusetts has suffered more damage from nor'easters because of the greater frequency of these coastal storms (one or two per year). The comparison of hurricanes to nor'easters reveals that the duration of high surge and winds in a hurricane is 6 to 12 hours, while a nor'easter's duration can be from 12 hours to 3 days.

Severe winter storms can pose a significant risk to property and human life. The rain, freezing rain, ice, snow, cold temperatures and wind associated with these storms can cause the following hazards:

- Disrupted power and phone service
- Unsafe roadways and increased traffic accidents
- Infrastructure and other property are also at risk from severe winter storms and the associated flooding that can occur following heavy snow melt
- Tree damage and fallen branches that cause utility line damage and roadway blockages
- Damage to telecommunications structures
- Reduced ability of emergency officials to respond promptly to medical emergencies or fires
- Elderly are affected by extreme weather

Location

Although the entire Commonwealth may be considered at risk to the hazard of severe winter storms, higher snow accumulations appear to be prevalent at higher elevations in Western and Central Massachusetts, and along the coast where snowfall can be enhanced by additional ocean moisture. Ice storms occur most frequently in the higher-elevation portions of Western and Central Massachusetts. Inland areas, especially those in floodplains, are also at risk for flooding and wind damage.

The entire City of Greenfield is susceptible to severe snowstorms and ice storms. Because these storms occur regionally, they impact the entire City. As a result, the location of occurrence is "Large," with over 50 percent of land area affected.

Extent

Since 2005, the Regional Snowfall Index (RSI) has become the descriptor of choice for measuring winter events that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale system from 1 to 5 as depicted in Table 3-15. The RSI is similar to the Fujita scale for tornadoes or the Saffir-Simpson scale for hurricanes, except that it includes an additional variable: population. The RSI is based on the spatial extent of the storm, the amount of snowfall, and population.

The RSI is a regional index. Each of the six climate regions (identified by the NOAA National Centers for Environmental Information) in the eastern two-thirds of the nation has a separate index. The RSI incorporated region-specific parameters and thresholds for calculating the index. The RSI is important because, with it, a storm event and its societal impacts can be assessed within the context of a region's historical events. Snowfall thresholds in Massachusetts (in the Northeast region) are 4, 10, 20, and 30 inches of snowfall, while thresholds in the Southeast U.S. are 2, 5, 10, and 15 inches.

Table 3-15: Regional Snowfall Index Categories

Category	RSI Value	Description
1	1—3	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

Source: NOAA National Climatic Data Center

Prior to the use of the RSI, the Northeast Snowfall Impact Scale (NESIS), developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service, was used to characterize and rank high-impact northeast snowstorms with large areas of 10-inch snowfall accumulations and greater. In contrast to the RSI, which is a regional index, NESIS is a quasi-national index that is calibrated to Northeast snowstorms. NESIS has five categories, as shown in Table 3-16.

Table 3-16: Northeast Snowfall Impact Scale Categories

Category	NESIS Value	Description
1	1—2.499	Notable
2	2.5—3.99	Significant

Table 3-16: Northeast Snowfall Impact Scale Categories		
Category	**NESIS Value**	**Description**
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

Source: NOAA National Climatic Data Center

Previous Occurrences

New England generally experiences at least one or two severe winter storms each year with varying degrees of severity. Severe winter storms typically occur during January and February; however, they can occur from late September through late April. According to NOAA's National Climatic Data Center, there have been 80 heavy snow events in Franklin County since 1996, resulting in $15,440,000 in damages; 29 winter storm events since 2002, resulting in $1,170,000 in damages; and two ice storms have resulted in damages of $3,150,000.

In 2018, New England was hit by three Nor'easters within the first two weeks of March. The first was Winter Storm Riley which brought damaging winds, heavy snow and coastal flooding. Then, Winter Storm Quinn dumped heavy snow, taking down more trees and causing additional power outages on top of those caused by Riley. The third Nor'easter, called Winter Storm Skylar, occurred on March 11-13 and brought over a foot of snow in Massachusetts. With severe winter storms occurring soon after each other, there is little time to recover from one storm before needing to brace for the next. Utilites companies may have to work for weeks or months to restore power after mounting failures, leaving some customers without power for extended time periods. Snow storage and disposal becomes more challenging and expensive when designated snow storage areas fill up, forcing municipalities to pay for snow removal and hauling. For example, after the second-highest snowfall record was set in Boston's recorded history in 2015, the City had to spend an estimated $35 million - double the allotted budget - on snow and ice removal, setting another record for the most money ever spent on snow removal, according to local news reporting.[11]

In December 2008, a major ice storm impacted the northeast. The hardest hit areas in southern New England were the Monadnock region of southwest New Hampshire, the Worcester Hills in central Massachusetts, and the east slopes of the Berkshires in western Massachusetts. Anywhere from half an inch to an inch of ice built up on many exposed surfaces. Combined with breezy conditions, the ice downed numerous trees, branches, and power lines which resulted in

[11] https://www.boston.com/news/local-news/2015/02/18/boston-to-set-record-for-most-dollars-spent-on-snow-removal

widespread power outages. More than 300,000 customers were reportedly without power in Massachusetts and an additional 300,000 were without power in the state of New Hampshire. Greenfield did not suffer as devastating a blow from this ice storm as some of its neighboring Franklin County towns at higher elevations and the impact was not widespread throughout. That notwithstanding, in affected areas there were downed trees, roadway blockages, and flooding. Necessary clean-up and mitigation efforts included debris removal, road repairs and culvert replacements. The total reimbursement from MEMA/FEMA for these efforts was $22,880.

Damage to the infrastructure in Massachusetts and New Hampshire amounted to roughly 80 million dollars. This amount does not include damage to private property. The extent of the damage and number of people affected prompted the governors of both Massachusetts and New Hampshire to request federal assistance. FEMA approved both requests. President Bush issued a Major Disaster Declaration for Public Assistance for seven Massachusetts counties and all of New Hampshire.

Based on data available from the National Oceanic and Atmospheric Administration, there are 210 winter storms since 1900 that have registered on the RSI scale. Of these, approximately 18 storms resulted in snow falls in all or parts of Franklin County of at least 10 inches. These storms are listed in Table 3-17, in order of their RSI severity.

Table 3-17: High-Impact Snowstorms in Franklin County, 1958 - 2018

Date	RSI Value	RSI Category	RSI Classification
2/22/1969	34.0	5	Extreme
3/12/1993	22.1	5	Extreme
1/6/1996	21.7	5	Extreme
2/5/1978	18.4	5	Extreme
2/23/2010	17.8	4	Crippling
2/15/2003	14.7	4	Crippling
1/29/1966	12.3	4	Crippling
3/12/2017	10.7	4	Crippling
2/27/1947	10.6	4	Crippling
12/25/1969	10.1	4	Crippling
1/22/2016	17.8	4	Major
12/4/2003	9.4	3	Major
2/8/2013	9.2	3	Major
2/2/1961	8.3	3	Major
2/10/1983	7.9	3	Major

Table 3-17: High-Impact Snowstorms in Franklin County, 1958 - 2018			
Date	**RSI Value**	**RSI Category**	**RSI Classification**
2/14/1958	7.9	3	Major
2/12/2007	6.9	3	Major
3/2/1960	6.9	3	Major
1/25/2015	6.2	3	Major
3/11/2018	4.3	2	Significant
11/29/2019	2.4	1	Notable

Source: https://www.ncdc.noaa.gov/snow-and-ice/rsi/societal-impacts

Probability of Future Events

Based upon the availability of records for Franklin County, the likelihood that a severe snow storm will hit Greenfield in any given year is "Very High," or a 70 to 100 percent probability in any given year.

Increased sea surface temperature in the Atlantic Ocean will cause air moving north over this ocean to hold more moisture. As a result, when these fronts meet cold air systems moving from the north, an even greater amount of snow than normal can be anticipated to fall on Massachusetts. Climate projections for Massachusetts indicate that in future decades, winter precipitation could increase annually by as much as 0.4-3.9 inches (an increase of 4-35%), but by the end of the century most of this precipitation is likely to fall as rain instead of snow. There are many human and environmental impacts that could result from this change including reduced snow cover for winter recreation and tourism, less spring snow melt to replenish aquifers and lower spring river flows for aquatic ecosystems.

Impact

The phrase "severe winter storm" encapsulates several types of natural hazards, including snowfall, wind, ice, sleet, and freezing rain hazards. Additional natural hazards that can occur as a result of winter storms include sudden and severe drops in temperature. Winter storms can also result in flooding and the destabilization of hillsides as snow or ice melts and begins to run off. The storms can also result in significant structural damage from wind and snow load as well as human injuries and economic and infrastructure impacts.

The Committeed determined that the impact of an event would be "Limited," with more than 10 percent of property in the affected area damaged and complete shutdown of facilities for more than 1 day possible.

Vulnerability

Society

According to the NOAA National Severe Storms Laboratory, every year, winter weather indirectly and deceptively kills hundreds of people in the U.S., primarily from automobile accidents, overexertion, and exposure. Winter storms are often accompanied by strong winds that create blizzard conditions with blinding wind-driven snow, drifting snow, and extreme cold temperatures with dangerous wind chill. These events are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. Injuries and deaths may occur due to traffic accidents on icy roads, heart attacks while shoveling snow, or hypothermia from prolonged exposure to cold.

Heavy snow can immobilize a region and paralyze a community, shutting down air and rail transportation, stopping the flow of supplies, and disrupting medical and emergency services. Accumulations of snow can cause buildings to collapse and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may perish. In the mountains, heavy snow can lead to avalanches.

The impact of a severe winter storm on life, health, and safety is dependent upon several factors, including the severity of the event and whether or not adequate warning time was provided to residents. Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. The entire population of Greenfield is exposed to severe winter weather events.

<u>Vulnerable Populations</u>

Vulnerable populations include the elderly living alone, who are susceptible to winter hazards due to their increased risk of injury and death from falls, overexertion, and/or hypothermia from attempts to clear snow and ice, or injury and death related to power failures. In addition, severe winter weather events can reduce the ability of these populations to access emergency services. People with low socioeconomic status are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact on their families. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply).

The population over the age of 65, individuals with disabilities, and people with mobility limitations or who lack transportation are also more vulnerable because they are more likely to seek or need medical attention, which may not be available due to isolation during a winter storm event. These individuals are also more vulnerable because they may have more difficulty if evacuation becomes necessary. People with limited mobility risk becoming isolated or “snowbound” if they are unable to remove snow from their homes. Rural populations may become isolated by downed trees, blocked roadways, and power outages. Residents relying on private wells could lose access to fresh drinking water and indoor plumbing during a power outage.

Table 3-18 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during a severe winter storm event.

Table 3-18: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884
Note: Individuals and households may be counted under multiple categories.
Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Health Impacts

Cold weather, which is a component of a severe winter storm, increases the risk of hypothermia and frostbite. Exposure to cold conditions can also exacerbate pre-existing respiratory and cardiovascular conditions. In addition to temperature-related dangers, however, severe winter storms also present other potential health impacts. For example, individuals may use generators in their homes if the power goes out or may use the heat system in their cars if they become trapped by snow. Without proper ventilation, both of these activities can result in carbon monoxide buildup that can be fatal. Loss of power can also lead to hypothermia. After Hurricane Sandy, the number of cases of cold exposure in New York City was three times greater than the same time period in previous years.[12] Driving during severe snow and ice conditions can also be very dangerous, as roads become slick and drivers can lose control of their vehicle. During and after winter storms, roads may be littered with debris, presenting a danger to drivers. Health impacts on people include the inability to travel to receive needed medical services and isolation in their homes. Additionally, natural gas-fueled furnaces, water heaters, and clothes dryers, and even automobile exhaust pipes, may become blocked by snow and ice, which can lead to carbon monoxide poisoning.

Economic Impacts

The entire building stock inventory in Greenfield is exposed to the severe winter weather hazard. In general, structural impacts include damage to roofs and building frames rather than building content. Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communication and power networks can be disrupted for days while utility companies work to repair the extensive damage.

Even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces. A specific area that is vulnerable to the winter storm hazard is the floodplain. Snow and ice melt can cause both riverine and urban flooding. The cost of snow and ice removal and repair of roads from the freeze/thaw process can drain local financial resources. The potential secondary impacts from winter storms, including loss of utilities, interruption of transportation corridors, loss of business functions, and loss of income for many individuals during business closures, also impact the local economy.

Similar to hurricanes and tropical storms, nor'easter events can greatly impact the economy, with impacts that include the loss of business functions (e.g., tourism and recreation), damage to inventories or infrastructure (the supply of fuel), relocation costs, wage losses, and rental losses due to the repair or replacement of buildings.

Infrastructure

All infrastructure and other elements of the built environment in Greenfield are exposed to the severe winter weather hazard. Potential structural damage to the facilities themselves may include damage to roofs and building frames. These facilities may not be fully operational if workers are unable to travel to ensure continuity of operations prior and after a severe winter

[12] Fink, Sheri. 2012. Hypothermia and Carbon Monoxide Poisoning Cases Soar in the City After Hurricane. New York Times. November 28.2012

event. Disruptions to key public services such as electricity, transportation, schools, and health care may become more common.[13] Table 3-19 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a severe winter storm.

Table 3-19: Estimated Potential Loss by Tax Classification in Greenfield				
Tax Classification	**Total Assessed Value FY2019**	**1% Damage Loss Estimate**	**5% Damage Loss Estimate**	**10% Damage Loss Estimate**
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

Agriculture

Severe winter weather can lead to flooding in low-lying agricultural areas. Ice that accumulates on branches in orchards and forests can cause branches to break, while the combination of ice and wind can fell trees. Storms that occur in spring can delay planting schedules. Frost that occurs after warmer periods in spring can cause cold weather dieback and damage new growth.

Energy

Severe weather can cause power outages from trees that fall during heavy snow and strong wind events. Severe ice events can take down transmission and distribution lines. The severe weather can impair a utility's ability to rapidly repair and recover the system.

Public Health

Severe winter weather presents many health hazards, as previously described in the discussion of the severe winter storm/nor'easter hazard profile. Severe winter storms and events with extended power outages may overburden hospitals and emergency shelters.

Public Safety

Public safety buildings may experience direct loss (damage) from downed trees, heavy snowfall, and high winds. Full functionality of critical facilities, such as police, fire and medical facilities, is essential for response during and after a winter storm event. Because power interruptions can

[13] Resilient MA 2018

occur, backup power is recommended for critical facilities and infrastructure. The ability of emergency responders to respond to calls may be impaired by heavy snowfall, icy roads, and downed trees.

Transportation

Other infrastructure elements at risk for this hazard include roadways, which can be obstructed by snow and ice accumulation or by windblown debris. Additionally, over time, roadways can be damaged from the application of salt and the thermal expansion and contraction from alternating freezing and warming conditions. Other types of infrastructure, including rail, aviation, port, and waterway infrastructure (if temperatures are cold enough to cause widespread freezing), can be impacted by winter storm conditions.

Water Infrastructure

Water infrastructure that is exposed to winter conditions may freeze or be damaged by ice.

Environment

Although winter storms are a natural part of the Massachusetts climate, and native ecosystems and species are well adapted to these events, changes in the frequency or severity of winter storms could increase their environmental impacts. Environmental impacts of severe winter storms can include direct mortality of individual plants and animals and felling of trees, which can damage the physical structure of the ecosystem. Similarly, if large numbers of plants or animals die as the result of a storm, their lack of availability can impact the food supply for animals in the same food web. If many trees fall or die within a small area, they can release large amounts of carbon as they decay. This unexpected release can cause further imbalance in the local ecosystem. The flooding that results when snow and ice melt can also cause extensive environmental impacts. Nor'easters can cause impacts that are similar to those of hurricanes and tropical storms and flooding. These impacts can include direct damage to species and ecosystems, habitat destruction, and the distribution of contaminants and hazardous materials throughout the environment.

Vulnerability Summary

Based on the above assessment, Greenfield faces a "High Risk" vulnerability rating from severe snow storms and ice storms. Severe Winter Storms / Ice Storms occur frequently in Greenfield. However, the severity of impact is considered "Limited", except for impact to population, which could be critical. The following problem statements summarize Greenfield's areas of greatest concern regarding severe winter storms.

Severe Winter Storm (Snow and Ice) Hazard Problem Statements
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris and snow storage/disposal location(s). Snow storage and disposal may become more challenging with the predicted frequency and severity of future winter storms.
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Greenfield's hazard tree program should maximize coordination between different City departments and the utilities companies.
• Red pine trees are top heavy and encroaching on the road shoulder of Oak Hill Access Road. A cutting plan is needed in order to minimize this hazard during severe winter storms.
• Some of Greenfield's residents rely on private wells, placing them at risk during prolonged power outages caused by severe winter storms.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City's evacuation routes may be impacted by severe winter storms and ice. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a winter storm.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with current population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stonely Burnham, and Franklin Medical Center.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
• The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.

Severe Winter Storm (Snow and Ice) Hazard Problem Statements
• Existing communication infrastructure issues and vulnerabilities could be exacerbated by severe winter storm hazards impacts.

3.5 HURRICANES / TROPICAL STORMS

Potential Effects of Climate Change

A 2017 U.S. Climate Science Special Report noted that there has been an upward trend in North Atlantic hurricane activity since 1970. The report forecasts that future hurricanes formed in the North Atlantic will drop more rain and may have higher wind speeds. This is because a warmer atmosphere will hold more water, and hurricanes are efficient at wringing water out of the atmosphere and dumping it on land. When extreme storms like Tropical Storm Irene travel over inland areas, they may release large quantities of precipitation and cause rivers to overtop their banks. Irene dumped more than 10 inches of rain in western Massachusetts. Buildings floated downriver in Shelburne Falls, flooded highways were closed, and 400,000 utility customers lost power (resilient MA, 2018). Figure 3-5 displays the potential effects of climate change on hurricanes and tropical storms from the Massachusetts State Hazard Mitigation and Climate Adaptation Plan.

Figure 3-5: Effects of Climate Change on Hurricanes and Tropical Storms

Potential Effects of Climate Change		
	EXTREME WEATHER AND RISING TEMPERATURES ➔ LARGER, STRONGER STORMS	As warmer oceans provide more energy for storms, both past events and models of future conditions suggest that the intensity of tropical storms and hurricanes will increase.
	CHANGES IN PRECIPITATION ➔ INCREASED RAINFALL RATES	Warmer air can hold more water vapor, which means the rate of rainfall will increase. One study found that hurricane rainfall rates were projected to rise 7 percent for every degree Celsius increase in tropical sea surface temperature.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

Hurricanes can range from as small as 50 miles across to as much as 500 miles across; Hurricane Allen in 1980 took up the entire Gulf of Mexico. There are generally two source regions for storms that have the potential to strike New England: (1) off the Cape Verde Islands near the west coast of Africa, and (2) in the Bahamas. The Cape Verde storms tend to be very large in diameter, since they have a week or more to traverse the Atlantic Ocean and grow. The Bahamas storms tend to be smaller, but they can also be just as powerful, and their effects can reach New England in only a day or two.

Tropical systems customarily come from a southerly direction and when they accelerate up the East Coast of the U.S., most take on a distinct appearance that is different from a typical hurricane. Instead of having a perfectly concentric storm with heavy rain blowing from one direction, then the calm eye, then the heavy rain blowing from the opposite direction, our storms (as viewed from satellite and radar) take on an almost winter-storm-like appearance. Although rain is often limited in the areas south and east of the track of the storm, these areas can experience the worst winds and storm surge. Dangerous flooding occurs most often to the north and west of the track of the storm. An additional threat associated with a tropical system making landfall is the possibility of tornado generation. Tornadoes would generally occur in the outer bands to the north and east of the storm, a few hours to as much as 15 hours prior to landfall.

The official hurricane season runs from June 1 to November 30. In New England, these storms are most likely to occur in August, September, and the first half of October. This is due in large part to the fact that it takes a considerable amount of time for the waters south of Long Island to warm to the temperature necessary to sustain the storms this far north. Also, as the region progresses into the fall months, the upper-level jet stream has more dips, meaning that the steering winds might flow from the Great Lakes southward to the Gulf States and then back northward up the eastern seaboard. This pattern would be conducive for capturing a tropical system over the Bahamas and accelerating it northward.

Tropical Storms

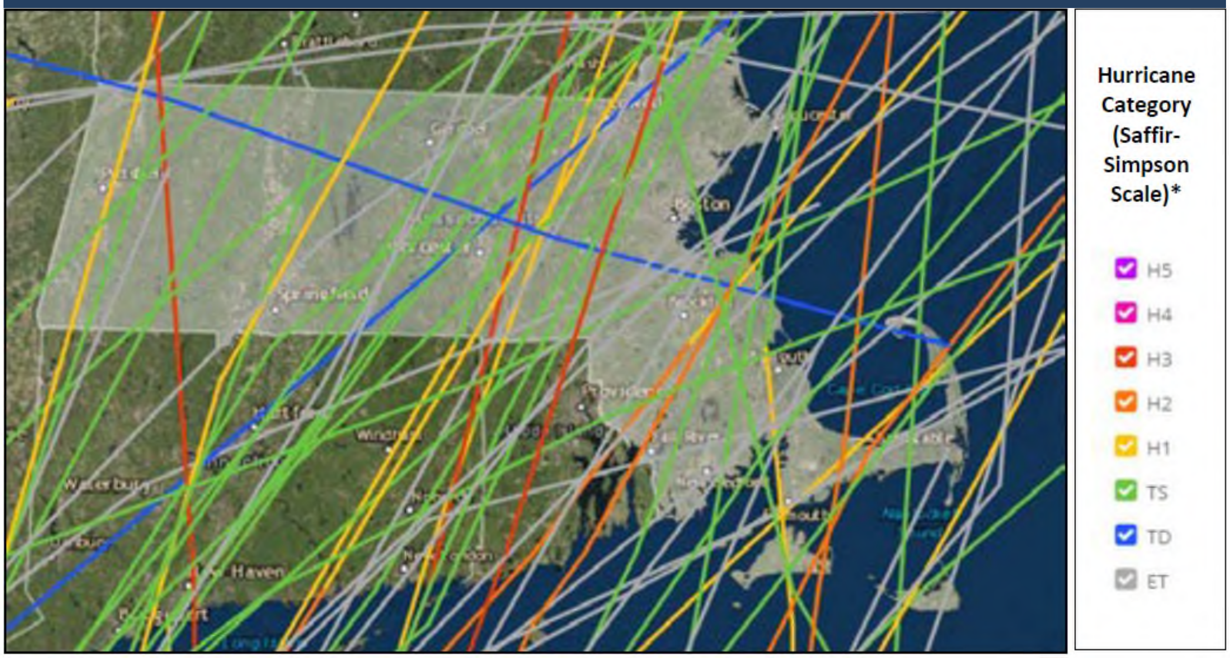
A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, thus gaining its status as a tropical storm versus a hurricane). Tropical storms strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms, such as nor'easters and polar lows. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings—a phenomenon called "warm core" storm systems.

The term "tropical" refers both to the geographical origin of these systems, which usually form in tropical regions of the globe, and to their formation in maritime tropical air masses. The term "cyclone" refers to such storms' cyclonic nature, with counterclockwise wind flow in the Northern Hemisphere and clockwise wind flow in the Southern Hemisphere.

Location

Because of the hazard's regional nature, all of Greenfield is at risk from hurricanes and tropical storms, with a "Large" location of occurrence with over 50 percent of land area affected. Ridge tops are more susceptible to wind damage. Inland areas, especially those in floodplains, are also at risk for flooding from heavy rain and wind damage. The majority of the damage following hurricanes and tropical storms often results from residual wind damage and inland flooding, as was demonstrated during recent tropical storms.

Figure 3-6: Historical Hurricane Paths within 65 Miles of Massachusetts



Source: NOAA, n.d. * TS=Tropical Storm, TD=Tropical Depression

NOAA's Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. This interactive tool tracks tropical cyclones from 1842 to 2017. According to this resource, over the time frame tracked, 63 events categorized as an extra-tropical storm or higher occurred within 65 nautical miles of Massachusetts. The tracks of these storms are shown in Figure 3-6. As this figure shows, the paths of these storms vary across the Commonwealth, but are more likely to occur toward the coast.

As described in the Flooding section of this plan, Greenfield is highly vulnerable to localized flooding in many places across the City, as well as inundation by floodwaters of the Green River in particular. These types of flooding can be caused by Hurricanes and Tropical Storms and impact homes, business, roads, critical facilities, and infrastructure.

Extent

Hurricanes are measured according to the Saffir-Simpson scale, which categorizes or rates hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to give an estimate of the potential property damage and flooding expected from a hurricane landfall. Wind speed is the determining factor in the scale. All winds are assessed using the U.S. 1-minute average, meaning the highest wind that is sustained for 1 minute. The Saffir-Simpson Scale described in Table 3-20 gives an overview of the wind speeds and range of damage caused by different hurricane categories.

Table 3-20: Saffir-Simpson Scale

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

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

Tropical storms and tropical depressions, while generally less dangerous than hurricanes, can be deadly. The winds of tropical depressions and tropical storms are usually not the greatest threat; rather, the rains, flooding, and severe weather associated with the tropical storms are what customarily cause more significant problems. Serious power outages can also be associated with these types of events. After Hurricane Irene passed through the region as a tropical storm in late August 2011, many areas of the Commonwealth were without power for more than 5 days.

While tropical storms can produce extremely powerful winds and torrential rain, they are also able to produce high waves, damaging storm surge, and tornadoes. They develop over large bodies of warm water and lose their strength if they move over land due to increased surface friction and loss of the warm ocean as an energy source. Heavy rains associated with a tropical storm, however, can produce significant flooding inland, and storm surges can produce extensive coastal flooding up to 25 miles from the coastline.

One measure of the size of a tropical cyclone is determined by measuring the distance from its center of circulation to its outermost closed isobar. If the radius is less than 2 degrees of latitude, or 138 miles, then the cyclone is "very small." A radius between 3 and 6 degrees of latitude, or 207 to 420 miles, is considered "average-sized." "Very large" tropical cyclones have a radius of greater than 8 degrees, or 552 miles.

Previous Occurrences
According to NOAA's Historical Hurricane Tracker tool, 63 hurricane or tropical storm events have occurred in the vicinity of Massachusetts between 1842 and 2016. The Commonwealth was impacted by tropical storms Jose and Phillipe in 2017. Therefore, there is an average of one storm every other year or 0.5 storms per year. Storms severe enough to receive FEMA disaster declarations, however, are far rarer, occurring every 9 years on average. The Commonwealth has not been impacted by any Category 4 or 5 hurricanes; however, Category 3 storms have historically caused widespread flooding. Winds have caused sufficient damage to impair the ability of individuals to remain in their homes.

In Massachusetts, major hurricanes occurred in 1904, 1938, 1954, 1955, 1960 and 1976, 1985, 1991 and 2010. The Great New England Hurricane of 1938, a Category 3 hurricane which occurred on September 21, 1938, was one of the most destructive and powerful storms ever to strike Southern New England. Sustained hurricane force winds occurred throughout most of Southern New England. Extensive damage occurred to roofs, trees and crops. Widespread power outages occurred, which in some areas lasted several weeks. Rainfall from this hurricane resulted in severe river flooding across sections of Massachusetts and Connecticut. The combined effects from a frontal system several days earlier and the hurricane produced rainfall of 10 to 17 inches across most of the Connecticut River Valley. This resulted in some of the worst flooding ever recorded in this area. The most recent hurricane to make landfall in Franklin County was Hurricane Bob, a weak category 2 hurricane, which made landfall in New England in August 1991. In Franklin County, Hurricane Bob caused roughly $5,555,556 in property and crop damages. No hurricane has tracked directly through the City of Greenfield.

Historic data for hurricane and tropical storm events indicate one hurricane and 17 tropical storms have been recorded in Franklin County. Hurricane Bob in 1991 caused over $5.5 million in property damage in the county, and over $500,000 in crop damage. As discussed in the Flooding section of this plan, Tropical Storm Irene caused over $26 million in property damage in Franklin County, mostly from flooding impacts.

Probability of Future Events

A 2017 U.S. Climate Science Special Report noted that there has been an upward trend in North Atlantic hurricane activity since 1970. The report forecasts that future hurricanes formed in the North Atlantic will drop more rain and may have higher wind speeds. This is because a warmer atmosphere will hold more water, and hurricanes are efficient at wringing water out of the atmosphere and dumping it on land.[14]

Greenfield's location in western Massachusetts reduces the risk of extremely high winds that are associated with hurricanes, although it can still experience some high wind events. Based upon past occurrences, Greenfield has a "Very High" probability, or a 50-100% chance, of experiencing a hurricane or tropical storm event in a given year.

Impact

The Vulnerability Assessment revealed an occurrence could have a "Catastrophic" impact on the City, with potential multiple deaths and injuries to citizens possible and with a potential of more than 50% of property damaged or destroyed.

Vulnerability

The entire City would be vulnerable to the impact of a hurricane or tropical storm. Areas prone to flooding are particularly vulnerable. Additionally high winds could impact the City's communication and energy infrastructure.

Society

Vulnerable Populations

Among the exposed populations, the most vulnerable include people with low socioeconomic status, people over the age of 65, people with medical needs, and those with low English language fluency. For example, people with low socioeconomic status are likely to consider the economic impacts of evacuation when deciding whether or not to evacuate. Individuals with medical needs may have trouble evacuating and accessing needed medical care while displaced. Those who have low English language fluency may not receive or understand the warnings to evacuate. During and after an event, rescue workers and utility workers are vulnerable to impacts from high water, swift currents, rescues, and submerged debris.

[14] ResilientMA: Climate Change Clearing House for the Commonwealth: http://resilientma.org/changes/extreme-weather. Accessed January 11, 2019.

Vulnerable populations may also be less likely to have adequate resources to recover from the loss of their homes and jobs or to relocate from a damaged neighborhood.

Table 3-21 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during a hurricane or tropical storm event.

Table 3-21: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884
Note: Individuals and households may be counted under multiple categories.
Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Health Impacts

The health impacts from hurricanes and tropical storms can generally be separated into impacts from flooding and impacts from wind. The potential health impacts of flooding are extensive, and are discussed in detail in the Flooding section. In general, some of the most serious flooding-related health threats include floodwaters sweeping away individuals or cars, downed power lines, and exposure to hazards in the water, including dangerous animals or infectious organisms. Contact with contaminated floodwaters can cause gastrointestinal illness.

Wind-related health threats associated with hurricanes are most commonly caused by projectiles propelled by the storm’s winds. Wind- and water-caused damage to residential structures can also increase the risk of threat impacts by leaving residents more exposed to the elements. Hurricanes that occur later in the year also increase the risk of hypothermia.

Economic Impacts

In addition to the human costs that extreme storms deliver when they permanently or temporarily displace people, the repair and reconstruction costs after storm damage can be enormous for homeowners and businesses. When bridges and culverts have been washed away and roads damaged, municipal and state agencies must secure the resources for expensive recovery projects in limited municipal budgets and from Federal disaster grant programs that are increasingly over-subscribed. Electrical grid, power plants and wastewater infrastructure repair costs are all expected to increase in the future.[15]

Infrastructure

Hurricanes and tropical storms could catastrophically impact the City, with a potential of more than 50% of property in affected area damaged or destroyed. Residential and commercial buildings built along rivers may be vulnerable to severe damage. Potential structural damage to the facilities themselves may include damage to roofs and building frames. These facilities may not be fully operational if workers are unable to travel to ensure continuity of operations prior and after a severe winter event. Table 3-22 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a hurricane or tropical storm.

Table 3-22: Estimated Potential Loss by Tax Classification

Tax Classification	Total Assessed Value FY2019	1% Damage Loss Estimate	5% Damage Loss Estimate	10% Damage Loss Estimate
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

Energy

Hurricanes and tropical storms often result in power outages and contact with damaged power lines during and after a storm, which may result in electrocution.

[15] ResilientMA: Climate Change Clearing House for the Commonwealth: http://resilientma.org/changes/extreme-weather. Accessed January 29, 2019.

Public Health

Combined sewer overflows associated with heavy rainfall can release contaminants, chemicals, and pathogens directly into the environment and into water systems. If a mass outbreak of waterborne illness were to occur, hospitals and medical providers may lack the capacity to treat patients.

Public Safety

Critical infrastructure, including local and state-owned police and fire stations, other public safety buildings, and facilities that serve as emergency operation centers may experience direct loss (damage) during a hurricane or tropical storm. Emergency responders may also be exposed to hazardous situations when responding to calls. Road blockages caused by downed trees may impair travel.

Transportation

Some roads and bridges are also considered critical infrastructure, particularly those providing ingress and egress and allowing emergency vehicles access to those in need. Costly damage to roads, bridges, and rail networks may occur as a result of hurricanes.[16]

Water and Wastewater Infrastructure

Wastewater treatment centers may face elevated risks of damage and destruction from hurricanes (resilient MA, 2018). Heavy rains can lead to contamination of well water and can release contaminants from septic systems (DPH, 2014). Heavy rainfall can also overburden stormwater systems, drinking water supplies, and sewage systems.

Environment

The environmental impacts of hurricanes and tropical storms are similar to those described for other hazards, including flooding, severe winter storms and other severe weather events. As described for human health, environmental impacts can generally be divided into short-term direct impacts and long-term impacts. As the storm is occurring, flooding may disrupt normal ecosystem function and wind may fell trees and other vegetation. Additionally, wind-borne or waterborne detritus can cause mortality to animals if they are struck or transported to a non-suitable habitat.

In the longer term, impacts to natural resources and the environment as a result of hurricanes and tropical storms are generally related to changes in the physical structure of ecosystems. For

[16] Resilient MA 2018.

example, flooding may cause scour in riverbeds and erode riverbanks, modifying the river ecosystem and depositing the scoured sediment in another location. Similarly, trees that fall during the storm may represent lost habitat for local species, or they may decompose and provide nutrients for the growth of new vegetation. If the storm spreads pollutants into natural ecosystems, contamination can disrupt food and water supplies, causing widespread and long-term population impacts on species in the area.

Vulnerability Summary

Based on the above analysis, Greenfield faces a “High” vulnerability from hurricanes and tropical storms. While historically there have been no Hurricane events in Greenfield, the Vulnerability Assessment revealed an occurrence could catastrophically impact the City, with potential multiple injuries to citizens possible and with a potential of more than 50% of property in affected area damaged or destroyed. The following problem statements summarize Greenfield’s greatest areas of concern regarding hurricanes and tropical storms.

Hurricane / Tropical Storm Hazard Problem Statements
• Although the City has “Greenfield Alerts”, a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Greenfield’s hazard tree program should maximize coordination between different City departments and the utilities companies.
• Red pine trees are top heavy and encroaching on the road shoulder of Oak Hill Access Road. A cutting plan is needed in order to minimize this hazard during tropical storm events.
• An estimated 72% of homes in Greenfield were built prior to the first State building code in 1975, potentially making them more vulnerable to damages from high winds associated with a hurricane or tropical storm.

Hurricane / Tropical Storm Hazard Problem Statements
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City’s evacuation routes may be impacted by a hurricane or tropical storm. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged by impacts of a hurricane or tropical storm.
• Evacuation and sheltering plans may need to be revised and updated to account for flooding on vital evacuation routes including River Street, Mill Street, Deerfield Street, Route 2A, and Shelburne Road. A central communication system should be devised to manage road closures due to flash flooding and to facilitate efficient evacuation. New signage and road closure devices are needed as part of a updated evacuation planning.
• An improved process is needed for estimating and tracking local crop damage caused by a hurricane or tropical storm hazard events.
• Heavy rain and strong winds associated with hurricanes and tropical storms exacerbates the risk of flooding, dam failures, and severe wind hazards. Also see the flooding, dam failure, and severe thunderstom, wind, or microburst hazard problem statements.

3.6 SEVERE THUNDERSTORMS / WIND / MICROBURSTS

Potential Effects of Climate Change

Climate change is expected to increase extreme weather events across the globe and in Massachusetts. Climate change leads to extreme weather because of warmer air and ocean temperatures and changing air currents. Warmer air leads to more evaporation from large water bodies and holds more moisture, so when clouds release their precipitation, there is more of it. In addition, changes in atmospheric air currents like jet streams and ocean currents can cause changes in the intensity and duration of stormy weather. While it is difficult to connect one storm to a changing climate, scientists point to the northeastern United States as one of the regions that is most vulnerable to an increase in extreme weather driven by climate change.[17]

Figure 3-7: Effects of Climate Change on Severe Thunderstorms, Wind, and Microbursts

Potential Effects of Climate Change		
	EXTREME WEATHER AND CHANGES IN PRECIPITATION ➔ MORE INTENSE AND FREQUENT THUNDERSTORMS AND DOWNPOURS	The Northeast has already experienced a larger increase in the intensity of rainfall events than any other region in the United States in the last fifty years, and this trend is expected to continue.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

A thunderstorm is a storm originating in a cumulonimbus cloud. Cumulonimbus clouds produce lightning, which locally heats the air to 50,000 degrees Celsius, which in turn produces an audible shock wave, known as thunder. Frequently during thunderstorm events, heavy rain and gusty winds are present. Less frequently, hail is present, which can become very large in size. Tornadoes can also be generated during these events. According to the National Weather Service, a thunderstorm is classified as "severe" when it produces damaging wind gusts in excess of 58 mph (50 knots), hail that is 1 inch in diameter or larger (quarter size), or a tornado.

Every thunderstorm has an updraft (rising air) and a downdraft (sinking air). Sometimes strong downdrafts known as downbursts can cause tremendous wind damage that is similar to that of a tornado. A small (less than 2.5 mile path) downburst is known as a "microburst" and a larger downburst is called a "macro-burst." An organized, fast-moving line of microbursts traveling

[17] ResilientMA: Climate Change Clearing House for the Commonwealth: http://resilientma.org/changes/extreme-weather. Accessed January 29, 2019.

across large areas is known as a "derecho." These occasionally occur in Massachusetts. Winds exceeding 100 mph have been measured from downbursts in Massachusetts.

Wind is air in motion relative to surface of the earth. For non-tropical events over land, the NWS issues a Wind Advisory (sustained winds of 31 to 39 mph for at least 1 hour or any gusts 46 to 57 mph) or a High Wind Warning (sustained winds 40+ mph or any gusts 58+ mph). For non-tropical events over water, the NWS issues a small craft advisory (sustained winds 25-33 knots), a gale warning (sustained winds 34-47 knots), a storm warning (sustained winds 48 to 63 knots), or a hurricane force wind warning (sustained winds 64+ knots). For tropical systems, the NWS issues a tropical storm warning for any areas (inland or coastal) that are expecting sustained winds from 39 to 73 mph. A hurricane warning is issued for any areas (inland or coastal) that are expecting sustained winds of 74 mph. Effects from high winds can include downed trees and/or power lines and damage to roofs, windows, and other structural components. High winds can cause scattered power outages. High winds are also a hazard for aircraft.

Location

The entire City of Greenfield is at risk for severe thunderstorms, wind and microbursts.

Extent

An average thunderstorm is 15 miles across and lasts 30 minutes; severe thunderstorms can be much larger and longer. The severity of thunderstorms can vary widely, from commonplace and short-term events to large-scale storms that result in direct damage and flooding. Thunderstorms can cause hail, wind, and flooding, with widespread flooding the most common characteristic that leads to a storm being declared a disaster. The severity of flooding varies widely based both on characteristics of the storm itself and the region in which it occurs. Lightning can occasionally also present a severe hazard. Southern New England typically experiences 10 to 15 days per year with severe thunderstorms.

Microbursts are typically less than three miles across. They can last anywhere from a few seconds to several minutes. Microbursts cause damaging winds up to 170 miles per hour in strength and can be accompanied by precipitation.

Figure 3-8: Beaufort Wind Scale

Beaufort number	Wind Speed (mph)	Seaman's term		Effects on Land
0	Under 1	Calm		Calm; smoke rises vertically.
1	1-3	Light Air		Smoke drift indicates wind direction; vanes do not move.
2	4-7	Light Breeze		Wind felt on face; leaves rustle; vanes begin to move.
3	8-12	Gentle Breeze		Leaves, small twigs in constant motion; light flags extended.
4	13-18	Moderate Breeze		Dust, leaves and loose paper raised up; small branches move.
5	19-24	Fresh Breeze		Small trees begin to sway.
6	25-31	Strong Breeze		Large branches of trees in motion; whistling heard in wires.
7	32-38	Moderate Gale		Whole trees in motion; resistance felt in walking against the wind.
8	39-46	Fresh Gale		Twigs and small branches broken off trees.
9	47-54	Strong Gale		Slight structural damage occurs; slate blown from roofs.
10	55-63	Whole Gale		Seldom experienced on land; trees broken; structural damage occurs.
11	64-72	Storm		Very rarely experienced on land; usually with widespread damage.
12	73 or higher	Hurricane Force		Violence and destruction.

Source: Developed in 1805 by Sir Francis Beaufort

Greenfield is susceptible to high winds from several types of weather events: before and after frontal systems, hurricanes and tropical storms, severe thunderstorms and tornadoes, and nor'easters. Sometimes, wind gusts of only 40 to 45 mph can cause scattered power outages from downed trees and wires. This is especially true after periods of prolonged drought or excessive rainfall, since both are situations that can weaken the root systems and make them more susceptible to the winds' effects. Winds measuring less than 30 mph are not considered to be hazardous under most circumstances. Wind speeds in a hurricane are measured using the Saffir-Simpson scale. Another scale developed for measuring wind is the Beaufort wind scale (see Figure 3-8).

Previous Occurrences

Since 1996, a total of 13 high wind events occurred in Franklin County (Table 3-23), causing a total of $288,000 in property damages. High winds are defined by the National Weather Service as sustained non-convective winds of 35 knots (40 mph) or greater lasting for 1 hour or longer, or gusts of 50 knots (58 mph) or greater for any duration. The probability of future high wind events is expected to increase as a result of climate projections for the state that suggest a greater occurrence of severe weather events in the future.

Table 3-23: High Wind Events in Franklin County			
Year	**# of High Wind Events**	**Annual Property Damage**	**Annual Crop Damage**
1996	2	$0	No Data
1999	1	$0	No Data
2003	2	$130,000	No Data
2004	1	$30,000	No Data
2005	1	$10,000	No Data
2006	3	$68,000	No Data
2011	1	$15,000	No Data
2013	2	$35,000	No Data
Total	**13**	**$288,000**	No Data

Source: NOAA Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

Thunderstorm winds are defined by the National Weather Service as winds arising from convection (occurring within 30 minutes of lightning being observed or detected) with speeds of at least 50 knots (58 mph), or winds of any speed (non-severe thunderstorm winds below 50 knots) producing a fatality, injury, or damage. Greenfield has experienced 28 thunderstorm wind events since 1994 (Table 3-24). These storms resulted in downed trees and wires and caused $222,000 in property damage.

Table 3-24: Thunderstorm Wind Events in Greenfield				
Year	**# of Thunderstorm Wind Events**	**Annual Property Damage**	**Annual Crop Damage**	**Event Description**
1994	1	$0	No Data	Large trees were blown down and a power line was knocked down.
1998	2	$0	No Data	In the first event, a wind gust of an estimated 68 mph was reported by a spotter in Greenfield. In the second event, an early morning severe thunderstorm downed at least two trees in Greenfield as reported by the local police.

Table 3-24: Thunderstorm Wind Events in Greenfield				
Year	**# of Thunderstorm Wind Events**	**Annual Property Damage**	**Annual Crop Damage**	**Event Description**
2001	1	$0	No Data	A severe thunderstorm moved across much of central and northeast Masachusetts.
2004	2	$10,000	No Data	Severe thunderstorms brought damaging winds and large hail to parts of western and north central Massachusetts. Penny sized hail was reported in Greenfield.
2005	1	$5,000	No Data	Thunderstorms produced damaging wind gusts, large hail, and flash flooding. The hardest hit counties include Hampden, Franklin, Worcester, and Plymouth. These storms also left as many as 51,000 electric customers without power.
2006	1	$5,000	No Data	Trees and wires were downed on Thayer Road and Bolton Road in Greenfield.
2008	3	$8,000	No Data	Trees were downed by thunderstorm winds.
2010	3	$70,000	No Data	Multiple trees downed throughout Greenfield, resulting in numerous road closures and power outages.
2011	1	$25,000	No Data	Large trees on Deerfield Street and on both sides of Interstate 91 were downed by thunderstorm winds.
2012	1	$2,000	No Data	A tree on Silver Street was uprooted.
2014	4	$45,000	No Data	During these events power lines on Shelburne Road, Route 2, Highland Avenue, Leyden Road, and Wisdom Way were downed. Additionally, trees on Colrain Street, Route 2, Leyden Road were downed by thunderstorm winds.
2015	1	$5,000	No Data	A large tree was downed onto wires on Shelburne Road by thunderstorm winds.

Table 3-24: Thunderstorm Wind Events in Greenfield				
Year	**# of Thunderstorm Wind Events**	**Annual Property Damage**	**Annual Crop Damage**	**Event Description**
2016	6	$44,000	No Data	During these events a large trees were downed on Turners Falls Road, Forest Avenue, the intersection of Congress and Orchard Streets, Mill Street, Prospect Avenue, and Leonard Street. Wires were also downed during these storms.
2017	1	$3,000	No Data	Trees and wires down on Mountain Road in Greenfield.

Source: NOAA Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

Secondary hazards of thunderstorms and severe weather include lightning and hail. In Franklin County, 22 lightning events since 1997 caused a total of $835,500 in property damages (Table 3-25).

Table 3-25: Lightning Events in Franklin County			
Year	**# of Lightning Events**	**Annual Property Damage**	**Annual Crop Damage**
1997	1	$3,000	No Data
2001	1	$20,000	No Data
2002	1	$15,000	No Data
2004	1	$35,000	No Data
2005	1	$50,000	No Data
2008	1	$10,000	No Data
2010	2	$25,000	No Data
2012	1	$500,000	No Data
2013	4	$49,000	No Data
2014	3	$93,000	No Data
2018	6	$35,500	No Data
Total	**22**	**$835,500**	No Data

Source: NOAA Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

A total of 42 hail events have been reported in Franklin County since 1998 (Table 3-26). Property damage was only recorded for one event, in the amount of $5,000. One hail event in 2008 resulted in $50,000 in crop damages. Pea to marble size hail fell in a swath from Colrain to

Shelburne damaging apple and peach orchards. An estimated 45 acres of apples and two to three acres of peaches were damaged by the hail.

Table 3-26: Hail Events in Franklin County			
Year	**# of Hail Events**	**Annual Property Damage**	**Annual Crop Damage**
1998	4	$0	No Data
2000	1	$0	No Data
2001	1	$0	No Data
2003	1	$0	No Data
2004	2	$0	No Data
2005	3	$5,000	No Data
2007	5	$0	No Data
2008	7	$0	$50,000
2009	2	$0	No Data
2010	4	$0	No Data
2011	4	$0	No Data
2012	1	$0	No Data
2013	3	$0	No Data
2017	3	$0	No Data
2018	1	$0	No Data
Total	**42**	**$5,000**	**$50,000**

Source: NOAA Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

Probability of Future Events

According to the National Weather Service, Massachusetts experiences between 20 to 30 thunderstorm days each year. Based on past occurrences, there is a "Very High" probability (50% - 100% chance) of a severe thunderstorm or winds affecting the City in a given year. Climate change is expected to increase the frequency and intensity of thunderstorms and other severe weather.

Impact

The entire City of Greenfield is vulnerable to high winds that can cause extensive damage. The U.S. is divided into four wind zones. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes. The Commonwealth is located within Wind Zone II, which includes wind speeds up to 180 mph. The entire Commonwealth is also located within the hurricane-susceptible region, and the western portion of the

Commonwealth is located within the special wind region, in which wind-speed anomalies are present and additional consideration of the wind hazard is warranted. The entire City of Greenfield can experience the effect and impact from severe thunderstorms, microbursts, and hail. The magnitude of impact of a severe thunderstorm event is likely “Critical,” with more than 25% of property in the affected area damaged or destroyed.

Vulnerability

Society

The entire population of Greenfield is considered exposed to high-wind and thunderstorm events. Downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Populations located outdoors are considered at risk and more vulnerable to many storm impacts, particularly lightning strikes, compared to those who are located inside. Moving to a lower risk location will decrease a person’s vulnerability.

<u>Vulnerable Populations</u>

Socially vulnerable populations are most susceptible to severe weather based on a number of factors, including their physical and financial ability to react or respond during a hazard, and the location and construction quality of their housing. In general, vulnerable populations include people over the age of 65, the elderly living alone, people with low socioeconomic status, people with low English language fluency, people with limited mobility or a life-threatening illness, and people who lack transportation or are living in areas that are isolated from major roads. The isolation of these populations is a significant concern.

Table 3-27 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during a severe weather event.

Table 3-27: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%

Table 3-27: Estimated Vulnerable Populations in Greenfield		
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Power outages can be life-threatening to those dependent on electricity for life support. Power outages may also result in inappropriate use of combustion heaters, cooking appliances and generators in indoor or poorly ventilated areas, leading to increased risks of carbon monoxide poisoning. People who work or engage in recreation outdoors are also vulnerable to severe weather.

Health Impacts

Both high winds and thunderstorms present potential safety impacts for individuals without access to shelter during these events. Extreme rainfall events can also affect raw water quality by increasing turbidity and bacteriological contaminants leading to gastrointestinal illness. Additionally, research has found that thunderstorms may cause the rate of emergency room visits for asthma to increase to 5 to 10 times the normal rate.[18] Much of this phenomenon is attributed to the stress and anxiety that many individuals, particularly children, experience during severe thunderstorms. The combination of wind, rain, and lightning from thunderstorms with pollen and mold spores can exacerbate asthma. The rapidly falling air temperatures characteristic of a thunderstorm as well as the production of nitrogen oxide gas during lightning strikes have also both been correlated with asthma.

Economic Impacts

Wind storms and severe thunderstorms events may impact the economy, including direct building losses and the cost of repairing or replacing the damage caused to the building. Additional economic impacts may include loss of business functions, water supply system

[18] Andrews, L.W. 2012. How Thunderstorms Affect Health. Psychology Today. June 2, 2012. Https://www.psychologytoday.com/blog/minding-the-body/201206/how-thunderstorms-affect-health

damage, inventory damage, relocation costs, wage losses, and rental losses due to the repair/replacement of buildings. Agricultural losses due to lightning and the resulting fires can be extensive. Lightning can be responsible for damage to buildings; can cause electrical, forest and/or wildfires; and can damage infrastructure, such as power transmission lines and communication towers.

Recovery and clean-up costs can also be costly, resulting in further economic impacts. Prolonged obstruction of major routes due to secondary hazards such as landslides, debris, or floodwaters can disrupt the shipment of goods and other commerce. Large, prolonged storms can have negative economic impacts on an entire region.

Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

Infrastructure

Damage to buildings is dependent upon several factors, including wind speed, storm duration, path of the storm track, and building construction. According to the Hazus wind model,[19] direct wind-induced damage (wind pressures and windborne debris) to buildings is dependent upon the performance of components and cladding, including the roof covering (shingles, tiles, membrane), roof sheathing (typically wood-frame construction only), windows, and doors, and is modeled as such. Structural wall failures can occur for masonry and wood-frame walls, and uplift of whole roof systems can occur due to failures at the roof/wall connections. Foundation failures (i.e., sliding, overturning, and uplift) can potentially take place in manufactured homes.

Massachusetts is divided into three design wind speeds for four risk categories, the limits of which are defined by the Massachusetts State Building Code (9th Edition). National wind data prepared by the American Society of Civil Engineers serve as the basis of these wind design requirements ("Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers ASCE-7). Generally speaking, structures should be designed to withstand the total wind load of their location. Greenfield falls within the 90 mph wind load zone. Refer to the State Building Code (9th Edition [780 CMR] Chapter 16 Structural Design, as amended by Massachusetts) for appropriate reference wind pressures, wind forces on roofs, and similar data.

[19] https://www.fema.gov/hazus-mh-hurricane-wind-model

All elements of the built environment are exposed to severe weather events such as high winds and thunderstorms. Table 3-28 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of high winds or a severe thunderstorm.

Table 3-28: Estimated Potential Loss by Tax Classification				
Tax Classification	**Total Assessed Value FY2019**	**1% Damage Loss Estimate**	**5% Damage Loss Estimate**	**10% Damage Loss Estimate**
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

Agriculture

Forestry species and agricultural crops, equipment, and infrastructure may be directly impacted by high winds. Trees are also vulnerable to lightning strikes.

Energy

The most common problem associated with severe weather is loss of utilities. Severe windstorms causing downed trees can create serious impacts on power and aboveground communication lines. Downed power lines can cause blackouts, leaving large areas isolated. Loss of electricity and phone connections would leave certain populations isolated because residents would be unable to call for assistance. Additionally, the loss of power can impact heating or cooling provision to citizens (including the young and elderly, who are particularly vulnerable to temperature-related health impacts).

Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage, and impacts can result in the loss of power, which can impact business operations. After an event, there is a risk of fire, electrocution, or an explosion.

Public Safety

Public safety facilities and equipment may experience a direct loss (damage) from high winds.

Transportation

Roads may become impassable due to flash or urban flooding, downed trees and power lines, or due to landslides caused by heavy, prolonged rains. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs.

Water & Wastewater Infrastructure

The hail, wind, and flash flooding associated with thunderstorms and high winds can cause damage to water infrastructure. Flooding can overburden stormwater, drinking water, and wastewater systems. Water and sewer systems may not function if power is lost.

Environment

As described under other hazards, such as hurricanes and severe winter storms, high winds can defoliate forest canopies and cause structural changes within an ecosystem that can destabilize food webs and cause widespread repercussions. Direct damage to plant species can include uprooting or total destruction of trees and an increased threat of wildfire in areas of tree debris. High winds can also erode soils, which can damage both the ecosystem from which soil is removed as well as the system on which the sediment is ultimately deposited.

Environmental impacts of extreme precipitation events are discussed in depth in the Flooding section, and often include soil erosion, the growth of excess fungus or bacteria, and direct impacts to wildlife. For example, research by the Butterfly Conservation Foundation shows that above average rainfall events have prevented butterflies from successfully completing their mating rituals, causing population numbers to decline. Harmful algal blooms and associated neurotoxins can also be a secondary hazard of extreme precipitation events as well as heat. Public drinking water reservoirs may also be damaged by widespread winds uprooting watershed forests and creating serious water quality disturbances.

Vulnerability Summary

Based on the above assessment, Greenfield has a “High” vulnerability to severe thunderstorms and wind events. Thunderstorms are common in New England, and can impact property, crops, utilities and the population of Greenfield. Microbursts are less common, but can cause significant damage when they do occur. The cascade effects of severe storms include utility losses and transportation accidents and flooding. Particular areas of vulnerability include low-income and elderly populations, trailer homes, and infrastructure such as roadways and utilities that can be damaged by such storms and the low-lying areas that can be impacted by flooding. The following problem statements summarize Greenfield’s areas of greatest concern regarding severe thunderstorms and wind events.

Severe Thunderstorm / Wind/Microbursts Hazard Problem Statements
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris and snow storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Greenfield's hazard tree program should maximize coordination between different City departments and the utilities companies.
• Red pine trees are top heavy and encroaching on the road shoulder of Oak Hill Access Road. A cutting plan is needed in order to minimize this hazard during severe thunderstorms, wind, or microbursts.
• Some of Greenfield's residents rely on private wells, placing them at risk during prolonged power outages caused by severe thunderstorms, wind, or microbursts.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with updated population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stonely Burnham, and Franklin Medical Center.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
• The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.
• An improved process is needed for estimating and tracking local crop damage caused by severe thunderstom, wind, or microburst hazard events.

Severe Thunderstorm / Wind/Microbursts Hazard Problem Statements
• Existing communication infrastructure issues and vulnerabilities could be exacerbated by severe thunderstorms, wind, or microbursts.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City's evacuation routes may be impacted by severe thunderstom, wind, or microburst hazard events. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a severe thunderstorms, wind, or microbursts.

3.7 TORNADOES

Potential Impacts of Climate Change

Climate change is expected to increase the frequency and intensity of severe weather, which can include tornadoes. However, tornadoes are too small to be simulated well by climate models. Therefore, specific predictions about how this hazard will change are not possible, given current technical limitations. As discussed in other sections in this Plan, the conditions that are conducive to tornadoes (which are also conducive to other weather phenomena, such as hurricanes and tropical storms) are expected to become more severe under global warming.

Figure 3-9: Impacts of Climate Change on Tornadoes

Potential Effects of Climate Change	
EXTREME WEATHER ➔ INCREASE IN FREQUENCY AND INTENSITY OF SEVERE THUNDERSTORMS	Future environmental changes may result in an increase in the frequency and intensity of severe thunderstorms, which can include tornadoes. However, the resolution of current climate models is too coarse to accurately simulate tornado formation and the confidence on model details associated with this potential increase is low.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

A tornado is a narrow, violently rotating column of air that extends from the base of a cumulonimbus cloud to the ground. The observable aspect of a tornado is the rotating column of water droplets, with dust and debris caught in the column. Tornadoes are the most violent of all atmospheric storms.

The following are common factors in tornado formation:

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

Tornadoes can form from individual cells within severe thunderstorm squall lines. They can also form from an isolated supercell thunderstorm. They can be spawned by tropical cyclones or the remnants thereof, and weak tornadoes can even occur from little more than a rain shower if air is converging and spinning upward. Most tornadoes occur in the late afternoon and evening hours, when the heating is the greatest. The most common months for tornadoes to occur are June, July, and August, although the Conway, Massachusetts, tornado (2017) occurred in February.

A tornadic waterspout is a rapidly rotating column of air extending from the cloud base (typically a cumulonimbus thunderstorm) to a water surface, such as a bay or the ocean. They can be formed in the same way as regular tornadoes, or can form on a clear day with the right amount of instability and wind shear. Tornadic waterspouts can have wind speeds of 60 to 100 mph, but since they do not move very far, they can often be navigated around. They can become a threat to land if they drift onshore.

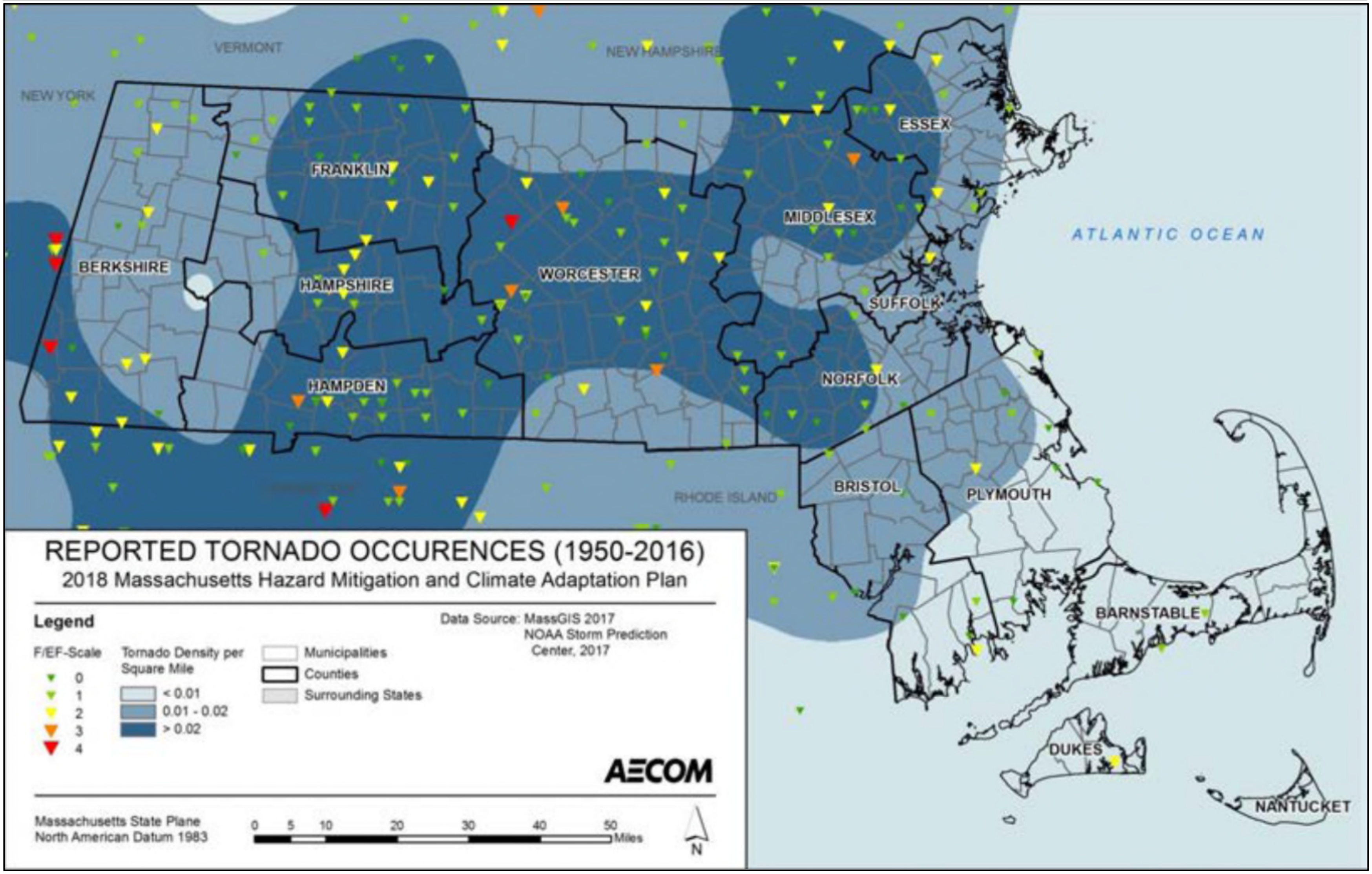
Location

Figure 3-10 illustrates the reported tornado occurrences, based on all-time initial touchdown locations across the Commonwealth as documented in the NOAA NCDC Storm Events Database. ArcGIS was used to calculate an average score per square mile. The analysis indicated that the area at greatest risk for a tornado touchdown runs from central to northeastern Massachusetts, and includes Greenfield and much of Franklin County. Tornadoes are rated as having an Area of Occurrence of “Medium.” If a tornado were to occur in Greenfield, it could impact 10% to 50% of the City.

Extent

The NWS rates tornadoes using the Enhanced Fujita scale (EF scale), which does not directly measure wind speed but rather the amount of damage created. This scale derives 3-second gusts estimated at the point of damage based on the assignment of 1 out of 8 degrees of damage to a range of different structure types. These estimates vary with height and exposure. This method is considerably more sophisticated than the original Fujita scale, and it allows surveyors to create more precise assessments of tornado severity. Figure 3-11 provides guidance from NOAA about the impacts of a storm with each rating.

Figure 3-10: Density of Reported Tornadoes per Square Mile



Source: NOAA Storm Prediction Center (SPC), as presented in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018.

Figure 3-11: Enhanced Fujita Scale & Guide to Tornado Severity

Scale	Wind Speed Estimate		Potential damage	Example of Damage
	mph	km/h		
EF0	65–85	105–137	Minor damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e., those that remain in open fields) are always rated EF0.	
EF1	86–110	138–177	Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.	
EF2	111–135	178–217	Considerable damage. Roofs torn off from well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.	
EF3	136–165	218–266	Severe damage. Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations are badly damaged.	
EF4	166–200	267–322	Devastating damage. Well-constructed and whole frame houses completely leveled; some frame homes may be swept away; cars and other large objects thrown and small missiles generated.	
EF5	>200	>322	Incredible damage. Strong-framed, well-built houses leveled off foundations and swept away; steel-reinforced concrete structures are critically damaged; tall buildings collapse or have severe structural deformations; cars, trucks, and trains can be thrown approximately 1 mile (1.6 km).	

Source: Wikipedia: https://en.wikipedia.org/wiki/Enhanced_Fujita_scale

Previous Occurrences

On June 1, 2011, thunderstorms forming ahead of a cold front across Southern New England organized into discrete supercells in an environment highly favorable for tornado formation. A tornado evaluated to be an EF-3 tornado entered Hampden County from the Berkshires, touched down in Westfield, and continued on a 38 mile long trek through West Springfield, Springfield, Wilbraham, Monson, Brimfield, and Sturbridge. This tornado was on the ground for an estimated 70 minutes. About two hours later, another supercell tracked just to the north of the storm track of the EF3 tornado. While its rotation was not as strong, it produced brief tornadoes in Wilbraham (EF1), North Brimfield (EF1), and Sturbridge (EF0). While the focus was on the tornadoes and their damage, damaging winds, large hail up to two inches in diameter, and some flash flooding also occurred across southern New England.

Since the 1950s, there have been over twenty tornadoes in Franklin County. In the last two decades, five tornadoes have been reported in Franklin County, in the Cities of Heath, Charlemont, Wendell, New Salem, and Conway (Table 3-29). The February 2017 tornado in the center of Conway was the most destructive, impacting forests and causing major property damage to several homes, barns, and a church that subsequently had to be torn down. Miraculously, no deaths or serious injuries were reported.

Table 3-29: Tornado Events in Franklin County

Date	Severity	Property Damage	Crop Damage	Event Narrative
7/3/1997	F1	$50,000	$0	A tornado touched down just west of Number Nine Road in Heath and then skipped along a path which ended about a mile into northwest Colrain. Many large trees were uprooted or snapped at their mid levels. A silo was destroyed and part of the roof of an attached barn was peeled back. A hay tractor was flipped over with its wheels in the air. Doors to a garage were blown in and the roof was partially ripped off. The tornado affected mostly wooded terrain and did extensive tree damage when it passed through a state forest. The path width was up to 100 yards. There were no injuries.
7/3/1997	F1	$50,000	$0	A tornado touched down in the eastern part of Charlemont and travelled east causing damage to a campground. Fifteen trailers were damaged from falling trees and flying debris. Two of the trailers were severely damaged and one was destroyed with seven trees falling on top of it. Eyewitnesses reported rotation in the clouds and debris. The tornado then moved through the higher

Table 3-29: Tornado Events in Franklin County				
Date	Severity	Property Damage	Crop Damage	Event Narrative
				terrain of the Catamount State Forest. The path was discontinuous and ranged in width from 50 to 100 yards. The tornado path ended in the Copeland Hills section of Colrain. There were no direct injuries reported.
7/11/2006	F2	$200,000	$0	Brief F2 touchdown in Wendell
9/1/2013	EF0	$0	$0	A Massachusetts Department of Conservation and Recreation employee observed a waterspout on Quabbin Reservoir in New Salem, MA. He was able to snap two pictures of the storm, one showing a funnel and another showing the funnel extended down to the water. The waterspout was very short lived, never hit land, and did no damage and injured no people. Winds aloft were not conducive for tornadic development, but the environment was unstable and a surface front was moving through the region.
2/25/2017	EF1	$400,000	$0	This tornado touched down at 7:23 pm on Main Poland Road in western Conway, Massachusetts. The path width started at 50 yards, with a sharp gradient evident of damage versus no damage. Large sections of forest had thick pine trees snapped at mid-tree. Numerous power lines were downed along the path into downtown Conway. The path width grew, reaching a maximum width of 200 yards near the Town Hall. Several houses were severely damaged on Whately Road, southeast of the Town Hall. Roofs were blown off, and in one case the side walls of a house were missing with the interior of the house exposed. On Hill View Road a large barn collapsed. One injury occurred when a tree landed on a house on South Conway Road east of town. That was where the visible damage path ended.

Source: NOAA Storm Events Database: https://www.ncdc.noaa.gov/stormevents/

Probability of Future Events

As highlighted in the National Climate Assessment, tornado activity in the U.S. has become more variable, and increasingly so in the last 2 decades. While the number of days per year that tornadoes occur has decreased, the number of tornadoes on these days has increased. Climate models show projections that the frequency and intensity of severe thunderstorms (which include tornadoes, hail, and winds) will increase. Based on past occurrences, there is a "Very Low" probability (less than a 1% chance) of a tornado affecting the City in a given year.

Impact

Tornadoes are potentially the most dangerous of local storms. If a major tornado were to strike in the populated areas of Greenfield, damage could be widespread. Fatalities could be high; many people could be displaced for an extended period of time; buildings could be damaged or destroyed; businesses could be forced to close for an extended period of time or even permanently; and routine services, such as telephone or power, could be disrupted. Therefore, the severity of impact of a tornado event is likely "Catastrophic," with more than 50% of property in the affected area damaged or destroyed and complete shutdown of facilities for 30 days or more.

Vulnerability

Society

The entire City of Greenfield has the potential for tornado formation, and is located in the area within Massachusetts described above as having higher-than-average tornado frequency. Residents of impacted areas may be displaced or require temporary to long-term shelter due to severe weather events. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life.

<u>Vulnerable Populations</u>

In general, vulnerable populations include people over the age of 65, people with low socioeconomic status, people with low English language fluency, people with compromised immune systems, and residents living in areas that are isolated from major roads. Power outages can be life-threatening to those who are dependent on electricity for life support and can result in increased risk of carbon monoxide poisoning. Individuals with limited communication capacity, such as those with limited internet or phone access, may not be aware of impending tornado warnings. The isolation of these populations is also a significant concern, as is the potential insufficiency of older or less stable housing to offer adequate shelter from tornadoes. Residents living in mobile homes are at increased risk to tornadoes.

An estimated 5,997 housing units in Greenfield, or 72% of all housing units in City, were built prior to the 1970s when the first building code went into effect in Massachusetts. An estimated

86 mobile homes are located in Greenfield, accounting for 1% of the total housing stock.[20] Table 3-30 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during a tornado event.

Table 3-30: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Health Impacts

The primary health hazard associated with tornadoes is the threat of direct injury from flying debris or structural collapse as well as the potential for an individual to be lifted and dropped by the tornado's winds. After the storm has subsided, tornadoes can present unique challenges to search and rescue efforts because of the extensive and widespread distribution of debris. The distribution of hazardous materials, including asbestos-containing building materials, can present an acute health risk for personnel cleaning up after a tornado disaster and for residents in the area. The duration of exposure to contaminated material may be far longer if drinking water reservoir or groundwater aquifers are contaminated. According to the EPA, properly designed storage facilities for hazardous materials can reduce the risk of those materials being spread during a tornado. Many of the health impacts described for other types of storms,

[20] U.S. Census Bureau 2013-2017 American Community Survey five-year estimates.

including lack of access to a hospital, carbon monoxide poisoning from generators, and mental health impacts from storm-related trauma, could also occur as a result of tornado activity.

Economic Impacts

Tornado events are typically localized; however, in those areas, economic impacts can be significant. Types of impacts may include loss of business functions, water supply system damage, damage to inventories, relocation costs, wage losses, and rental losses due to the repair or replacement of buildings. Recovery and clean-up costs can also be costly. The damage inflicted by historical tornadoes in Massachusetts varies widely, but the average damage per event is approximately $3.9 million.

Because of differences in building construction, residential structures are generally more susceptible to tornado damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

Infrastructure

All critical facilities and infrastructure in Greenfield are exposed to tornado events. Table 3-31 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a tornado.

Table 3-31: Estimated Potential Loss by Tax Classification in Greenfield

Tax Classification	Total Assessed Value FY2019	1% Damage Loss Estimate	5% Damage Loss Estimate	10% Damage Loss Estimate
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

Agriculture

Forestry species and agricultural crops, equipment, and infrastructure may be directly impacted by tornadoes.

Energy

High winds could down power lines and poles adjacent to roads. Damage to above-ground transmission infrastructure can result in extended power outages.

Public Safety

Public safety facilities and equipment may experience direct loss (damage) from tornadoes. Shelters and other critical facilities that provide services for people whose property is uninhabitable following a tornado may experience overcrowding and inadequate capacity to provide shelter space and services.

Transportation

Incapacity and loss of roads and bridges are the primary transportation failures resulting from tornadoes, and these failures are primarily associated with secondary hazards, such as landslide events. Tornadoes can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating populations, and disrupting ingress and egress. Of particular concern are bridges and roads providing access to isolated areas and to the elderly. Prolonged obstruction of major routes due to secondary hazards, such as landslides, debris, or floodwaters, can disrupt the shipment of goods and other commerce. If the tornado is strong enough to transport large debris or knock out infrastructure, it can create serious impacts on power and aboveground communication lines.

Water & Wastewater Infrastructure

The hail, wind, debris, and flash flooding associated with tornadoes can cause damage to infrastructure, such as storage tanks, hydrants, residential pumping fixtures, and distribution systems. Water and wastewater utilities are also vulnerable to potential contamination due to chemical leaks from ruptured containers. Ruptured service lines in damaged buildings and broken hydrants can lead to loss of water and pressure.

Environment

Direct impacts may occur to flora and fauna small enough to be uprooted and transported by the tornado. Even if the winds are not sufficient to transport trees and other large plants, they may still uproot them, causing significant damage to the surrounding habitat. As felled trees decompose, the increased dry matter may increase the threat of wildfire in vegetated areas. Additionally, the loss of root systems increases the potential for soil erosion.

Disturbances created by blowdown events may also impact the biodiversity and composition of the forest ecosystem. Invasive plant species are often able to quickly capitalize on the resources (such as sunlight) available in disturbed and damaged ecosystems. This enables them to gain a foothold and establish quickly with less competition from native species. In addition to damaging existing ecosystems, material transported by tornadoes can also cause environmental havoc in surrounding areas. Particular challenges are presented by the possibility of asbestos-contaminated building materials or other hazardous waste being transported to natural areas or bodies of water, which could then become contaminated. Public drinking water reservoirs may also be damaged by widespread winds uprooting watershed forests and creating serious water quality disturbances.

Vulnerability Summary

Overall, Greenfield has a "Medium" vulnerability to tornadoes. Tornadoes are not common occurrences in Greenfield, but can cause significant damage when they do occur. The cascade effects of tornadoes include utility losses and transportation accidents and flooding. Losses associated with the flood hazard are discussed earlier in this section. Particular areas of vulnerability include low-income and elderly populations, mobile homes, and infrastructure such as roadways and utilities that can be damaged by such storms and the low-lying areas that can be impacted by flooding. The following problem statements summarize Greenfield's areas of greatest concern regarding tornadoes.

Tornado Hazard Problem Statements
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Greenfield's hazard tree program should maximize coordination between different City departments and the utilities companies.
• Red pine trees are top heavy and encroaching on the road shoulder of Oak Hill Access Road. A cutting plan is needed in order to minimize this hazard during a tornado.

- Some of Greenfield's residents rely on private wells, placing them at risk during prolonged power outages caused by a tornado.
- The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with updated population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stoneleigh Burnham School, and Franklin Medical Center.
- New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
- The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.
- An improved process is needed for estimating and tracking local crop damage caused by a tornado.
- Existing communication infrastructure issues and vulnerabilities could be exacerbated by a tornado.
- East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
- Many of the City's evacuation routes may be impacted by a tornado. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a tornado.
- Also see severe thunderstorm, wind, and microburst problem statements.

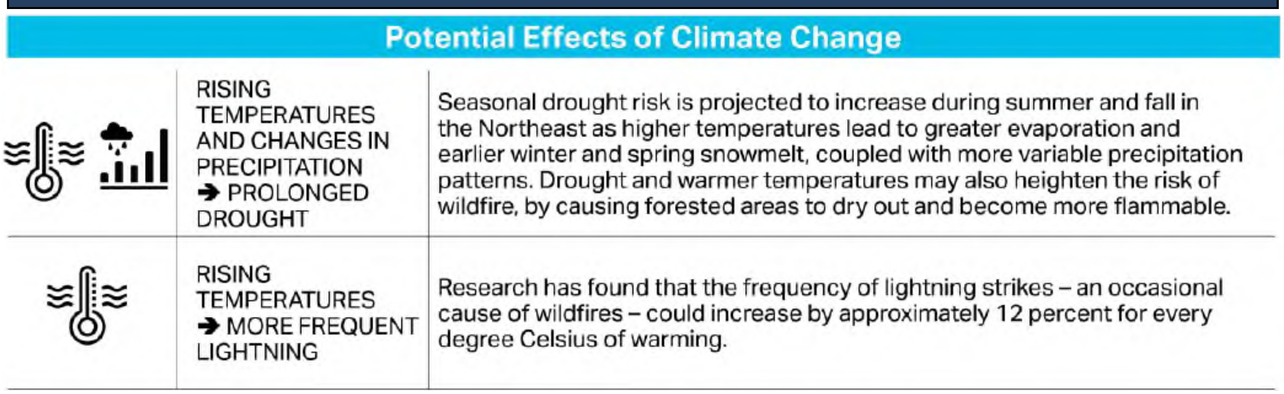
3.8 WILDFIRE

Potential Impacts of Climate Change

Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Periods of hot, dry weather create the highest fire risk. Therefore, the predicted increase in average and extreme temperatures in the Commonwealth may intensify wildfire danger by warming and drying out vegetation. A recent study published in *the Proceedings of the National Academy of Sciences* found that climate change has likely been a significant contributor to the expansion of wildfires in the western U.S., which have nearly doubled in extent in the past three decades.[21] Another study found that the frequency of lightning strikes—an occasional cause of wildfires—could increase by approximately 12 percent for every degree Celsius of warming.[22] Finally, the year-round increase in temperatures is likely to expand the duration of the fire season.

Climate change is also interacting with existing stressors to forests, making them more vulnerable to wildfire. Drought, invasive species, and extreme weather events, all can lead to more dead, downed, or dying trees, increasing the fire load in a forest.

Figure 3-12: Impacts of Climate Change on Wildfires



Potential Effects of Climate Change		
	RISING TEMPERATURES AND CHANGES IN PRECIPITATION ➔ PROLONGED DROUGHT	Seasonal drought risk is projected to increase during summer and fall in the Northeast as higher temperatures lead to greater evaporation and earlier winter and spring snowmelt, coupled with more variable precipitation patterns. Drought and warmer temperatures may also heighten the risk of wildfire, by causing forested areas to dry out and become more flammable.
	RISING TEMPERATURES ➔ MORE FREQUENT LIGHTNING	Research has found that the frequency of lightning strikes – an occasional cause of wildfires – could increase by approximately 12 percent for every degree Celsius of warming.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

A wildfire can be defined as any non-structure fire that occurs in vegetative wildland that contains grass, shrub, leaf litter, and forested tree fuels. Wildfires in Massachusetts are caused

[21] Abatzoglou, J.T. and Williams, A.P. 2016. Impact of anthropogenic climate change on wildfire across western US forests 2016 113 (42) 11770-11775; published ahead of print October 10, 2016, doi:10.1073/pnas.1607171113

[22] Romps, D.M. et al. 2014. Projected increase in lightning strikes in the United States due to global warming. Science. November 14, 2014. http://science.sciencemag.org/content/346/6211/851

by natural events, human activity, or prescribed fire. Wildfires often begin unnoticed but spread quickly, igniting brush, trees, and potentially homes. The wildfire season in Massachusetts usually begins in late March and typically culminates in early June, corresponding with the driest live fuel moisture periods of the year. April is historically the month in which wildfire danger is the highest. Drought, snowpack level, and local weather conditions can impact the length of the fire season.

Fire Ecology and Wildfire Behavior

The "wildfire behavior triangle" reflects how three primary factors influence wildfire behavior: fuel, topography, and weather. Each point of the triangle represents one of the three factors, and arrows along the sides represent the interplay between the factors. For example, drier and warmer weather with low relative humidity combined with dense fuel loads and steeper slopes can result in dangerous to extreme fire behavior.

How a fire behaves primarily depends on the characteristics of available fuel, weather conditions, and terrain, as described below.

- Fuel:
    - Lighter fuels such as grasses, leaves, and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs, and trunks take longer to warm and ignite.
    - Snags and hazard trees, especially those that are diseased or dying, become receptive to ignition when influenced by environmental factors such as drought, low humidity, and warm temperatures.
- Weather:
    - Strong winds, especially wind events that persist for long periods or ones with significant sustained wind speeds, can exacerbate extreme fire conditions or accelerate the spread of wildfire.
    - Dry spring and summer conditions, or drought at any point of the year, increases fire risk. Similarly, the passage of a dry, cold front through the region can result in sudden wind speed increases and changes in wind direction.
    - 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.
- Terrain:

- Topography of a region or a local area influences the amount and moisture of fuel.
- Barriers such as highways and lakes can affect the spread of fire.
- Elevation and slope of landforms can influence fire behavior because fire spreads more easily uphill compared to downhill.

The wildland-urban interface is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. There are a number of reasons that the wildland-urban interface experiences an increased risk of wildfire damage. Access and fire suppression issues on private property in the wildland-urban interface can make protecting structures from wildfires difficult. This zone also faces increased risk because structures are built in densely wooded areas, so fires started on someone's property are more easily spread to the surrounding forest.

Fire is also used extensively as a land management tool to replicate natural fire cycles, and it has been used to accomplish both fire-dependent ecosystem restoration and hazard fuel mitigation objectives on federal, state, municipal, and private lands in Massachusetts since the 1980s. for example, over the past 16 years, the Massachusetts Division of Fisheries and Wildlife (MassWildlife) has used a combination of tree harvesting, shrub mowing, and prescribed burning to benefit rare species and to reduce the risk of a catastrophic wildfire in the Montague Plains Wildlife Management Area, a rare pitch pine-scrub oak forest in Montague. Approximately 880 acres have been treated since 2004 to restore woodland and shrubland habitats. MassWildlife has cooperative agreements with the Department of Conservation and Recreation and the City of Montague Conservation Commission to restore sandplain habitats on their inholdings within the plains, and works closely with local fire departments and the DCR Bureau of Fire Control to ensure that firefighters have adequate access in the event of a wildfire and are familiar with the changes in vegetation and fuels resulting from habitat management activities.[23]

In Massachusetts, the DCR Bureau of Forest Fire Control is the state agency responsible for protecting 3.5 million acres of state, public, and private wooded land and for providing aid, assistance, and advice to the Commonwealth's cities and Citys. The Bureau coordinates efforts with a number of entities, including fire departments, local law enforcement agencies, the Commonwealth's county and statewide civil defense agencies, and mutual aid assistance organizations.

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[23] "Background information on Montague Plains Wildlife Management Area," MA Division of Fisheries and Wildlife, as published in the *2018 Montague Open Space and Recreation Plan*.

Bureau units respond to all fires that occur on state-owned forestland and are available to municipal fire departments for mutual assistance. Bureau firefighters are trained in the use of forestry tools, water pumps, brush breakers, and other motorized equipment, as well as in fire behavior and fire safety. Massachusetts also benefits from mutual aid agreements with other state and federal agencies. The Bureau is a member of the Northeastern Forest Fire Protection Commission, a commission organized in 1949 by the New England states, New York, and four eastern Canadian Provinces to provide resources and assistance in the event of large wildfires. Massachusetts DCR also has a long-standing cooperative agreement with the U.S. Department of Agriculture's Forest Service both for providing qualified wildfire-fighters for assistance throughout the U.S. and for receiving federal assistance within the Commonwealth. Improved coordination and management efforts seem to be reducing the average damage from wildfire events. According to the Bureau's website, in 1911, more than 34 acres were burned on average during each wildfire. As of 2017, that figure has been reduced to 1.17 acres.

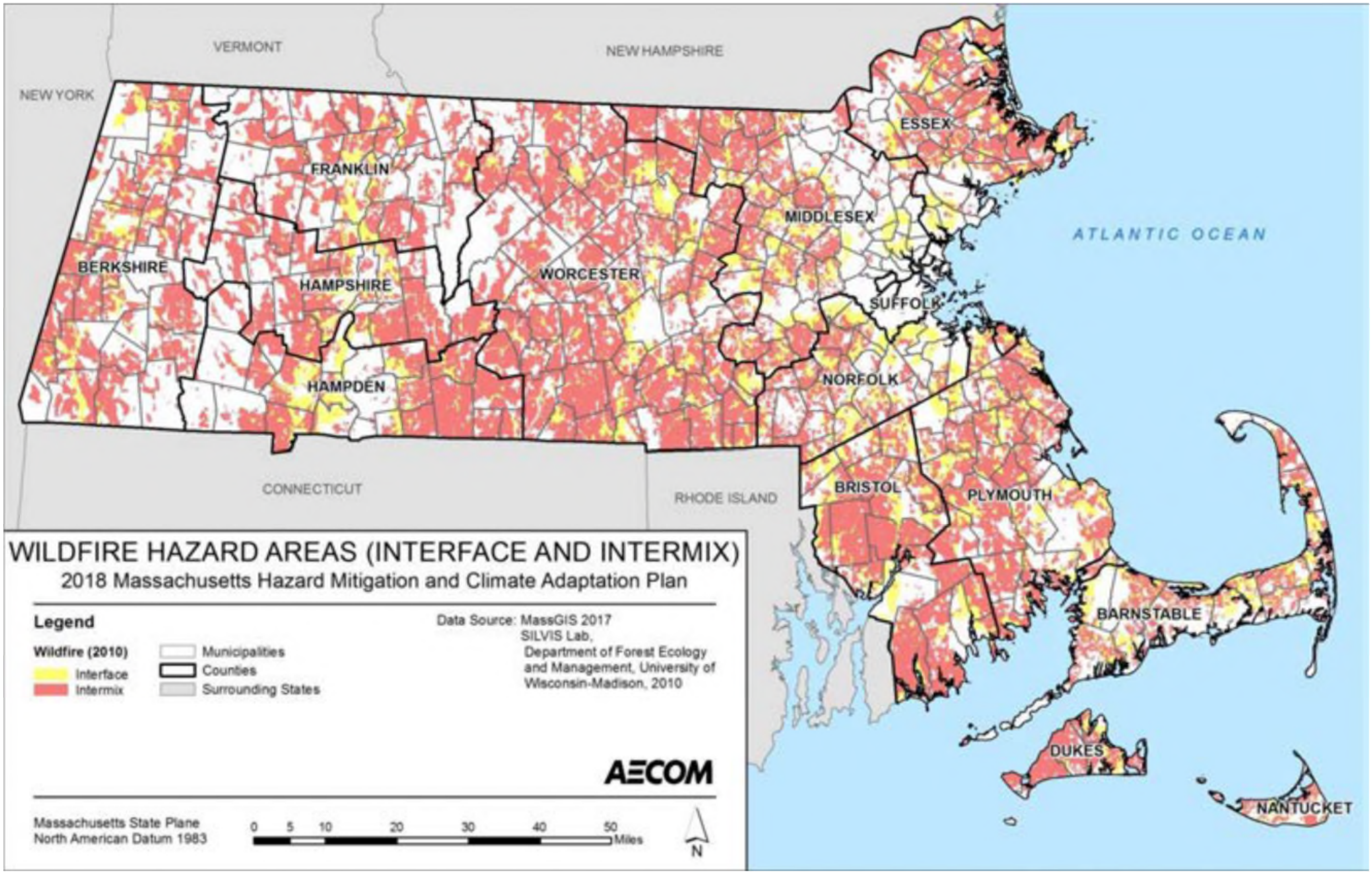
Location

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. The SILVIS Lab at the University of Wisconsin-Madison Department of Forest Ecology and Management classifies exposure to wildlife hazard as "interface" or "intermix." Intermix communities are those where housing and vegetation intermingle and where the area includes more than 50 percent vegetation and has a housing density greater than one house per 16 hectares (approximately 6.5 acres). 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. These areas are shown in Figure 3-13. Inventoried assets (population, building stock, and critical facilities) were overlaid with these data to determine potential exposure and impacts related to this hazard. Greenfield has several areas of "intermix" zones within City.

The Northeast Wildfire Risk Assessment Geospatial Work Group completed a geospatial analysis of fire risk in the 20-state U.S. Forest Service Northeastern Area. The assessment is comprised of three components—fuels, wildland-urban interface, and topography (slope and aspect)—that are combined using a weighted overlay to identify wildfire-prone areas where hazard mitigation practices would be most effective. Figure 3-14 illustrates the areas identified for the Commonwealth. Greenfield is less forested than other towns in Franklin County, and therefore the location of occurrence is "Medium" with approximately 10-50% of the City affected.

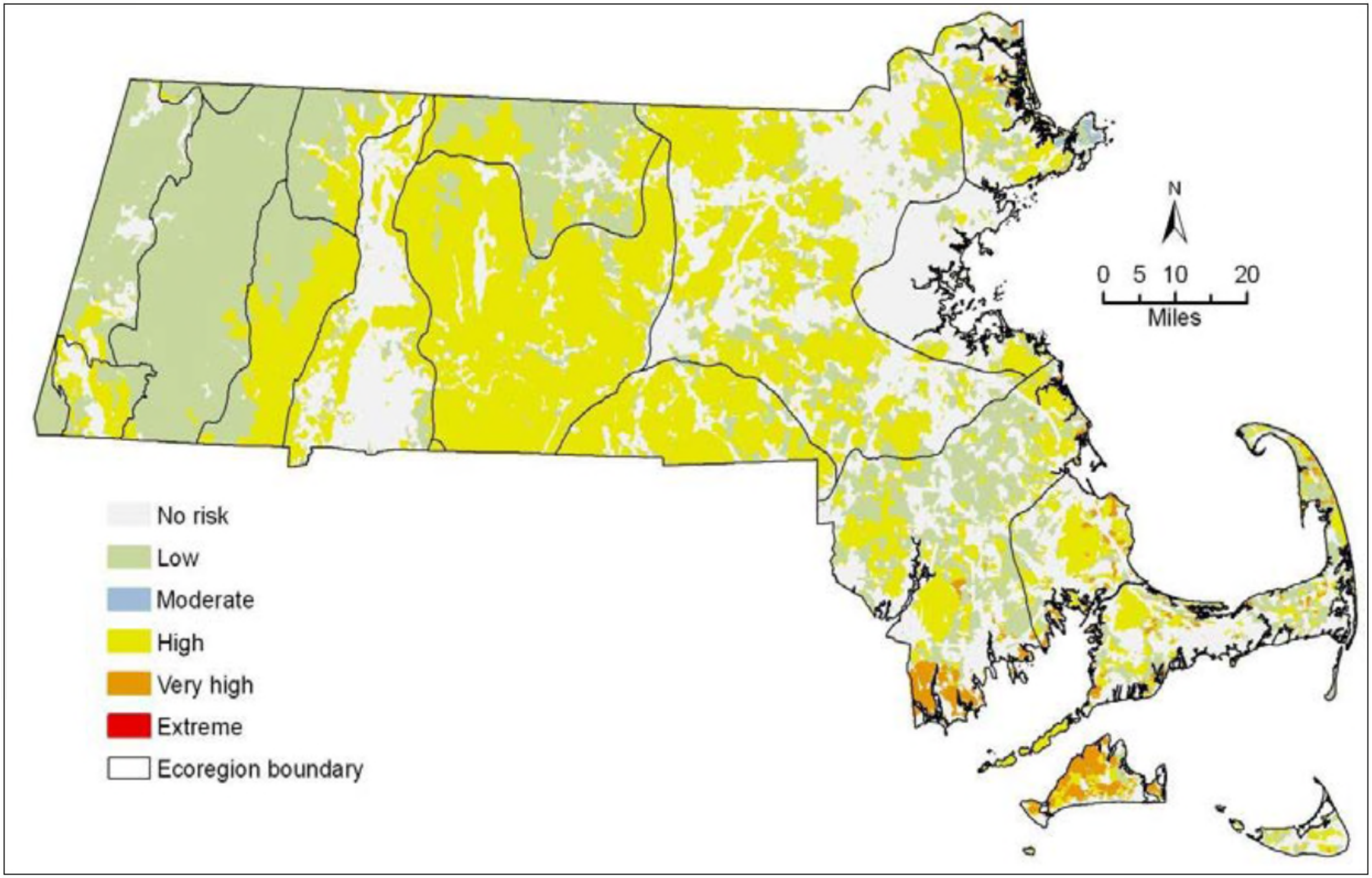
Early detection of wildfires is a key part of the Bureau's overall effort. Early detection is achieved by trained Bureau observers who staff the statewide network of 42 operating fire towers. During periods of high fire danger, the Bureau conducts county-based fire patrols in forested areas. These patrols assist cities and Citys in prevention efforts and allow for the quick deployment of mobile equipment for suppression of fires during their initial stage. Figure 3-15 displays the Bureau's fire control districts and fire towers in Massachusetts.

Figure 3-13: Wildland-Urban Interface and Intermix for the Commonwealth of Massachusetts



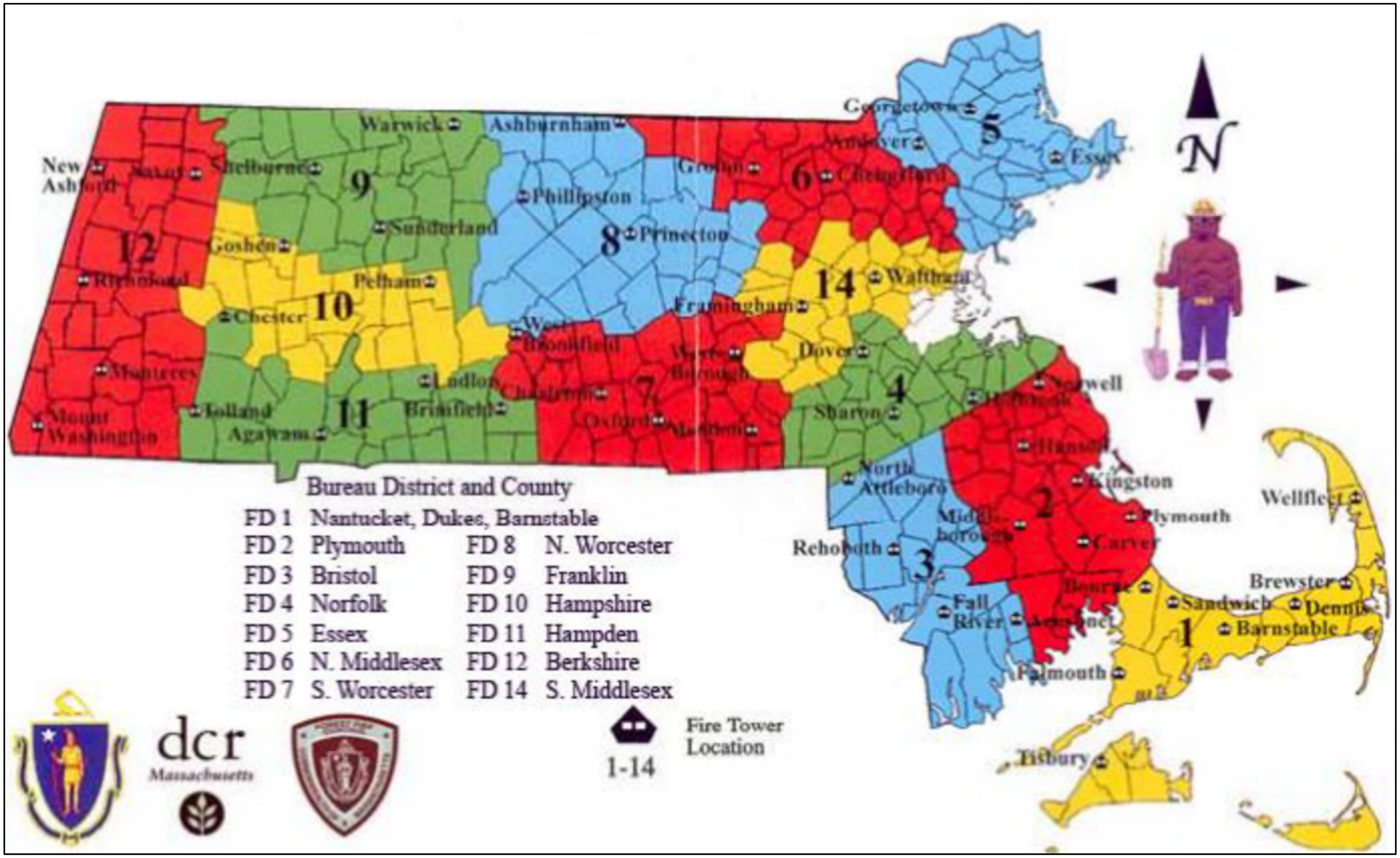
Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Figure 3-14: Wildfire Risk Areas for the Commonwealth of Massachusetts



Source: Northeast Wildfire Risk Assessment Geospatial Work Group, 2009, as presented in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018.

Figure 3-15: Massachusetts Bureau of Forest Fire Control Districts and Tower Network



Source: Massachusetts Department of Conservation and Recreation, Bureau of Forest Fire Control, 2018, as presented in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018.

Extent

The National Wildfire Coordinating Group defines seven classes of wildfires:

- Class A: 0.25 acre or less
- Class B: more than 0.25 acre, but less than 10 acres
- Class C: 10 acres or more, but less than 100 acres
- Class D: 100 acres or more, but less than 300 acres
- Class E: 300 acres or more, but less than 1,000 acres
- Class F: 1,000 acres or more, but less than 5,000 acres
- Class G: 5,000 acres or more.

Unfragmented and heavily forested areas of the state are vulnerable to wildfires, particularly during droughts. The greatest potential for significant damage to life and property from fire exists in areas designated as wildland-urban interface areas. A wildland-urban interface area defines the conditions where highly flammable vegetation is adjacent to developed areas. Fires can be classified by physical parameters such as their fireline intensity, or Byram's intensity, which is the rate of energy per unit length of the fire front (BTU [British thermal unit] per foot of fireline per second). Wildfires are also measured by their behavior, including total heat release during burnout of fuels (BTU per square foot) and whether they are crown-, ground-, or surface-burning fires. Following a fire event, the severity of the fire can be measured by the extent of mortality and survival of plant and animal life aboveground and belowground and by the loss of organic matter.[24]

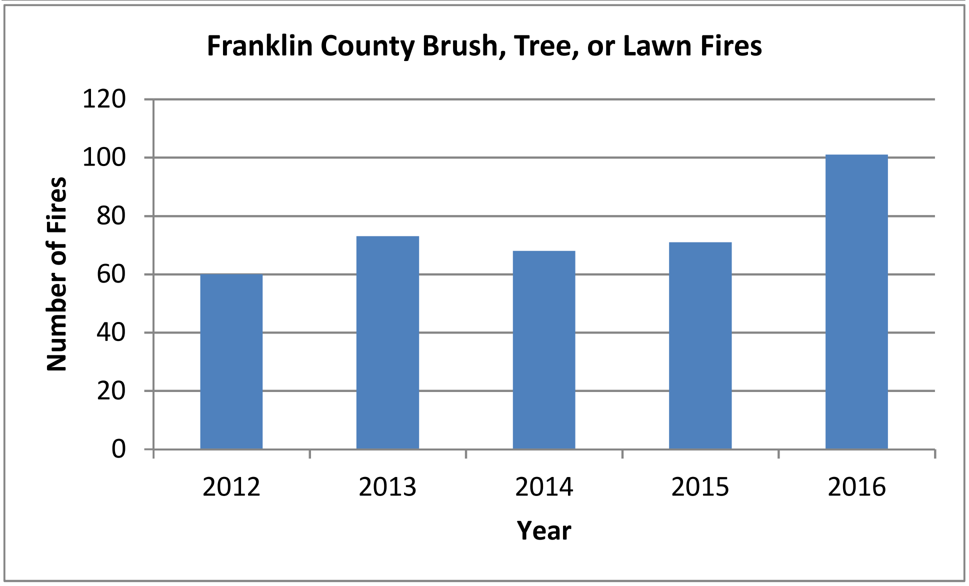
If a fire breaks out and spreads rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

Previous Occurrences

In the last five years (2012 – 2016) Franklin County has averaged 75 brush, tree, or lawn fires a year, with the highest reported number of fires occurring in 2016 (Figure 3-16). During 2016, Franklin County and Massachusetts experienced one of the worst droughts in the last 50 years.

[24] National Parks Service (NPS), compiled by George Wooten. n.d. Fire and fuels management: Definitions, ambiguous terminology and references. https://www.nps.gov/olym/learn/management/upload/fire-wildfire-definitions-2.pdf

Figure 3-16: Outdoor Vegetation Fires in Franklin County 2012 - 2016



Source: Massachusetts Fire Incident Reporting System County Profiles.

While wildfires have not been a significant problem in Greenfield there is always a possibility that changing land use patterns and weather conditions will increase a community's vulnerability. For example, drought conditions can make forests and other open, vegetated areas more vulnerable to ignition. While moderate drought conditions were experienced in the western half of the state in July 2011, they were back to normal by October. Historically, drought has not been a problem in the City of Greenfield. Once the fire starts, it will burn hotter and be harder to extinguish. Soils and root systems starved for moisture are also vulnerable to fire. Residential growth in rural, forested areas increases the total area that is vulnerable to fire and places homes and neighborhoods closer to areas where wildfires are more likely to occur.

Lightning can also be a cause of wildfires, brush fires, and structural fires. In June of 2005 severe thunderstorms accompanied by lightning affected portions of western Massachusetts, northeast Massachusetts, and southwest New Hampshire. During the storm, lightning struck the basement of a ranch style house in Greenfield, causing $50,000 of structural damage to the house.

Probability of Future Events

It is difficult to predict the likelihood of wildfires in a probabilistic manner because a number of factors affect fire potential and because some conditions (e.g., ongoing land use development patterns, location, and fuel sources) exert changing pressure on the wildland-urban interface zone. However, based on the frequency of past occurrences, Greenfield has a “Moderate” probability (2% to 25% chance) that it will experience a wildfire in a given year.

Impact

Unfragmented and heavily forested areas of Greenfield are vulnerable to wildfires, particularly during droughts. The greatest potential for significant damage to life and property from fire exists in areas designated as wildland-urban interface areas. A wildland-urban interface area defines the conditions where highly flammable vegetation is adjacent to developed areas. The greatest impact in Greenfield from a wildfire is to the natural environment, which faces a “Limited” impact from wildfires, with more than 10% of property in the affected area damaged or destroyed.

Vulnerability

Society

As demonstrated by historical wildfire events, potential losses from wildfire include human health and the lives of residents and responders. The most vulnerable populations include emergency responders and those within a short distance of the interface between the built environment and the wildland environment.

Vulnerable Populations

All individuals whose homes or workplaces are located in wildfire hazard zones are exposed to this hazard, as wildfire behavior can be unpredictable and dynamic. However, 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. Landowners with pets or livestock may face additional challenges in evacuating if they cannot easily transport their animals. Outside of the area of immediate impact, sensitive populations, such as those with compromised immune systems or cardiovascular or respiratory diseases, can suffer health impacts from smoke inhalation. Individuals with asthma are more vulnerable to the poor air quality associated with wildfire. Finally, firefighters and first responders are vulnerable to this hazard if they are deployed to fight a fire in an area they would not otherwise be in.

Table 3-32 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during a wildfire event.

Table 3-32: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Health Impacts

Smoke and air pollution from wildfires can be a severe health hazard. Smoke generated by wildfire consists of visible and invisible emissions containing particulate matter (soot, tar, and minerals), gases (water vapor, carbon monoxide, carbon dioxide (CO_2), and nitrogen oxides), and toxics (formaldehyde and benzene). Emissions from wildfires depend on the type of fuel, the moisture content of the fuel, the efficiency (or temperature) of combustion, and the weather. Other public health impacts associated with wildfire include difficulty in breathing, reactions to odor, and reduction in visibility. Due to the high prevalence of asthma in Massachusetts, there is a high incidence of emergency department visits when respiratory irritants like smoke envelop an area. Wildfires may also threaten the health and safety of those fighting the fires. First responders are exposed to dangers from the initial incident and the aftereffects of smoke inhalation and heat-related illness.

Economic Impacts

Wildfire events can have major economic impacts on a community, both from the initial loss of structures and the subsequent loss of revenue from destroyed businesses and a decrease in tourism. Individuals and families also face economic risk if their home is impacted by wildfire. The exposure of homes to this hazard is widespread. Additionally, wildfires can require thousands of taxpayer dollars in fire response efforts and can involve hundreds of operating hours on fire apparatus and thousands of man-hours from volunteer firefighters. There are also many direct and indirect costs to local businesses that excuse volunteers from work to fight these fires.

Infrastructure

For the purposes of this planning effort, all elements of the built environment located in the wildland interface and intermix areas are considered exposed to the wildfire hazard. Table 3-33 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a wildfire.

Table 3-33: Estimated Potential Loss by Tax Classification in Greenfield

Tax Classification	Total Assessed Value FY2019	1% Damage Loss Estimate	5% Damage Loss Estimate	10% Damage Loss Estimate
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

Agriculture

While Massachusetts does not experience wildfires at the same magnitude as those in western states, wildfires do occur and are a threat to the agriculture sector. The forestry industry is especially vulnerable to wildfires. Barns, other wooden structures, and animals and equipment in these facilities are also susceptible to wildfires.

Energy

Distribution lines are subject to wildfire risk because most poles are made of wood and susceptible to burning. Transmission lines are at risk to faulting during wildfires, which can result in a broad area outage. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion.

Public Health

As discussed in the Populations section of the wildfire hazard profile, wildfires impact air quality and public health. Widespread air quality impairment can lead to overburdened hospitals.

Public Safety
Wildfire is a threat to emergency responders and all infrastructure within the vicinity of a wildfire. There are numerous locations within the City where the supply and/or pressure of municipal water is insufficient for fire fighting. These areas are vulnerable if impacted by wildfire. They include the end of Hope Street, Raymond Road, Newell Pond Road, Graves Road, and Lover Lane.

Transportation
Most road and railroads would be without damage except in the worst scenarios. However, fires can create conditions that block or prevent access, and they can isolate residents and emergency service providers. The wildfire hazard typically does not have a major direct impact on bridges, but wildfires can create conditions in which bridges are obstructed.

Water Infrastructure
In addition to potential direct losses to water infrastructure, wildfires may result in significant withdrawal of water supplies. Coupled with the increased likelihood that drought and wildfire will coincide under the future warmer temperatures associated with climate change, this withdrawal may result in regional water shortages and the need to identify new water sources. The City's municipal water supply is ample under normal conditions but is vulnerable to weather related water shortages, such as drought. The City does not have a backup water supply for drinking water and firefighting, which has been needed since the 1970's and is identified in the 2016 *Water Supply Master Plan*. The West Side Water Project plan feasibility study and cost estimates should be updated in order to begin the process of constructing a new water storage tank in Greenfield.

Environment
Fire is a natural part of many ecosystems and serves important ecological purposes, including facilitating the nutrient cycling from dead and decaying matter, removing diseased plants and pests, and regenerating seeds or stimulating germination of certain plants. However, many wildfires, particularly man-made wildfires, can also have significant negative impacts on the environment. In addition to direct mortality, wildfires and the ash they generate can distort the flow of nutrients through an ecosystem, reducing the biodiversity that can be supported.

Frequent wildfires can eradicate native plant species and encourage the growth of fire-resistant invasive species. Some of these invasive species are highly flammable; therefore, their establishment in an area increases the risk of future wildfires. There are other possible feedback loops associated with this hazard. For example, every wildfire contributes to atmospheric CO_2 accumulation, thereby contributing to global warming and increasing the probability of future wildfires (as well as other hazards). There are also risks related to hazardous material releases during a wildfire. During wildfires, containers storing hazardous materials could rupture due to excessive heat and act as fuel for the fire, causing rapid spreading of the wildfire and escalating it to unmanageable levels. In addition, these materials could leak into surrounding areas, saturating soils and seeping into surface waters to cause severe and lasting environmental damage.

Vulnerability Summary

Based on the above assessment, Greenfield faces a "Low" vulnerability from wildfire and brushfires. While wildfires have caused minimal damage, injury and loss of life to date in Greenfield, their potential to destroy property and cause injury or death exists. Existing and future mitigation efforts should continue to be developed and employed that will enable Greenfield to be prepared for these events when they occur. Wildfires can also cause utility disruption and air-quality problems. Particular areas of vulnerability include low-income and elderly populations, and residents living in the interface area adjacent to large areas of unfragmented forests. The following problem statements summarize the areas of greatest concern to Greenfield regarding wildfires.

Wildfire Hazard Problem Statements
• Some residents in Greenfield live within or adjacent to heavily forested areas in "intermix" and "interface" zones. This increases the risk of impacts to the population from a wildfire.
• There are locations in the City where water volume and/or pressure is low and would be insufficient for firefighting, especially during dry periods or drought.
• The City lacks a backup water supply for drinking water and firefighting, which has been needed since the 1970's and is identified in the 2016 *Water Supply Master Plan*. The West Side Water Project plan feasibility study and cost estimates should be updated in order to begin the process of constructing a new water storage tank in Greenfield.
• Many Cities in the region rely on volunteer fire departments and mutual aid to assist in firefighting. During dry spells or drought, firefighting resources in Greenfield and surrounding towns could be strained if multiple wildfires break out at the same time.
• Greenfield does not have a forest stewardship plan for City-owned properties that includes climate change considerations.
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency

Wildfire Hazard Problem Statements
situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Education materials should continue to be distributed to inform residents about brushfire and wildfire risks and to promote general fire safety practices.
• Many of the City's evacuation routes could be impacted by wildfire.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with updated population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stonely Burnham, and Franklin Medical Center.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
• The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.
• An improved process is needed for estimating and tracking local crop damage caused by a wildfire.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City's evacuation routes may be impacted by wildfire. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a wildfire.

3.9 EARTHQUAKES

Potential Impacts of Climate Change

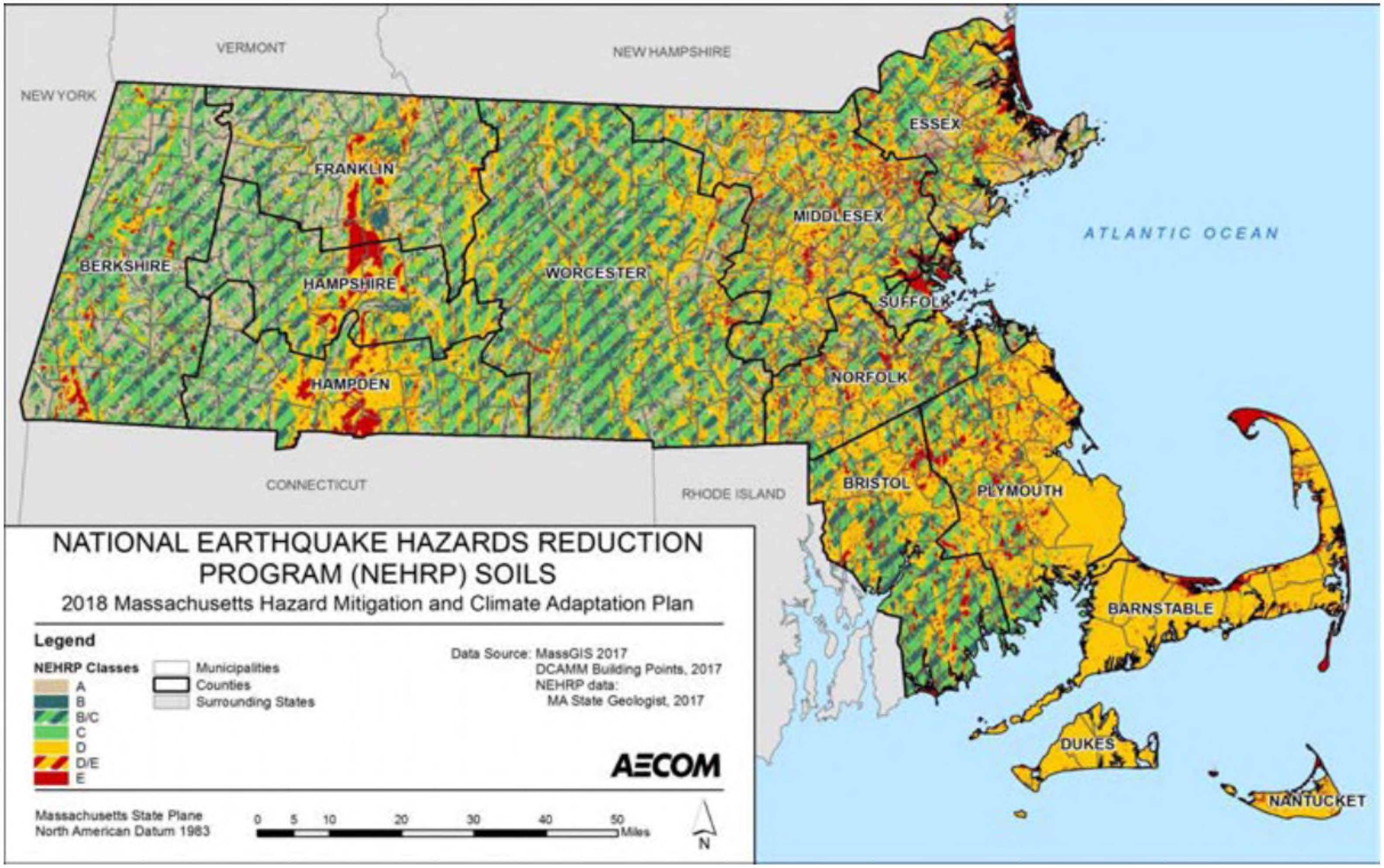
The State Hazard Mitigation and Climate Adaptation Plan does not identify any effects of climate change on the earthquake hazard in Massachusetts.

Hazard Description

An earthquake is the vibration of the Earth's surface that follows a release of energy in the Earth's crust. These earthquakes often occur along fault boundaries. As a result, areas that lie along fault boundaries—such as California, Alaska, and Japan—experience earthquakes more often than areas located within the interior portions of these plates. New England, on the other hand, experiences intraplate earthquakes because it is located deep within the interior of the North American plate. Scientists are still exploring the cause of intraplate earthquakes, and many believe these events occur along geological features that were created during ancient times and are now weaker than the surrounding areas.

Ground shaking is the primary cause of earthquake damage to man-made structures. This damage can be increased due to the fact that soft soils amplify ground shaking. A contributor to site amplification is the velocity at which the rock or soil transmits shear waves (S waves). The National Earthquake Hazards Reduction Program (NEHRP) developed five soil classifications, which are defined by their S-wave velocity, that impact the severity of an earthquake. The soil classification system ranges from A to E, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. These soil types are shown in Figure 3-17.

Figure 3-17: National Earthquake Hazards Reduction Program Soil Types in Massachusetts



Note: This map should be viewed as a first-order approximation of the NEHRP soil classifications. They are not intended for site-specific engineering design or construction. The map is provided only as a guide for use in estimating potential damage from earthquakes. The maps do not guarantee or predict seismic risk or damage. However, the maps certainly provide a first step by highlighting areas that may warrant additional, site-specific investigation if high seismic risk coincides with critical facilities, utilities, or roadways. Sources: Mabee and Duncan, 2017; Preliminary NEHRP Soil Classification Map of Massachusetts, as presented in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018.

Location

New England is located in the middle of the North American Plate. One edge of the North American Plate is along the West Coast where the plate is pushing against the Pacific Ocean Plate. The eastern edge of the North American Plate is located at the middle of the Atlantic Ocean, where the plate is spreading away from the European and African Plates. New England's earthquakes appear to be the result of the cracking of the crustal rocks due to compression as the North American Plate is being very slowly squeezed by the global plate movements. As a result, New England epicenters do not follow the major mapped faults of the region, nor are they confined to particular geologic structures or terrains. Because earthquakes have been detected all over New England, seismologists suspect that a strong earthquake could be centered anywhere in the region. Furthermore, the mapped geologic faults of New England currently do not provide any indications detailing specific locations where strong earthquakes are most likely to be centered.

In addition to earthquakes occurring within the Commonwealth, earthquakes in other parts of New England can impact widespread areas. This is due in part to the fact that earthquakes in the eastern U.S. are felt over a larger area than those in the western U.S. The difference between seismic shaking in the East versus the West is primarily due to the geologic structure and rock properties that allow seismic waves to travel farther without weakening.[25]

Because of the regional nature of the hazard, the entire City is susceptible to earthquakes, and the location of occurrence would be "Large," with over 50% of the City affected.

Extent

The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth. The focal depth of an earthquake is the depth from the surface to the region where the earthquake's energy originates (the focus). Earthquakes with focal depths up to about 43.5 miles are classified as shallow. Earthquakes with focal depths of 43.5 to 186 miles are classified as intermediate. The focus of deep earthquakes may reach depths of more than 435 miles. The focus of most earthquakes is concentrated in the upper 20 miles of the Earth's crust. The depth to the Earth's core is about 3,960 miles, so even the deepest earthquakes originate in relatively shallow parts of the Earth's interior. The epicenter of an earthquake is the point on the Earth's surface directly above the focus.

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a

[25] U.S. Geological Survey (USGS). 2012. New Evidence Shows Power of East Coast Earthquakes. Accessed May 6, 2013. http://www.usgs.gov/newsroom/article.asp?ID=3447

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 sizes of earthquakes. The Richter scale is the most widely known scale for measuring earthquake magnitude. It has no upper limit and is not used to express 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.

The perceived severity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and severity varies with location. Intensity is expressed by the Modified Mercalli Scale, which describes how strongly an earthquake was felt at a particular location. The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Seismic hazards are also expressed in terms of PGA, which is defined by USGS as "what is experienced by a particle on the ground" in terms of percent of acceleration force of gravity. More precisely, seismic hazards are described in terms of Spectral Acceleration, which is defined by USGS as "approximately what is experienced by a building, as modeled by a particle on a massless vertical rod having the same natural period of vibration as the building" in terms of percent of acceleration force of gravity (percent g). Tables 3-34 and 3-35 summarize the Richter scale magnitudes, Modified Mercali Intensity scale, and associated damage.

Table 3-34: Richter Scale Magnitudes and EffectsRichter Scale Magnitudes and Effects

Magnitude	Effects
< 3.5	Generally not felt, but recorded.
3.5 - 5.4	Often felt, but rarely causes damage.
5.4 - 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 kilometers across where people live.
7.0 - 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or >	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Source: US Federal Emergency Management Agency

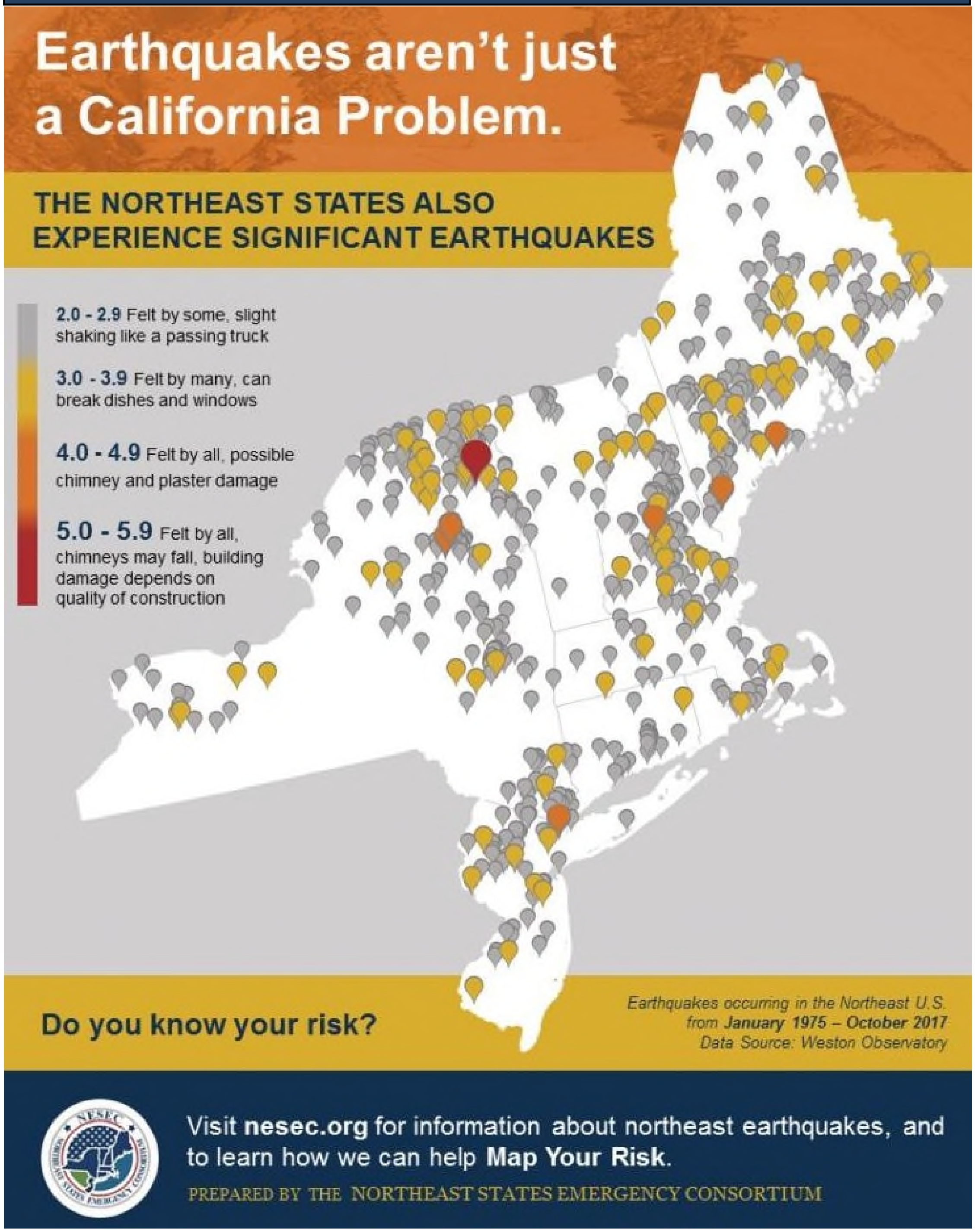
Table 3-35: Modified Mercalli Intensity Scale for and Effects			
Scale	**Intensity**	**Description of Effects**	**Correspondin g Richter Scale Magnitude**
I	Instrumental	Detected only on seismographs.	
II	Feeble	Some people feel it.	< 4.2
III	Slight	Felt by people resting; like a truck rumbling by.	
IV	Moderate	Felt by people walking.	
V	Slightly Strong	Sleepers awake; church bells ring.	< 4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards.	< 8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

Source: US Federal Emergency Management Agency

Previous Occurrences

Although it is well documented that the zone of greatest seismic activity in the U.S. is along the Pacific Coast in Alaska and California, in the New England area, an average of six earthquakes are felt each year (Figure 3-18). Damaging earthquakes have taken place historically in New England (Table 3-36). According to the Weston Observatory Earthquake Catalog, 6,470 earthquakes have occurred in New England and adjacent areas. However, only 35 of these events were considered significant. The most recent earthquakes in the region that could have affected the City of Greenfield are shown in Figure 3-18. There is no record of any damage to the City of Greenfield as a result of these earthquakes.

Figure 3-18: Earthquakes Occurring in the Northeast from 1975 - 2017



Source: Northeast States Emergency Consortium (NESEC) http://nesec.org/earthquakes-hazards/.

Table 3-36: Northeast States Record of Historic Earthquakes			
State	**Years of Record**	**Number of Earthquakes**	**Years with Damaging Earthquakes**
Connecticut	1678 - 2016	115	1791
Maine	1766 - 2016	454	1973, 1904
Massachusetts	1668 - 2016	408	1727, 1755
New Hampshire	1638 - 2016	320	1638, 1940
Rhode Island	1766 - 2016	34	
Vermont	1843 - 2016	50	
New York	1737 - 2016	551	1737, 1929, 1944, 1983, 2002
Total Number of Earthquakes felt: 1,932			

Source: Northeast States Emergency Consortium website, http://nesec.org/earthquakes-hazards/

Probability of Future Events

Earthquakes cannot be predicted and may occur at any time. However, a 1994 report by the USGS, based on a meeting of experts at the Massachusetts Institute of Technology, provides an overall probability of occurrence. Earthquakes above magnitude 5.0 have the potential for causing damage near their epicenters, and larger magnitude earthquakes have the potential for causing damage over larger areas. This report found that the probability of a magnitude 5.0 or greater earthquake centered somewhere in New England in a 10-year period is about 10 percent to 15 percent. This probability rises to about 41 percent to 56 percent for a 50-year period. The last earthquake with a magnitude above 5.0 that was centered in New England took place in the Ossipee Mountains of New Hampshire in 1940. Based on past events, Greenfield has “Very Low” probability, or less than 1% chance in a given year, of being impacted by an earthquake.

Impact

Ground shaking from earthquakes can rupture gas mains and disrupt other utility service, damage buildings, bridges and roads, and trigger other hazardous events such as avalanches, flash floods (dam failure) and fires. Un-reinforced masonry buildings, buildings with foundations that rest on filled land or unconsolidated, unstable soil, and mobile homes not tied to their foundations are at risk during an earthquake. Massachusetts introduced earthquake design requirements into the building code in 1975 and improved building code for seismic reasons in the 1980s. However, these specifications apply only to new buildings or to extensively-modified existing buildings. Buildings, bridges, water supply lines, electrical power lines and facilities built before the 1980s may not have been designed to withstand the forces of an earthquake. The seismic standards have also been upgraded with the 1997 revision of the State Building Code. Liquefaction of the land near water could also lead to extensive destruction.

Greenfield faces potentially "Minor - Catastrophic" impacts from earthquakes, with more than 25%-50% of property damaged in the affected area.

Vulnerability

Society

The entire population of Greenfield is potentially exposed to direct and indirect impacts from earthquakes. 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. In addition, the time of day also exposes different sectors of the community to the hazard. There are many ways in which earthquakes could impact the lives of residents. Business interruptions could keep people from working, road closures could isolate populations, and loss of utilities could impact populations that suffered no direct damage from an event itself. People who reside or work in unreinforced masonry buildings are vulnerable to liquefaction.

Vulnerable Populations

The populations most vulnerable to an earthquake event include people over the age of 65 (20% of Greenfield's population) and those living below the poverty level (37% of Greenfield's population). These socially vulnerable populations are most susceptible, based on a number of factors, including their physical and financial ability to react or respond during a hazard, the location and construction quality of their housing, and the inability to be self-sustaining after an incident due to a limited ability to stockpile supplies. Residents living in homes built prior to the 1970s when the State building code first went into effect, and residents living in mobile homes, are also more vulnerable to earthquakes. An estimated 5,997 housing units in Greenfield, or 72% of all housing units in City, were built prior to the 1970s. An estimated 86 mobile homes are located in Greenfield, accounting for 1% of the total housing stock.[26]

Earthen dams and levees are highly susceptible to seismic events, and the impacts of their eventual failures can be considered secondary risks for earthquakes. As mentioned previously,

[26] U.S. Census Bureau 2013-2017 American Community Survey five-year estimates.

there are many dams on the Deerfield and Connecticut Rivers directly upstream of Greenfield. In the rare event that a compromise of any of these facility's dam should occur, residents would have to evacuate their homes. There is also a small, unnamed privately owned dam that needs removal in City. Dam failure at Moore and Harriman Dams was identified by City officials as a specific area of concern during the City's Municipal Vulnerability Preparedness Community Building Workshop in 2018, and discussed in more detail in the Dam Failure section.

<u>Health Impacts</u>

The most immediate health risk presented by the earthquake hazard is trauma-related injuries and fatalities, either from structural collapse, impacts from nonstructural items such as furniture, or the secondary effects of earthquakes, such as landslides and fires. Following a severe earthquake, health impacts related to transportation impediments and lack of access to hospitals may occur, as described for other hazards. If ground movement causes hazardous material (in storage areas or in pipelines) to enter the environment, additional health impacts could result, particularly if surface water, groundwater, or agricultural areas are contaminated.

<u>Economic Impacts</u>

Earthquakes also have impacts on the economy, including loss of business functions, damage to inventories, relocation costs, wage losses, and rental losses due to the repair or replacement of buildings. Lifeline-related losses include the direct repair cost for transportation and utility systems. Additionally, economic losses include the business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake as well as temporary living expenses for those displaced.

Infrastructure

All elements of the built environment in Greenfield are exposed to the earthquake hazard. Table 3-37 identifies the assessed value of all residential, open space, commercial, and industrial land uses in City, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of an earthquake.

Table 3-37: Estimated Potential Loss by Tax Classification in Greenfield				
Tax Classification	**Total Assessed Value FY2019**	**1% Damage Loss Estimate**	**5% Damage Loss Estimate**	**10% Damage Loss Estimate**
Residential	$1,075,391,345	$10,753,913	$53,769,567	$107,539,135
Open Space	$0	$0	$0	$0
Commercial	$272,964,916	$2,729,649	$13,648,246	$27,296,492

Table 3-37: Estimated Potential Loss by Tax Classification in Greenfield				
Industrial	$39,114,922	$391,149	$1,955,746	$3,911,492
Total	**$1,387,471,183**	**$13,874,712**	**$69,373,559**	**$138,747,118**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section.

In addition to these direct impacts, there is increased risk associated with hazardous materials releases, which have the potential to occur during an earthquake from fixed facilities, transportation-related incidents (vehicle transportation), and pipeline distribution. These failures can lead to the release of materials to the surrounding environment, including potentially catastrophic discharges into the atmosphere or nearby waterways, and can disrupt services well beyond the primary area of impact.

Agriculture

Earthquakes can result in loss of crop yields, loss of livestock, and damage to barns, processing facilities, greenhouses, equipment, and other agricultural infrastructure. Earthquakes can be especially damaging to farms and forestry if they trigger a landslide.

Energy

Earthquakes can damage power plants, gas lines, liquid fuel storage infrastructure, transmission lines, utility poles, solar and wind infrastructure, and other elements of the energy sector. Damage to any components of the grid can result in widespread power outages.

Public Health

A significant earthquake may result in numerous injuries that could overburden hospitals.

Public Safety

Police stations, fire stations, and other public safety infrastructure can experience direct losses (damage) from earthquakes. The capability of the public safety sector is also vulnerable to damage caused by earthquakes to roads and the transportation sector.

Transportation

Earthquakes can impact many aspects of the transportation sector, including causing damage to roads, bridges, vehicles, and storage facilities and sheds. Damage to road networks and bridges can cause widespread disruption of services and impede disaster recovery and response.

Water and Wastewater Infrastructure

Due to their extensive networks of aboveground and belowground infrastructure—including pipelines, pump stations, tanks, administrative and laboratory buildings, reservoirs, chemical storage facilities, and treatment facilities—water and wastewater utilities are vulnerable to earthquakes. Additionally, sewer and water treatment facilities are often built on ground that is subject to liquefaction, increasing their vulnerability. Earthquakes can cause ruptures in storage and process tanks, breaks in pipelines, and building collapse, resulting in loss of water and loss of pressure, and contamination and disruption of drinking water services. Damage to wastewater infrastructure can lead to sewage backups and releases of untreated sewage into the environment.

Environment

Earthquakes can impact natural resources and the environment in a number of ways, both directly and through secondary impacts. For example, damage to gas pipes may cause explosions or leaks, which can discharge hazardous materials into the local environment or the watershed if rivers are contaminated. Fires that break out as a result of earthquakes can cause extensive damage to ecosystems, as described in the Wildfire section. Primary impacts of an earthquake vary widely based on strength and location. For example, if strong shaking occurs in a forest, trees may fall, resulting not only in environmental impacts but also potential economic impacts to the landowner or forestry businesses relying on that forest. If shaking occurs in a mountainous environment, cliffs may crumble and caves may collapse. Disrupting the physical foundation of the ecosystem can modify the species balance in that ecosystem and leave the area more vulnerable to the spread of invasive species.

Vulnerability Summary

Based on this analysis, Greenfield has a "Low" vulnerability to earthquakes. The following problem statements summarize Greenfield’s areas of greatest concern regarding earthquakes.

Earthquake Hazard Problem Statements
• An estimated 72% of homes in Greenfield were built prior to the first State building code in 1975, potentially making them more vulnerable to damages from earthquakes.
• Greenfield residents who rely on private wells for water are at risk during prolonged power outages and breakage cause by earthquakes.
• Damage from an earthquake to the High Hazard dams upstream of Greenfield is of concern. There are six major dams of concern on the Deerfield River, including Harriman Dam, where a failure would reach Greenfield in approximately 4 hours. See dam failure problem statements.
• Although the City has “Greenfield Alerts”, a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses.

Earthquake Hazard Problem Statements
Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with updated population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stonely Burnham, and Franklin Medical Center.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations in its CEMP, explore additional sheltering options, and pursue supportive partnerships for sheltering in the community.
• The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City’s evacuation routes may be impacted by an earthquake. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during or after an earthquake.

3.10 DAM FAILURE

Potential Impacts of Climate Change

The State Hazard Mitigation and Climate Adaptation Plan does not identify any effects of climate change on the dam failure hazard in Massachusetts.

Hazard Description

Dams and levees and their associated impoundments provide many benefits to a community, such as water supply, recreation, hydroelectric power generation, and flood control. However, they also pose a potential risk to lives and property. Dam or levee failure is not a common occurrence, but dams do represent a potentially disastrous hazard. When a dam or levee fails, the potential energy of the stored water behind the dam is released rapidly. Most dam or levee failures occur when floodwaters above overtop and erode the material components of the dam. Often dam or levee breeches lead to catastrophic consequences as the water rushes in a torrent downstream, flooding an area engineers refer to as an "inundation area." The number of casualties and the amount of property damage will depend upon the timing of the warning provided to downstream residents, the number of people living or working in the inundation area, and the number of structures in the inundation area.

Many dams in Massachusetts were built during the 19th Century without the benefit of modern engineering design and construction oversight. Dams of this age can fail because of structural problems due to age and/or lack of proper maintenance, as well as from structural damage caused by an earthquake or flooding.

The Massachusetts Department of Conservation and Recreation Office of Dam Safety is the agency responsible for regulating dams in the state (M.G.L. Chapter 253, Section 44 and the implementing regulations 302 CMR 10.00). The regulations apply to dams that are in excess of 6 feet in height (regardless of storage capacity) or have more than 15 acre feet of storage capacity (regardless of height). Dam safety regulations enacted in 2005 transferred significant responsibilities for dams from the State of Massachusetts to dam owners, including the responsibility to conduct dam inspections.

Dams and reservoirs licensed and subject to inspection by Federal Energy Regulatory Commission FERC are excluded from the provisions of the state regulations provided that all FERC-approved periodic inspection reports are provided to the DCR. FERC inspections of high and significant hazard projects are conducted on a yearly basis. FERC requires that an Emergency Action Plan (EAP) be created and updated annually for licensing of hydropower facilities. The primary purpose of an EAP is to "provide operating and mobilization and notification procedures to be followed in the case of an emergency" such as a sudden release of water caused by a natural disaster or accident.

Location

Greenfield is located at the confluence of the Connecticut and Deerfield Rivers. Both of these rivers have large dams associated with hydroelectric generating projects that are regulated by the Federal Energy Regulatory Commission (FERC). The Connecticut River has 15 dams upstream of Greenfield. The northern-most dam is the Moore Dam, located in Littleton, NH. The closest upstream dam is the Turners Falls Dam, which is located just east of Greenfield.

There are 10 hydroelectric dams along the 73-mile length of the Deerfield River as it flows through Vermont and Massachusetts. Of particular note are the projects on the Deerfield River owned by Great River Hydro LLC (Somerset Dam, Harriman Dam and Sherman Dam) and Brookfield Renewable Power (Fife Brook Dam and Bear Swamp Upper Reservoir) and licensed by the FERC. All of these dams are classified as High Hazard Dams. The remaining five dams on the Deerfield River are classified as Low Hazard Dams.

The City of Greenfield owns four dams. Three of these dams are High Hazard dams: the Greenfield Electric Light & Power Dam and the Pumping Station Dam, both located on the Green River, and the Upper Glen Reservoir Dam, which is located in the neighboring Town of Leyden on Glen Brook. Wiley Russell Dam, classified as a Low Hazard dam, is located on the Green River.

The Committee noted several locations where beaver activity is known to be having an impact on the landscape. These included dams on Montague City Road, Cherry Rum Plaza, and along the south side of Route 2A.

Extent

Often dam or levee breaches lead to catastrophic consequences as the water ultimately rushes in a torrent downstream flooding an area engineers refer to as an "inundation area." The number of casualties and the amount of property damage will depend upon the timing of the warning provided to downstream residents, the number of people living or working in the inundation area, and the number of structures in the inundation area.

Dams in Massachusetts are assessed according to their risk to life and property. The state has three hazard classifications for dams:

- *High Hazard*: Dams located where failure or improper operation will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads.

- *Significant Hazard*: Dams located where failure or improper operation may cause loss of life and damage to homes, industrial or commercial facilities, secondary highways or railroads or cause interruption of use or service of relatively important facilities.

- *Low Hazard*: Dams located where failure or improper operation may cause minimal property damage to others. Loss of life is not expected.

Owners of dams are required to hire a qualified engineer to inspect and report results using the following inspection schedule:

- Low Hazard Potential dams – 10 years
- Significant Hazard Potential dams – 5 years
- High Hazard Potential dams – 2 years

The time intervals represent the maximum time between inspections. More frequent inspections may be performed at the discretion of the state. As noted previously, dams and reservoirs licensed and subject to inspection by the Federal Energy Regulatory Commission (FERC) are excluded from the provisions of the state regulations provided that all FERC-approved periodic inspection reports are provided to the DCR. FERC inspections of high and significant hazard projects are conducted on a yearly basis. All other dams are subject to the regulations unless exempted in writing by DCR.

The Emergency Action Plans (EAPs) for the High Hazard FERC-regulated dams and the High Hazard dams owned by the City of Greenfield and regulated by DCR include a series of inundation maps for each dam that illustrate potential flooding conditions for downstream areas that include portions of Greenfield adjacent to the Green, Deerfield and Connecticut Rivers. The most recent inundation mapping for these projects is shown on the maps at the end of Section 2 of this plan.

Inundation maps for the Harriman Dam (located on the Deerfield River) extend from the dam downstream to Holyoke, roughly 86 miles away. Under sunny conditions (with no additional precipitation added to released water), water from a catastrophic failure of the Harriman Dam would reach the I-91 bridge (60.9 miles from origin) over the Deerfield River in 3.5 hours. In four hours, it will reach Greenfield (63.5 miles from origin). It will reach the Route 5 Bridge (67.6 miles from origin) in 4.6 hours and the confluence of the Deerfield and Connecticut Rivers (68.9 miles from origin) in 5 hours. As the flood joins with the Connecticut River it is expected to significantly increase in magnitude and velocity.

In 2010 the Franklin Regional Council of Governments (FRCOG) and the University of Massachusetts Transportation Center (UMTC) prepared a study that examined the impact of a Harriman Dam failure on the transportation network in the Citys within the inundation zone as well as the county. Building upon this exercise, the FRCOG developed City-specific recommendations in the event of flooding caused by failure of the Harriman Dam. An analysis was conducted for each of the municipalities located along the path of the flood including identification of critical facilities located within town boundaries. The recommendations are intended to be used as a starting point for the development of specific emergency plans in each municipality.

Under “Probable Maximum Flood” (PMF) conditions, the worst-case scenario, floodwaters from a catastrophic failure of the Sherman Dam would reach the Route 5 Bridge in 3.2 hours. Both “Sunny Day” and PMF conditions are presented on the inundation maps for the five High Hazard Dams.

Of additional concern is the Moore Dam, located on the Connecticut River in the Towns of Littleton, New Hampshire, and Waterford, Vermont, approximately 166 miles upstream from the Turners Falls Dam. According to the Emergency Action Plan, flooding caused by a failure of the dam would reach Greenfield within 25 hours under Probable Maximum Flood (PMF) conditions. Flood waters would inundate a large area along the Deerfield River between Interstate 91 and Routes 5/10.

The remaining dams on the Deerfield River are classified as Low Hazard Dams; therefore, no Emergency Action Plan or inundation mapping are required by FERC. Consultants hired by the previous owners, TransCanada, examined a “Sunny Day” failure scenario for these dams to determine the downstream flooding hazard potential. Next, the incremental impact was determined for a dam failure that occurred at a flow equivalent to the 100-year frequency flood. For these two scenarios, the study indicates that the additional flooding above the 100-year flood stage was insignificant and therefore these projects do not present a significant hazard to life and property. However, the cascading failure of one or more of these dams that would occur if one of the High Hazard dams failed would result in the catastrophic flooding shown on the inundation maps in the EAP.

The 100-year flood plain covers about 10.32 percent, or roughly 1,449 acres of the City, including an estimated 43 acres of developed residential land. An inundation area due to dam failure would cover substantially more acreage. Emergency responders should review inundation areas in the updated Emergency Action Plans and the findings and recommendations from the 2010 Harriman Dam study and Town Recommendations and identify possible evacuation routes, since significant portions of Greenfield, including sections of Interstate 19 and Route 5/10 may be flooded.

Overall, the Committee identified the possible extent of flooding due to beaver dams as small.

Previous Occurrences

To date, there have been no known dam or levee failures in Greenfield.

Probability of Future Events

Currently the frequency of dam failures is “Very Low” with a less than 1 percent chance of a dam failing in any given year.

Dams are designed partly based on assumptions about a river’s flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or all of its designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream.

Throughout the western United States, communities downstream of dams are already seeing increases in stream flows from earlier releases from dams. Dams are constructed with safety features known as “spillways.” Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events often referred to as “design failures,” result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures.

Impact

A dam failure in Greenfield is likely to have a “Catastrophic” impact, with multiple deaths and injuries possible, more than 50% of property in the affected area damaged or destroyed, and a possible complete shutdown of facilities for 30 days or more.

Vulnerability

Dam failures, while rare, can destroy roads, structures, facilities, utilities, and impact the population of Greenfield. 43 acres of residential land is located within the floodplain in

Greenfield, while 13.57 acres of Commercial land, and 1.86 acres of Industrial land are also located within the floodplain in Greenfield. Existing and future mitigation efforts should continue to be developed and employed that will enable Greenfield to be prepared for these events when they occur. Particular areas of vulnerability include low-income and elderly populations, buildings in the floodplain or inundation areas, and infrastructure such as roadways and utilities that can be damaged by such events.

Society

Vulnerable Populations

The most vulnerable members of the population are those living or working within the floodplain or dam inundation areas, and in particular, those who would be unable to evacuate quickly, including people over the age of 65, households with young children under the age of 5, people with mobility limitations, people with low socioeconomic status, and people with low English fluency who may not understand emergency instructions provided in English.

Economic Impacts

Economic impacts are not limited to assets in the inundation area, but may extend to infrastructure and resources that serve a much broader area. In addition to direct damage from dam failure, economic impacts include the amount of time required to repair or replace and reopen businesses, governmental and nonprofit agencies, and industrial facilities damaged by the dam failure.[27]

Infrastructure

Structures that lie in the inundation area of each of the dams in Greenfield are vulnerable to a dam failure. Buildings located within the floodplain are also vulnerable to dam failure in Greenfield. There are critical facilities in Greenfield located either within the 100-year floodplain, in a dam inundation area, or in areas prone to localized flooding. Table 3-13 on page 56 shows the total value of replacing the structures and contents of buildings located in the flood hazard area in Greenfield. In total, the structures and building contents are valued in excess of $5.7 million. It is evident that catastrophic flooding would cause significant economic, financial and environmental damage.

Environment

Examples of environmental impacts from a dam failure include:

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[27] *Assessing the Consequences of Dam Failure: A How-To Guide*. Federal Emergency Management Agency (FEMA). March 2012.
https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

- Pollution resulting from septic system failure, back-up of sewage systems, petroleum products, pesticides, herbicides, or solvents
- Pollution of the potable water supply or soils
- Exposure to mold or bacteria during cleanup
- Changes in land development patterns
- Changes in the configuration of streams or the floodplain
- Erosion, scour, and sedimentation
- Changes in downstream hydro-geomorphology
- Loss of wildlife habitat or biodiversity
- Degradation to wetlands
- Loss of topsoil or vegetative cover
- Loss of indigenous plants or animals[28]

Vulnerability Summary

There are High Hazard Dams on the Green River and upstream of the City on Glen Brook in Leyden and on the Deerfield and Connecticut Rivers. Due to the City's current dam inspection schedule and the current EAPs and inundation mapping for all High Hazard dams plus the lead time for evacuation if dams on the Deerfield or Connecticut River were to fail, the Committee determined that the City has a "Low" vulnerability from dam or levee failure.

Dam Failure Hazard Problem Statements
• While the chance is low, a catastrophic dam failure at a major facility upstream of Greenfield would resulting in devastating flooding in which roads, buildings and infrastructure would be inundated and evacuations would be needed. There are five major dams of concern on the Deerfield River, including Harriman Dam, where a failure would reach Greenfield in approximately 5 hours. Moore Dam is of concern on the Connecticut River, and Leyden Glen Dam is of concern on the Green River. EAPs and maps of the Dam Inundation Areas are current and should be shared with all City departments and coupled with a public outreach effort to inform residents and business located there.
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency

[28] *Assessing the Consequences of Dam Failure: A How-To Guide*. Federal Emergency Management Agency (FEMA). March 2012.
https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

Dam Failure Hazard Problem Statements
situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• Great River Hydro and Leyden Glen dam failure notification system should be tested. The City's Standard Operating Procedures (SOPs) for flooding, including managing road closures, evacuation, and sheltering may need to be revised and updated to consider new dam inundation and flood-prone areas in the City. Vulnerable neighborhoods and elderly housing such as The Arbors have a greater need for flood warnings and flood prevention.
• Beaver activity is occurring in proximity to residential settlement, commercial buildings and facilities, and municipal infrastructure. Continued monitoring and risk assessment is needed to mitigate damage from a potential beaver dam failure.
• New initiatives are needed to improve household disaster preparedness City-wide and to better reach vulnerable populations, including seniors and disabled residents with lessened mobility or medical needs, as well as homeless or transient people who may be difficult to reach in the event of an emergency. The City may need to review and update evacuation planning for vulnerable populations, explore additional sheltering options, and pursued supportive partnerships for sheltering in the community.
• The Comprehensive Emergency Management Plan (CEMP) needs to be completed and updated with updated population data and to foster communication and collaboration between the City and its major points of education and employment, including Greenfield Community College, Stoneleigh Burnham, and Franklin Medical Center.
• The designated emergency shelters may not be accessible to residents who lack access to transportation. 11% of Greenfield households do not have access to a car.
• An improved process is needed for estimating and tracking local crop damage caused by a dam failure.
• Existing communication infrastructure issues and vulnerabilities could be exacerbated by a dam failure.
• The concrete retaining walls on the streambanks of the Green River along Deerfield Street and Meridian Streets are in need of inspections.

Dam Failure Hazard Problem Statements
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City's evacuation routes may be impacted by flooding from dam failure. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a flood.
• Also see flooding problem statements.

3.11 DROUGHT

Potential Impacts of Climate Change

Although total annual precipitation is anticipated to increase over the next century, seasonal precipitation is predicted to include more severe and unpredictable dry spells. More rain falling over shorter time periods will reduce groundwater recharge, even in undeveloped areas, as the ground becomes saturated and unable to absorb the same amount of water if rainfall were spread out. The effects of this trend will be exacerbated by the projected reduction in snowpack, which can serve as a significant water source during the spring melt to buffer against sporadic precipitation. Also, the snowpack melt is occurring faster than normal, resulting not only in increased flooding but a reduced period in which the melt can recharge groundwater and the amount of water naturally available during the spring growing period.

Reduced recharge can in turn affect base flow in streams that are critical to sustain ecosystems during dry periods and groundwater-based water supply systems. Reservoir-based water supply systems will also need to be assessed to determine whether they can continue to meet projected demand by adjusting their operating rules to accommodate the projected changes in precipitation patterns and associated changes in hydrology. Finally, rising temperatures will also increase evaporation, exacerbating drought conditions.

Figure 3-19: Impacts of Climate Change on Drought

Potential Effects of Climate Change		
	RISING TEMPERATURES AND CHANGES IN PRECIPITATION ➔ PROLONGED DROUGHT	The frequency and intensity of droughts are projected to increase during summer and fall in the Northeast as higher temperatures lead to greater evaporation and earlier winter and spring snowmelt, and precipitation patterns become more variable and extreme.
	RISING TEMPERATURES AND CHANGES IN PRECIPITATION ➔ REDUCED SNOWPACK	Due to climate change, the proportion of precipitation falling as snow and the extent of time snowpack remains are both expected to decrease. This reduces the period during which snowmelt can recharge groundwater Supplies, bolster streamflow, and provide water for the growing period.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

Droughts can vary widely in duration, severity, and local impact. They may have widespread social and economic significance that requires the response of numerous parties, including water suppliers, firefighters, farmers, and residents. Droughts are often defined as periods of deficient precipitation. How this deficiency is experienced can depend on factors such as land use change, the existence of dams, and water supply withdrawals or diversions. For example, impervious surfaces associated with development can exacerbate the effects of drought due to decreased groundwater recharge.

Drought is a natural phenomenon, but its impacts are exacerbated by the volume and rate of water withdrawn from these natural systems over time as well as the reduction in infiltration from precipitation that is available to recharge these systems. Groundwater withdrawals for drinking water can reduce groundwater levels, impacting water supplies as well as base flow (flow of groundwater) in streams. A reduction in base flow is significant, especially in times of drought, as this is often the only source of water to the stream. In extreme situations, groundwater levels can fall below stream channel bottom, and groundwater becomes disconnected from the stream, resulting in a dry channel.

Natural infiltration is reduced by impervious cover (pavement, buildings) on the land surface and by the interruption of natural small-scale drainage patterns in the landscape caused by development and drainage infrastructure. Sewer collection systems can also reduce groundwater levels when groundwater infiltrates into them. This is a common problem for wastewater collection systems in Franklin County, where many of the existing pipes were put in place over 100 years ago. Also, when drains are connected to the sanitary system, groundwater and precipitation are transported to wastewater treatment plants where effluent is typically discharged to surface water bodies and not returned to the groundwater.

Highly urbanized areas with traditional stormwater drainage systems tend to result in higher peak flood levels during rainfall events and rapid decline of groundwater levels during periods of low precipitation. Thus, the hydrology in these areas becomes more extreme during floods and droughts.[29] The importance of increasing infiltration is widely recognized, and the implementation of nature-based solutions to help address this problem is discussed further in later portions of this plan.

Location

Greenfield falls on the edge of a region in Massachusetts that is more prone to severe and extreme drought based on the number of weeks these areas experienced drought conditions from 2001-2017 (Figure 3-20). Because of this hazard's regional nature, a drought would impact the entire City, resulting in a "large" location of occurrence, or more than 50 percent of total land area affected.

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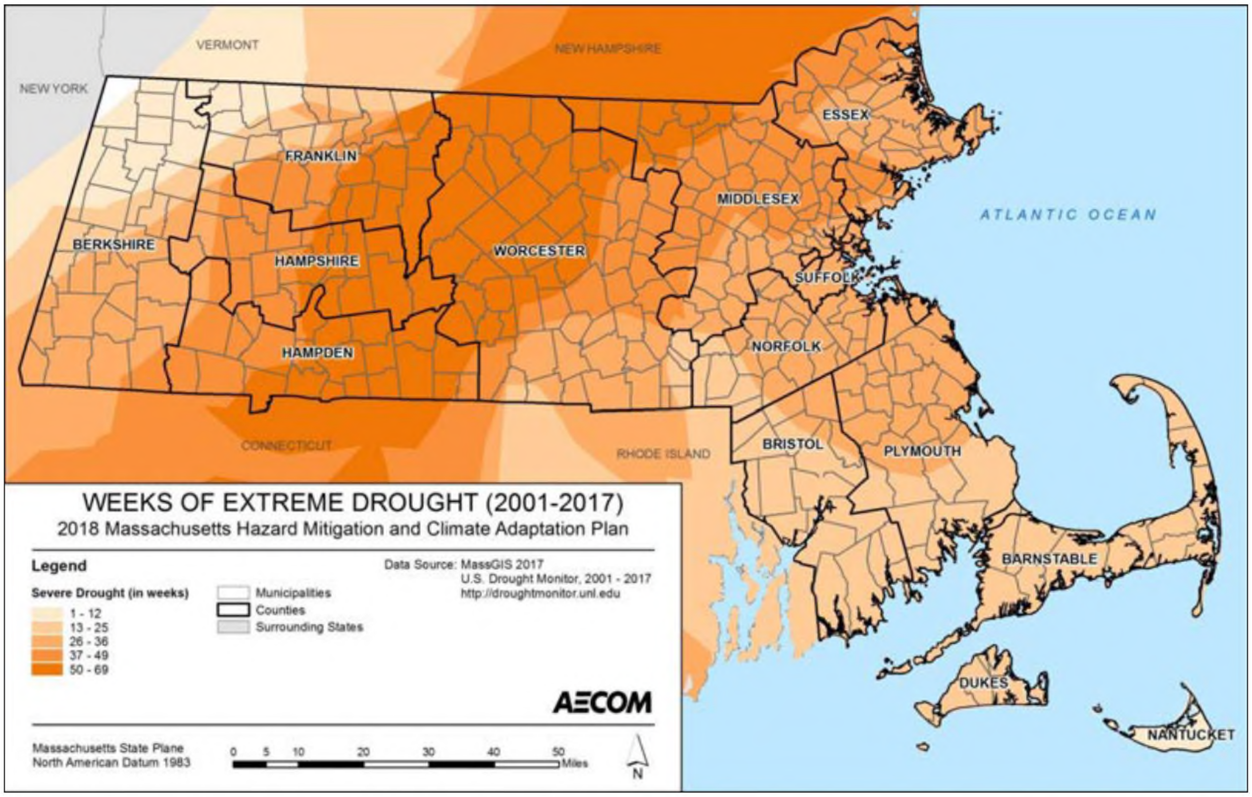
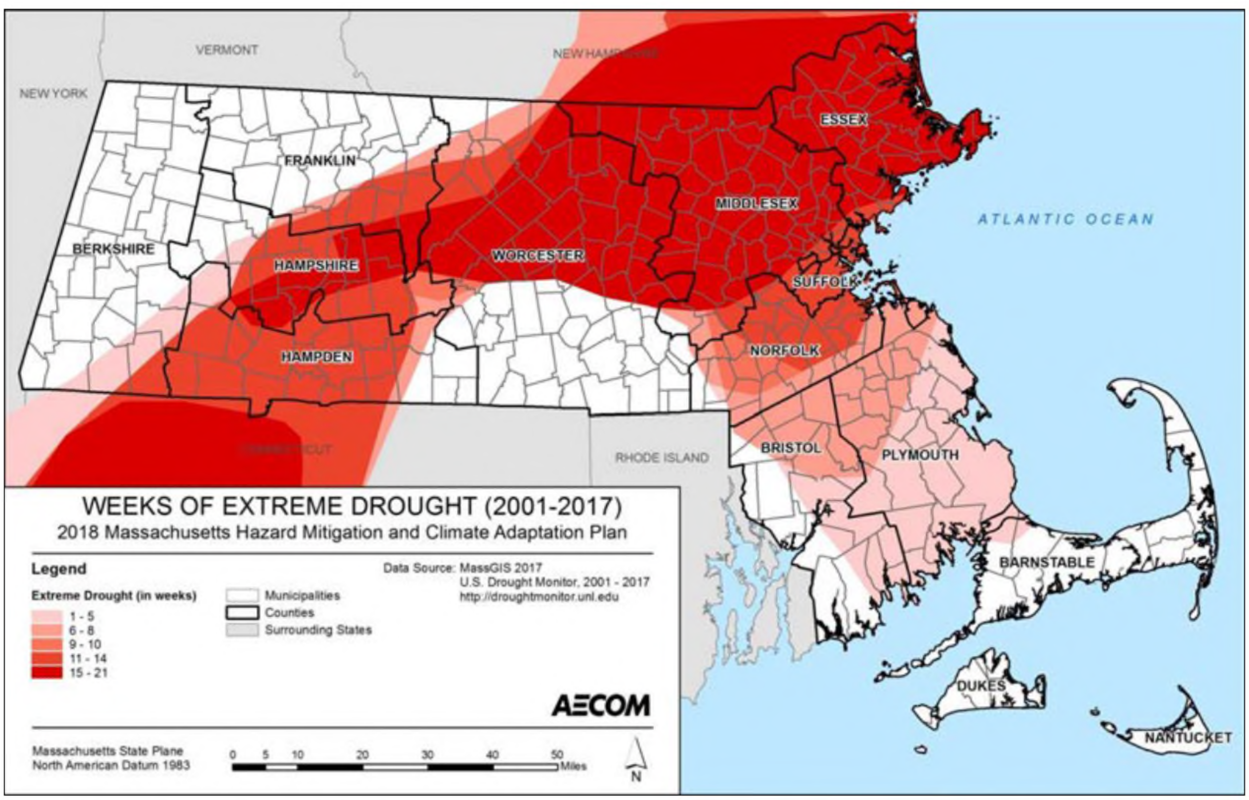
[29] ERG and Horsley Witten Group. 2017. Using Green Infrastructure to Improve Resilience in the Commonwealth of Massachusetts: Final Project Report.

Figure 3-20: Areas Experiencing Severe or Extreme Drought, 2001 - 2017





Source: U.S. Drought Monitor, 2017, as presented in the *2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan.*

Extent

The severity of a drought would determine the scale of the event and would vary among City residents depending on whether the residents' water supply is derived from a private well or the public water system. The majority of residents in Greenfield rely on the public water supply, which draws from both groundwater and surfacewater resources. The remaining residents depend on private wells for water. Massachusetts' wells are permitted according to their ability to meet demand for 180 days at maximum capacity with no recharge; if these conditions extended beyond the thresholds that determine supply capacity the damage from a drought could be widespread due to depleted groundwater supplies.

The U.S. Drought Monitor categorizes drought on a D0-D4 scale as shown below.

Table 3-38: U.S. Drought Monitor		
Classification	**Category**	**Description**
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water- use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

Previous Occurrences

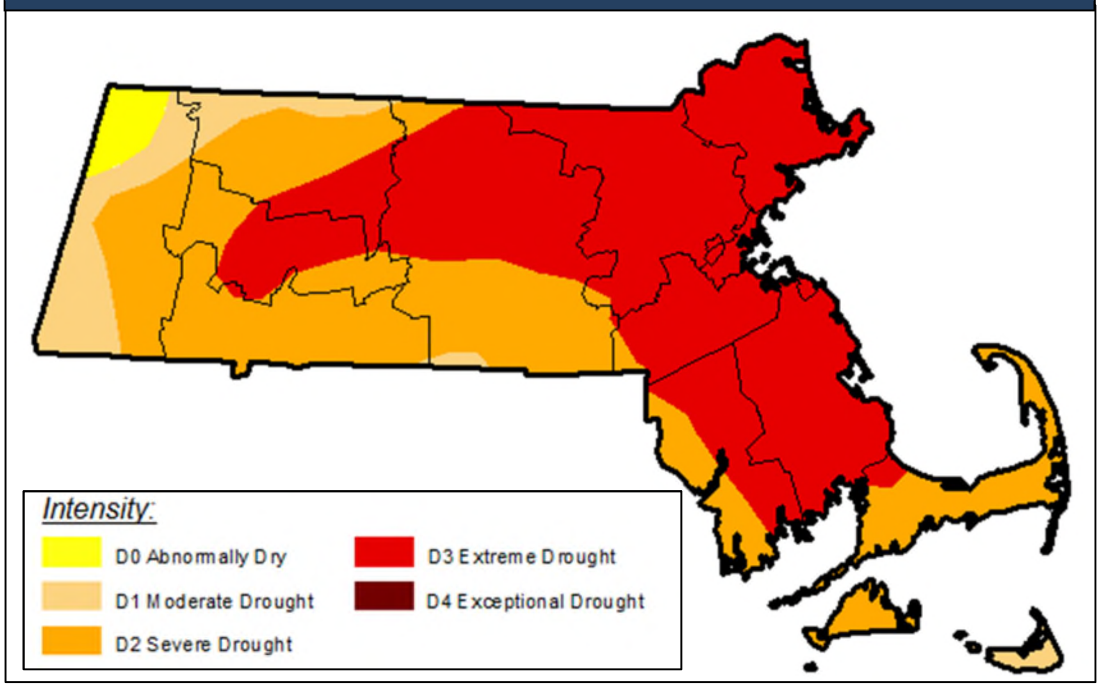
In Massachusetts, six major droughts have occurred statewide since 1930. They range in severity and length, from three to eight years. In many of these droughts, water-supply systems were found to be inadequate.

Beginning in 1960 in western Massachusetts and in 1962 in eastern Massachusetts through 1969, Massachusetts experienced the most significant drought on record, according to the

United States Geological Survey. The severity and duration of the drought caused significant impacts on both water supplies and agriculture. Although short or relatively minor droughts occurred over the next 50 years, the next long-term event began in March 2015, when Massachusetts began experiencing widespread abnormally dry conditions. In July 2016, based on a recommendation from the Drought Management Task Force (DMTF), the Secretary of EOEEA declared a Drought Watch for Central and Northeast Massachusetts and a Drought Advisory for Southeast Massachusetts and the Connecticut River Valley. Drought warnings were issued in five out of six drought regions of the state. Many experts stated that this drought was the worst in more than 50 years.

By September 2016, 78% of Franklin County was categorized as “severe drought” (D2) or higher, and 26% of the County was categorized as “extreme drought” (D3) (Figure 3-21).[30] By May 2017, the entire Commonwealth had returned to “normal” due to wetter-than-normal conditions in the spring of 2017. Greenfield was not adversely impacted by the 2016 drought.

Figure 3-21: Drought Conditions in Massachusetts on September 20, 2016



Source: U.S. Drought Monitor. https://droughtmonitor.unl.edu/

Probability of Future Events

According to the 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, on a monthly basis over the 162-year period of record from 1850 to 2012, there is a 2% chance of

[30] U.S. Drought Monitor, accessed February 13, 2019. https://droughtmonitor.unl.edu/Data/DataTables.aspx?state,MA

being in a drought warning level. As noted previously, rising temperatures and changes in precipitation due to climate change could increase the frequency of episodic droughts, like the one experienced across the Commonwealth in the summer of 2016. Therefore, the Committee determined that drought has a "Very High" probability of future occurrence, or between a 50-100% chance of occurring in any given year.

Impact

Due to the water richness of western Massachusetts, Greenfield is unlikely to be adversely affected by anything other than a major, extended drought. The major impact to residents would be private wells running dry or being contaminated due to low water levels. Farmers could be impacted economically by the extended lack of water. Drought may increase the probability of a wildfire occurring. The prolonged lack of precipitation dries out soil and vegetation, which becomes increasingly prone to ignition as long as the drought persists. Additionally, firefighting capabilities could be compromised in a drought if aquifers, fire ponds, or rivers used for pumping water are low. As a result, the impact of a drought would be "Limited" with only minimal property damage or disruption on quality of life.

Vulnerability

The number and type of impacts increase with the persistence of a drought as the effect of the precipitation deficit cascades down parts of the watershed and associated natural and socioeconomic assets. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that may be discernible relatively quickly to farmers. The impact of this same precipitation deficit may not affect hydroelectric power production, drinking water supply availability, or recreational uses for many months.

Society

The entire population of Greenfield is vulnerable to drought events. However, the vulnerability of populations to this hazard can vary significantly based on water supply sources and municipal water use policies.

<u>Vulnerable Populations</u>

Drought conditions can cause a shortage of water for human consumption and reduce local firefighting capabilities. Public water supplies (PWS) provide water for both of these services and may struggle to meet system demands while maintaining adequate pressure for fire suppression and meeting water quality standards. The Massachusetts Department of Environmental Protection (DEP) requires all PWS to maintain an emergency preparedness plan. Areas of the City with poor water pressure include, the end of Hope Street, Raymond Road, Newell Pond Road, Graves Road, and Lovers Lane.

Other parts of Greenfield are outside of municipal water supply area and are served by private wells. Residential well owners are as vulnerable as their ability to find an alternate short- or long-term water supply (i.e. install a new well) or temporarily relocate in the event their well runs dry.

Health Impacts

With declining groundwater levels, residential well owners may experience dry wells or sediment in their water due to the more intense pumping required to pull water from the aquifer and to raise water from a deeper depth. Wells may also develop a concentration of pollutants, which may include nitrates and heavy metals (including uranium) depending on local geology. The loss of clean water for consumption and for sanitation may be a significant impact depending on the affected population's ability to quickly drill a deeper or a new well or to relocate to unaffected areas.

During a drought, dry soil and the increased prevalence of wildfires can increase the amount of irritants (such as pollen or smoke) in the air. Reduced air quality can have widespread deleterious health impacts, but is particularly significant to the health of individuals with pre-existing respiratory health conditions like asthma. Lowered water levels can also result in direct environmental health impacts, as the concentration of contaminants in swimmable bodies of water will increase when less water is present. Stagnant water bodies may develop and increase the prevalence of mosquito breeding, thus increasing the risk for vector-borne illnesses.

Economic Impacts

The economic impacts of drought can be substantial, and would primarily affect the agriculture, recreation and tourism, forestry, and energy sectors.

Infrastructure

Agriculture

Drier summers and intermittent droughts may strain irrigation water supplies, stress crops, and delay harvests. Insufficient irrigation will impact the availability of produce, which may result in higher demand than supply. This can drive up the price of local food. Farmers with wells that are dry are advised to contact the Massachusetts Department of Agricultural Resources to explore microloans through the Massachusetts Drought Emergency Loan Fund or to seek federal Economic Injury Disaster Loans.

Water and Wastewater Infrastructure

As noted already, drought affects both groundwater sources and smaller surface water reservoir supplies. Water supplies for drinking, agriculture, and water-dependent industries may be depleted by smaller winter snowpacks and drier summers anticipated due to climate change. Reduced precipitation during a drought means that water supplies are not replenished at a normal rate. This can lead to a reduction in groundwater levels and problems such as reduced pumping capacity or wells going dry. Shallow wells are more susceptible than deep wells. Suppliers may struggle to meet system demands while maintaining adequate water supply pressure for fire suppression requirements. Private well supplies may dry up and need to either be deepened or supplemented with water from outside sources.

The Greenfield Water Department serves 95% of the of City, and the municipal water system works well when all water sources and infrastructure are operational. However, a loss or compromise of water supply or infrastructure within the system affects the volume and pressure in the entire system. To help with the problem, the City is currently working to upgrade the pipe sizes of water mains on West Street and Phillips Street, which are side streets off of Conway Street, close to the downtown area.

The City currently lacks an emergency short-term backup water supply, which has been needed since the 1970's and is identified in the 2016 *Water Supply Master Plan*. The West Side Water Project identified in the plan would construct a 1-3.5 million gallon water storage tank on the west side of the City off of Gorge Road and a 20 inch water transmission main to Main Street. The project would provide backup drinking water supply in addition to the Rocky Mountain Storage tank, as well as supplemental volumes to maintain adequate pressure for firefighting.

Environment

Drought has a wide-ranging impact on a variety of natural systems. Some of those impacts can include the following:[31]

- Reduced water availability, specifically, but not limited to, habitat for aquatic species
- Decreased plant growth and productivity
- Increased wildfires
- Greater insect outbreaks
- Increased local species extinctions
- Lower stream flows and freshwater delivery to downstream estuarine habitats
- Increased potential for hypoxia (low oxygen) events
- Reduced forest productivity

[31] Clark, J.S. et al. 2016. The impacts of increasing drought on forest dynamics, structure, and biodiversity in the United States. Global Change Biology, 22, 2329–2352. Doi: 10.1111/gcb.13160.

- Direct and indirect effects on goods and services provided by habitats (such as timber, carbon sequestration, recreation, and water quality from forests)
- Limited fish migration or breeding due to dry streambeds or fish mortality caused by dry streambeds

In addition to these direct natural resource impacts, a wildfire exacerbated by drought conditions could cause significant damage to Greenfield's environment as well as economic damage related to the loss of valuable natural resources.

Vulnerability Summary

Based on the above assessment, Greenfield has a vulnerability of "Medium" from drought. While such a drought would require water saving measures to be implemented, there would be no foreseeable damage to structures or loss of life resulting from the hazard. The following problem statements summarize Greenfield's areas of greatest concern regarding droughts.

Drought Hazard Problem Statements
• Some residents in Greenfield live within or adjacent to heavily forested areas in "intermix" and "interface" zones. This increases the risk of impacts to the population from a wildfire during drought conditions.
• There are locations in the City where water volume and/or pressure is insufficient for fighting fires, which could be exacerbated by a drought. Also see Wildfire problem statements.
• The City currently lacks an emergency backup water supply, which has been needed since the 1970's and is identified in the 2016 *Water Supply Master Plan*. The West Side Water Project plan feasibility study and cost estimates should be updated in order to begin the process of constructing a new water storage tank in Greenfield.
• Some of Greenfield's residents and farms are serviced by private wells that run the risk of going dry during prolonged drought.
• Greenfield does not have a forest stewardship plan that includes climate change considerations, such as drought.
• An improved process is needed for estimating and tracking local crop damage caused by a drought.

3.12 LANDSLIDES

Potential Impacts of Climate Change

According to the 2018 *Massachusetts State Hazard Mitigation and Climate Adaptation Plan*, slope saturation by water is already a primary cause of landslides in the Commonwealth. Regional climate change models suggest that New England will likely experience warmer, wetter winters in the future as well as more frequent and intense storms throughout the year. This increase in the frequency and severity of storm events could result in more frequent soil saturation conditions, which are conducive to an increased frequency of landslides. Additionally, an overall warming trend is likely to increase the frequency and duration of droughts and wildfire, both of which could reduce the extent of vegetation throughout the Commonwealth. The loss of the soil stability provided by vegetation could also increase the probability of landslides wherever these events occur.

Figure 3-22: Impacts of Climate Change on Landslides

Potential Effects of Climate Change		
	CHANGES IN PRECIPITATION AND EXTREME WEATHER ➔ SLOPE SATURATION	Regional climate change models suggest that Massachusetts will likely experience more frequent and intense storms throughout the year. This change could result in more frequent soil saturation conditions, which are conducive to an increased frequency of landslides.
	RISING TEMPERATURES ➔ REDUCED VEGETATION EXTENT	An increased frequency of drought events is likely to reduce the extent of vegetation throughout the Commonwealth. The loss of the soil stability provided by vegetation could also increase the probability of landslides wherever these events occur.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

The term landslide includes a wide range of ground movements, such as rock falls, deep failure of slopes, and shallow debris flows. The most common types of landslides in Massachusetts include translational debris slides, rotational slides, and debris flows. Most of these events are caused by a combination of unfavorable geologic conditions (silty clay or clay layers contained in glaciomarine, glaciolacustrine, or thick till deposits), steep slopes, and/or excessive wetness leading to excess pore pressures in the subsurface. Historical landslide data for the Commonwealth suggests that most landslides are preceded by two or more months of higher than normal precipitation, followed by a single, high-intensity rainfall of several inches or more.[32] This precipitation can cause slopes to become saturated.

[32] Mabee, S.B., Duncan, C.C. 2013. Slope Stability Map of Massachusetts. Prepared for the Massachusetts Emergency Management Agency, the Federal Emergency Management Agency and the Massachusetts

Landslides associated with slope saturation occur predominantly in areas with steep slopes underlain by glacial till or bedrock. Bedrock is relatively impermeable relative to the unconsolidated material that overlies it. Similarly, glacial till is less permeable than the soil that forms above it. Thus, there is a permeability contrast between the overlying soil and the underlying, and less permeable, unweathered till and/or bedrock. Water accumulates on this less permeable layer, increasing the pore pressure at the interface. This interface becomes a plane of weakness. If conditions are favorable, failure will occur.

Landslides are created by human activities as well, including deforestation, cultivation and construction, which destabilize already fragile slopes. Some human activities that could cause landslides include:

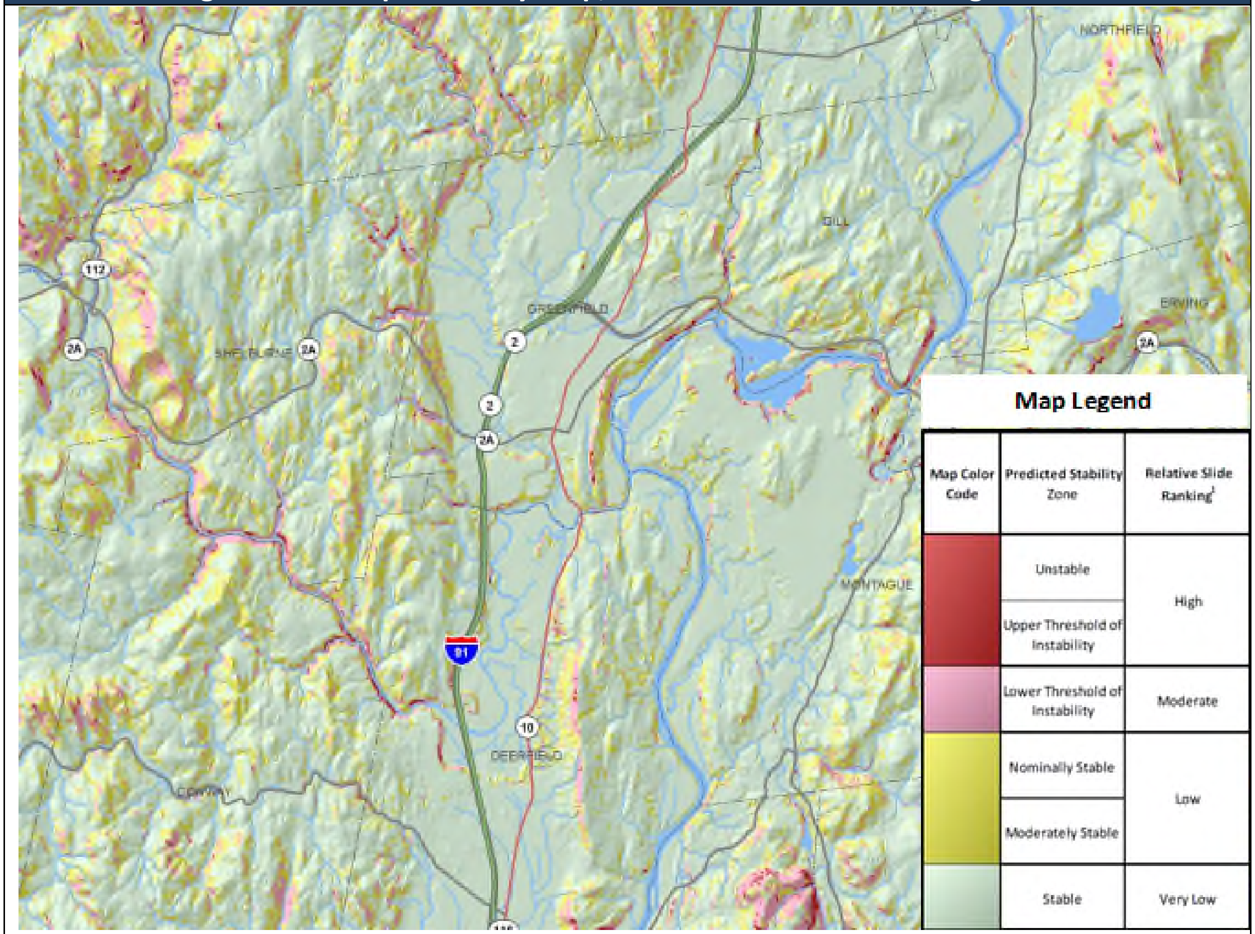
- vibrations from machinery or traffic;
- blasting;
- earthwork which alters the shape of a slope, or which imposes new loads on an existing slope;
- in shallow soils, the removal of deep-rooted vegetation that binds colluvium to bedrock; and
- construction, agricultural or forestry activities (logging) which change the amount of water which infiltrates the soil.

Location

In 2013, the Massachusetts Geological Survey prepared an updated map of potential landslide hazards for the Commonwealth (funded by FEMA's Hazard Mitigation Grant Program) to provide the public, local governments, and emergency management agencies with the location of areas where slope movements have occurred or may possibly occur in the future under conditions of prolonged moisture and high-intensity rainfall. This project was designed to provide statewide mapping and identification of landslide hazards that can be used for community level planning as well as prioritizing high-risk areas for mitigation.

Department of Conservation and Recreation.
http://www.geo.umass.edu/stategeologist/Products/Landslide_Map/Slope_Stability_Map_MA_Report.pdf

Figure 3-23: Slope Stability Map, Greenfield and Surrounding Towns



Source: Massachusetts Geologic Survey and UMass Amherst, 2013

Greenfield has areas in the City with high and moderate landslide rankings. These areas are shown in Figure 3-23 and are mostly located along the steep slopes of the hilly terrain in Rocky Mountain Park.

Extent

Natural variables that contribute to the overall extent of potential landslide activity in any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult. As a result, estimations of the potential severity of landslides are informed by previous occurrences as well as an examination of landslide susceptibility. Information about previous landslides can provide insight as to both where landslides may occur and what types of damage may result. It is important to note, however, that landslide susceptibility only identifies areas potentially affected and does not imply a time frame when a landslide might occur. The distribution of susceptibility in Greenfield is depicted on the Slope Stability Map, with areas of higher slope instability considered to also be more susceptible to the landslide hazard.

Previous Occurrences

According to WWLP News, early in the morning on March 7 of 2011, torrential rains swept away a piece of cemetery into the backyards of homes and nearby streets in Greenfield, MA. The landslide sent silt, mud, and debris down from the Green River Cemetery into homes on nearby Meridian Street. Residents did not hear a thing. A passerby called 911 and alerted authorities that part of the Green River Cemetery had slid down onto Meridian Street. Residents of three homes were evacuated. This area of Greenfield has been in the news before due to other landslides.

According to the Greenfield Recorder, state geologists estimated that about 1,500 to 3,000 cubic yards of mud and debris came down into the yards but that no graves were involved.[33] Three inches of rain in Greenfield over a day and a half contributed to the disaster that caused thousands of dollars worth of damage. The company called in to divert water away from homes below and help clear their yards of some of the mud found that a drainage system that had been installed in 1986 was plugged and buried by the mudslide. The drainage system was cleaned out and was found to be in good shape and should handle any future rains adequately. The City indicated that it is the responsibility of the Cemetery board to make sure the system is evaluated and cleared of any silt accumulation on a regular basis.

The aftermath of the mudslide from the Green River Cemetery included cleanup on a nearby street and bridge.

Relatively small landslides have been reported on Factory Hollow Road along the Fall River, on Mead Street and Wisdom Way, Brook Road and Shelburne Road.

[33] The Greenfield Recorder, November 26, 2011.

Probability of Future Events

In general, landslides are most likely during periods of higher than average rainfall. The ground must be saturated prior to the onset of a major storm for a significant landslide to occur. Increasing heavy precipitation events will increase the risk of landslides in Greenfield. There is a "High" probability, or a 25-50% chance, of a landslide happening in the next year.

Impact

Homes located on lots with significant slopes (i.e., 10% or greater), or that are located at the bottom of steep slopes, are at greater risk of impacts from landslides. The impact of a landslide in Greenfield would be likely be "Limited" depending on where it occurs. More than 10% of property in the affected area could be damaged or destroyed.

Vulnerability

Society

Vulnerable Populations

Populations who rely on potentially impacted roads for vital transportation needs are considered to be particularly vulnerable to this hazard. In Greenfield, many residents may be vulnerable to landslides due to the fact that many homes are built on property below steep slopes, and also because alternative routes for accessing homes may be limited if Meridian Street or Route 5/10 were blocked by a landslide.

Health Impacts

People in landslide hazard zones are exposed to the risk of dying during a large-scale landslide; however, damage to infrastructure that impedes emergency access and access to health care is the largest health impact associated with this hazard. Mass movement events in the vicinity of major roads could deposit many tons of sediment and debris on top of the road. Restoring vehicular access is often a lengthy and expensive process.

Economic Impacts

A landslide's impact on the economy and estimated dollar losses are difficult to measure. Landslides can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property, and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity are difficult to measure. Additionally, ground failure threatens transportation corridors, fuel and energy conduits, and communication lines

Infrastructure

Landslides can result in direct losses as well as indirect socioeconomic losses related to damaged infrastructure. Infrastructure located within areas shown as unstable on the Slope Stability Map should be considered to be exposed to the landslide hazard.

Agriculture

Landslides that affect farmland can result in significant loss of livelihood and long-term loss of productivity. Forests can also be significantly impacted by landslides.

Energy

The energy sector is vulnerable to damaged infrastructure associated with landslides. Transmission lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide may cause a tower to collapse, bringing down the lines and causing a transmission fault. Transmission faults can cause extended and broad area outages.

Public Health

Landslides can result in injury and loss of life. Landslides can impact access to power and clean water and also increase exposure to vector-borne diseases.

Public Safety

Access to major roads is crucial to life safety after a disaster event and to response and recovery operations. The ability of emergency responders to reach people and property impacted by landslides can be impaired by roads that have been buried or washed out by landslides. The instability of areas where landslides have occurred can also limit the ability of emergency responders to reach survivors.

Transportation

Landslides can significantly impact roads and bridges. Landslides can block egress and ingress on roads, isolating neighborhoods and causing traffic problems and delays for public and private transportation. These impacts can result in economic losses for businesses. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.

The possibility of a landslide in the vicinity of a highway or major road represents a significant economic vulnerability for the City and State. For example, the damage to a 6-mile stretch of Route 2 caused by tropical storm Irene (2011), which included debris flows, four landslides, and fluvial erosion and undercutting of infrastructure, cost $23 million for initial repairs.

Water and Wastewater Infrastructure

Surface water bodies may become directly or indirectly contaminated by landslides. Landslides can block river and stream channels, which can result in upstream flooding and reduced downstream flow. This may impact the availability of drinking water. Water and wastewater infrastructure may be physically damaged by mass movements.

Environment

Landslides can affect a number of different facets of the environment, including the landscape itself, water quality, and habitat health. Following a landslide, soil and organic materials may enter streams, reducing the potability of the water and the quality of the aquatic habitat. Additionally, mass movements of sediment may result in the stripping of forest trees and soils, which in turn impacts the habitat quality of the animals that live in those forests. Flora in the area may struggle to re-establish following a significant landslide because of a lack of topsoil.

Vulnerability Summary

Based on the above assessment, Greenfield has a hazard index rating of “Medium” for landslides. The following problem statements summarize Greenfield’s areas of greatest concern regarding landslides.

Landslide Hazard Problem Statements
• Roads, buildings, and utilities downslope of steep and unstable soils are at risk of damage due to landsides, as identified on the Slope Stability Map, including areas in Rocky Mountain Park. An inventory is needed to determine what critical infrastructure is at the greatest risk of being damaged during a landslide.
• The REPC is working to identify options for regional and local debris management. The regional plan approved by MassDEP several years ago was never implemented because the communities that would serve as regional sites did not execute MOUs. The City is being urged by MassDEP to select and provide disaster debris storage/disposal location(s).
• Emergency shelters may not be adequately staffed or supplied with water, food, and first aid supplies. There is a need to inventory the supplies currently available at Greenfield shelters.
• East-west evacuation access across the City is poor. The Silver Street bridge, an important east-west connection, has a down-graded weight limit that does not accommodate large fire trucks and emergency vehicles.
• Many of the City’s evacuation routes may be impacted by a landslide. There are areas of City where residents might become isolated if roads, bridges, or culverts were blocked or damaged during a landslide.

3.13 EXTREME TEMPERATURES

Potential Impacts of Climate Change

Beyond the overall warming trend associated with global warming and climate change, Greenfield will experience increasing days of extreme heat in the future. Generally, extreme heat is considered to be over 90 degrees Fahrenheit (°F), because at temperatures above that threshold, heat-related illnesses and mortality show a marked increase. The average summer across the Commonwealth during the years between 1971 and 2000 included 4 days over 90°F. Climate scientists project that by mid-century, the state could have a climate that resembles that of southern states today, with between 10-28 days over 90°F. By the end of the century, extreme heat could occur between 13-56 days during summer, depending on how successful we are in reducing greenhouse gas emissions.[34]

Figure 3-24: Impacts of Climate Change on Extreme Temperatures

Potential Effects of Climate Change	
RISING TEMPERATURES ➔ HIGHER EXTREME TEMPERATURES	The average summer across the Massachusetts during the years between 1971 and 2000 included 4 days over 90°F (i.e. extreme heat days). Climate scientists project that by mid-century, the state could have a climate that resembles that of southern states today, with an additional 10-28 days over 90°F during summer. By the end of the century, extreme heat could occur between 13-56 days during summer.
RISING TEMPERATURES ➔ HIGHER AVERAGE TEMPERATURES	Compared to an annual 1971-2000 average temperature baseline of 47.6°F, annual average temperatures in Massachusetts are projected to increase by 3.8 to 10.8 degrees (likely range) by the end of the 21st century; slightly higher in western Massachusetts.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

There is no universal definition for extreme temperatures. The term is relative to the usual weather in the region based on climatic averages. Extreme heat for Massachusetts is usually defined as a period of three or more consecutive days above 90 degrees Fahrenheit (°F), but more generally as a prolonged period of excessively hot weather, which may be accompanied by high humidity. Extreme cold is also considered relative to the normal climatic lows in a region.

Massachusetts has four seasons with several defining factors, and temperature is one of the most significant. Extreme temperatures can be defined as those that are far outside the normal ranges. The average highs and lows of the hottest and coolest months in Franklin County (using Greenfield data as a proxy) are provided in Table 3-39.

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[34] ResilientMA: Climate Change Clearing House for the Commonwealth: http://resilientma.org/changes/rising-temperatures. Accessed March 1, 2019.

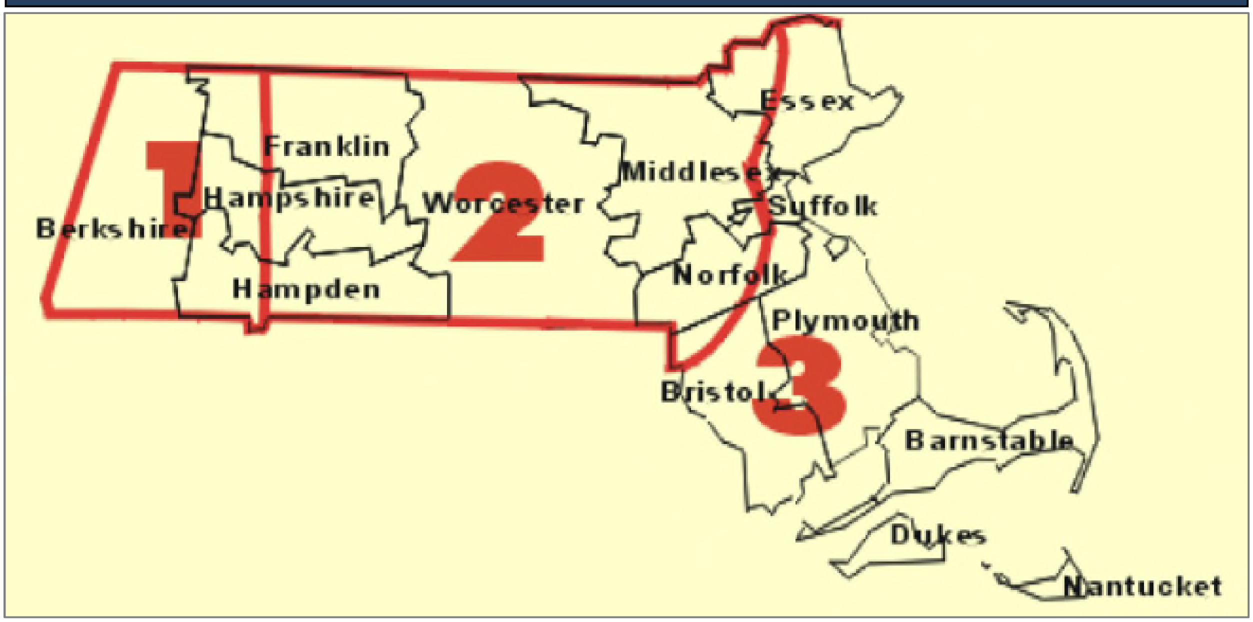
Table 3-39: Annual Average High and Low Temperatures (Greenfield)		
	July (Hottest Month)	January (Coldest Month)
Average High (°F)	81°	33°
Average Low (°F)	57°	12°

Note: Average temperatures are for the years 1981-2010.
Source: U.S. Climate Data.

Location

According to the NOAA, Massachusetts is made up of three climate divisions: Western, Central, and Coastal, as shown in Figure 3-25. Average annual temperatures vary slightly over the divisions, with annual average temperatures of around 46°F in the Western division (area labeled "1" in the figure), 49°F in the Central division (area labeled "2" in the figure) and 50°F in the Coastal division (area labeled "3" in the figure). Greenfield falls within the Central climate division.

Figure 3-25: Climate Divisions in Massachusetts



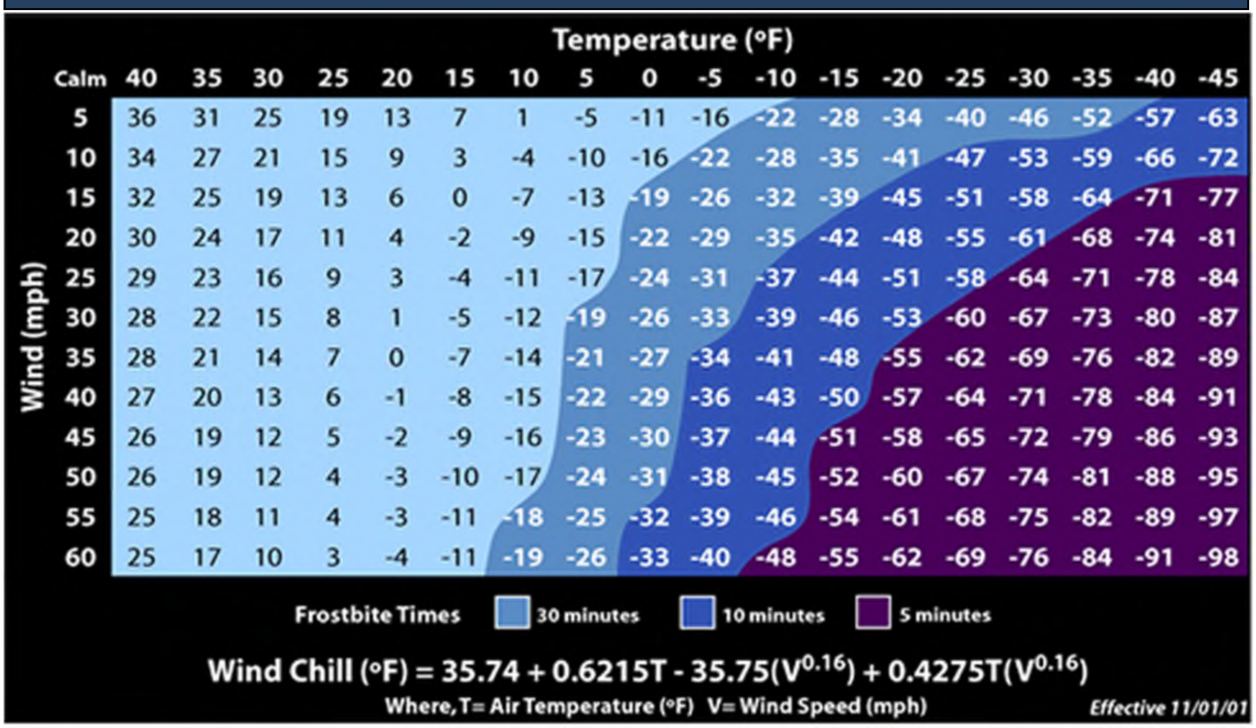
Source: NOAA, as presented in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018

Extreme temperature events occur more frequently and vary more in the inland regions of the State where temperatures are not moderated by the Atlantic Ocean. The severity of extreme heat impacts, however, is greater in densely developed urban areas like Boston than in suburban and rural areas, due to the urban "heat island" effect, described in more detail in the Impacts sub-section.

Extent

The extent (severity or magnitude) of extreme cold temperatures is generally measured through the Wind Chill Temperature Index. Wind Chill Temperature is the temperature that people and animals feel when they are outside, and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body loses heat at a faster rate, causing the skin's temperature to drop. The National Weather Service (NWS) issues a Wind Chill Advisory if the Wind Chill Index is forecast to dip to –15°F to –24°F for at least three hours, based on sustained winds (not gusts). The NWS issues a Wind Chill Warning if the Wind Chill Index is forecast to fall to –25°F or colder for at least three hours. On November 1, 2001, the NWS implemented a Wind Chill Temperature Index designed to more accurately calculate how cold air feels on human skin. Figure 3-26 shows the Wind Chill Temperature Index.

Figure 3-26: National Weather Service Wind Chill Chart



Temperature (°F)

Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
	5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
	10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
	15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
	20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
	25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
	30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
	40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
	45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
	50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
	55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
	60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Source: National Weather Service: https://www.weather.gov/safety/cold-wind-chill-chart

The NWS issues a Heat Advisory when the NWS Heat Index is forecast to reach 100 to 104°F for two or more hours. The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach 105°F or higher for two or more hours. The NWS Heat Index is based both on temperature and relative humidity, and describes a temperature equivalent to what a person would feel at a baseline humidity level. It is scaled to the ability of a person to lose heat to their environment. The relationship between these variables and the levels at which the NWS considers various health hazards to become relevant are shown in Figure 3-27. It is important to know that the heat index values are devised for shady, light wind conditions. Exposure to full sunshine can increase heat index values by up to 15°F. In addition, strong winds, particularly with very hot, dry air, can increase the risk of heat-related impacts.

Figure 3-27: National Weather Service Heat Index

NWS Heat Index

Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service: https://www.weather.gov/safety/heat-index

Previous Occurrences

Since 1994, there have been 33 cold weather events within the Commonwealth, ranging from Cold/Wind Chill to Extreme Cold/Wind Chill events. Information on severe cold weather events in Greenfield and Franklin County was not available prior to 2015. However, detail on recent extreme events is provided below.

In February 2015, a series of snowstorms piled nearly 60 inches on the city of Boston in 3 weeks and caused recurrent blizzards across eastern Massachusetts. While Greenfield and western Massachusetts was not impacted as much from the snow, temperature gauges across the Commonwealth measured extreme cold, with wind chills as low as -31°F. Wind chills as low as 28 below zero were recorded at the Orange Municipal Airport.

In February 2016, one cold weather event broke records throughout the state. Arctic high pressure brought strong northwest winds and extremely cold wind chills to southern New England. Wind chills as low as 38 below zero were reported in Orange.

According to the NOAA's Storm Events Database, there have been 43 warm weather events (ranging from Record Warmth/Heat to Excessive Heat events) since 1995 in Massachusetts. Excessive heat results from a combination of temperatures well above normal and high humidity. Whenever the heat index values meet or exceed locally or regionally established heat or excessive heat warning thresholds, an event is reported in the database. Information on excessive heat was not available for Greenfield or Franklin County prior to 2018.

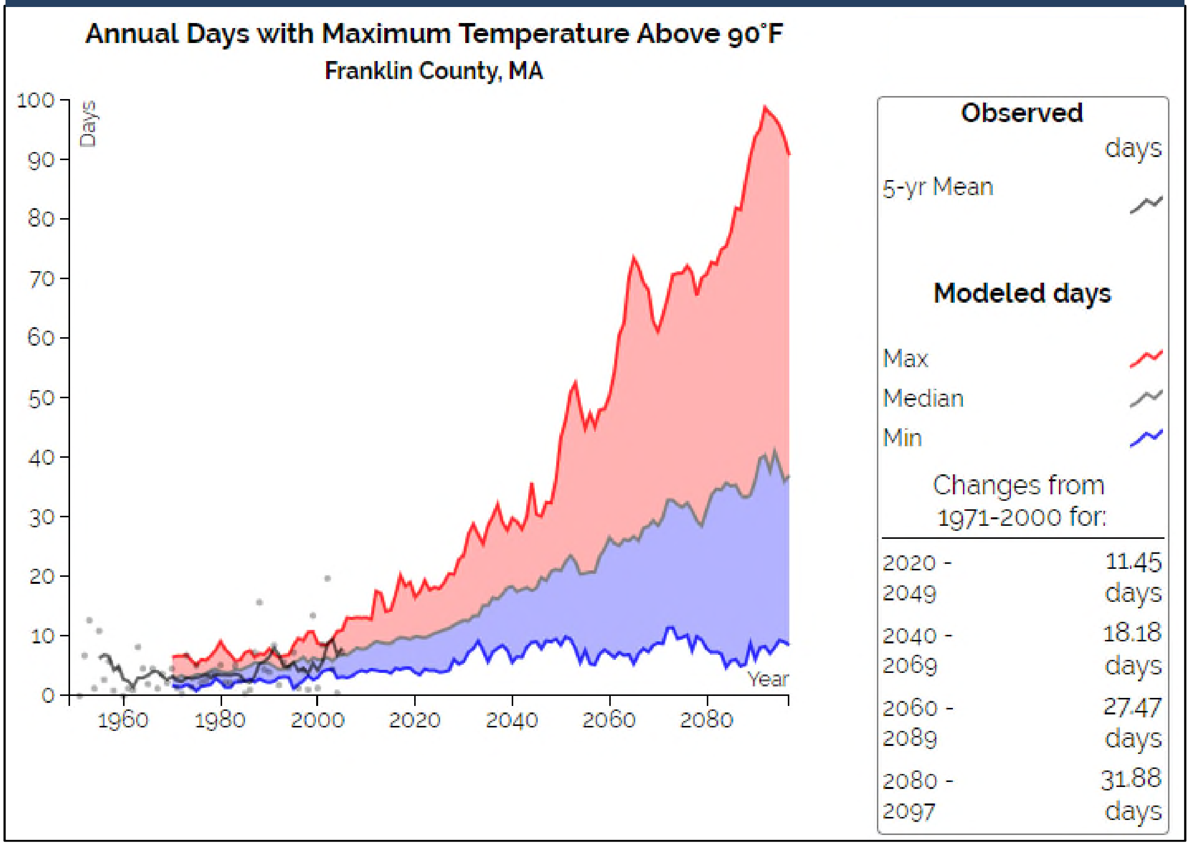
In 2012, Massachusetts temperatures broke 27 heat records. Most of these records were broken between June 20 and June 22, 2012, during the first major heat wave of the summer to hit Massachusetts and the East Coast. In July 2013, a long period of hot and humid weather occurred throughout New England. One fatality occurred on July 6, when a postal worker collapsed as the Heat Index reached 100°F. In Franklin County, excessive heat was recorded for July 1, 2018, when a heat index of 107°F was observed at the Orange Municipal Airport from 1:00 PM to 5:00 PM.

Probability of Future Events

There are a number of climatic phenomena that determine the number of extreme weather events in a specific year. However, there are significant long-term trends in the frequency of extreme hot and cold events. In the last decade, U.S. daily record high temperatures have occurred twice as often as record lows (as compared to a nearly 1:1 ratio in the 1950s). Models suggest that this ratio could climb to 20:1 by midcentury, if GHG emissions are not significantly reduced. The data support the trends of an increased frequency of extreme hot weather events and a decreased frequency of extreme cold weather events.

The average, maximum, and minimum temperatures in Franklin County are likely to increase significantly over the next century (resilient MA, 2018). This gradual change will put long-term stress on a variety of social and natural systems, and will exacerbate the influence of discrete events. Significant increases in maximum temperatures are anticipated, particularly under a higher GHG emissions scenario. Figure 3-28 displays the projected increase in the number of days per year over 90°F. The number of days per year with daily maximum temperatures over 90°F is projected to increase by 18 days by the 2050s, and by 32 days by the end of the century (for a total of 36 days over 90°F), compared to the average observed range from 1971 to 2000 of 4 days per year. Under a high emissions scenario, however, there could be as many as 100 days with a maximum temperature above 90°F by the end of the century.

Figure 3-28: Projected Annual Days with a Maximum Temperature Above 90°F



Source: resilient MA, 2018.

Impact

Extreme Cold

Extreme cold is a dangerous situation that can result in health emergencies for susceptible people, such as those without shelter or who are stranded or who live in homes that are poorly insulated or without heat. Extreme cold events are events when temperatures drop well below normal in an area. Extreme cold temperatures are characterized by the ambient air temperature dropping to approximately 0°F or below.

When winter temperatures drop significantly below normal, staying warm and safe can become a challenge. Extremely cold temperatures often accompany a winter storm, which may also cause power failures and icy roads. During cold months, carbon monoxide may be high in some areas because the colder weather makes it difficult for car emission control systems to operate effectively, and temperature inversions can trap the resulting pollutants closer to the ground.

Staying indoors as much as possible can help reduce the risk of car crashes and falls on the ice, but cold weather also can present hazards indoors. Many homes may be too cold, either due to a power failure or because the heating system is not adequate for the weather. Exposure to cold temperatures, whether indoors or outside, can cause other serious or life-threatening health problems. Power outages may also result in inappropriate use of combustion heaters, cooking appliances, and generators in indoor or poorly ventilated areas, leading to increased risk of carbon monoxide poisoning or fire.

Extreme Heat

A heat wave is defined as three or more days of temperatures of 90°F or above. A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population. Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined.

Heat impacts can be particularly significant in urban areas. Buildings, roads, and other infrastructure replace open land and vegetation. Dark-colored asphalt and roofs also absorb more of the sun's energy. These changes cause urban areas to become warmer than the surrounding areas. This forms "islands" of higher temperatures, often referred to as "heat islands." The term "heat island" describes built-up areas that are hotter than nearby rural or shaded areas. Heat islands occur on the surface and in the atmosphere. On a hot, sunny day, the sun can heat dry, exposed urban surfaces to temperatures 50°F to 90°F hotter than the air. Heat islands can affect communities by increasing peak energy demand during the summer, air conditioning costs, air pollution and GHG emissions, heat-related illness and death, and water quality degradation.

Extreme heat events can also have impacts on air quality. Many conditions associated with heat waves or more severe events—including high temperatures, low precipitation, strong sunlight and low wind speeds—contribute to a worsening of air quality in several ways. High temperatures can increase the production of ozone from volatile organic compounds and other aerosols. Weather patterns that bring high temperatures can also transport particulate matter air pollutants from other areas of the continent. Additionally, atmospheric inversions and low wind speeds allow polluted air to remain in one location for a prolonged period of time.

Vulnerability

The entire City of Greenfield is vulnerable to extreme temperatures.

Society

Vulnerable Populations

According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include: (1) people over the age of 65, who are less able to withstand temperature extremes due to their age, health conditions, and limited mobility to access shelters; (2) infants and children under 5 years of age; (3) individuals with pre-existing medical conditions that impair heat tolerance (e.g., heart disease or kidney disease); (4) low-income individuals who cannot afford proper heating and cooling; (5) people with respiratory conditions, such as asthma or chronic obstructive pulmonary disease; and (6) the general public who may overexert themselves when working or exercising during extreme heat events or who may experience hypothermia during extreme cold events. Additionally, people who live alone—particularly the elderly and individuals with disabilities—are at higher risk of heat-related illness due to their isolation and potential reluctance to relocate to cooler environments.

An additional element of vulnerability to extreme temperature events is homelessness, as homeless individuals have a limited capacity to shelter from dangerous temperatures. Two homeless people died from exposure to extreme cold in January 2019 in Greenfield.

Table 3-40 estimates the number of vulnerable populations and households in Greenfield. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides City officials and emergency response personnel with information to help plan for responding to the needs of Greenfield residents during an extreme temperature event.

Table 3-40: Estimated Vulnerable Populations in Greenfield		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%

Table 3-40: Estimated Vulnerable Populations in Greenfield		
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

Health Impacts

When people are exposed to extreme heat, they can suffer from potentially deadly illnesses, such as heat exhaustion and heat stroke. Heat is the leading weather-related killer in the U.S., even though most heat-related deaths are preventable through outreach and intervention. A study of heat-related deaths across Massachusetts estimated that when the temperature rises above the 85th percentile (hot: 85-86°F), 90th percentile (very hot: 87-89°F) and 95th percentile (extremely hot: 89-92°F) there are between five and seven excess deaths per day in Massachusetts. These estimates were higher for communities with high percentages of African American residents and elderly residents on days exceeding the 85th percentile.[35] A 2013 study of heart disease patients in Worcester, MA, found that extreme heat (high temperature greater than the 95th percentile) in the 2 days before a heart attack resulted in an estimated 44 percent increase in mortality. Living in poverty appeared to increase this effect.[36] In 2015, researchers analyzed Medicare records for adults over the age of 65 who were living in New England from 2000 to 2008. They found that a rise in summer mean temperatures of 1°C resulted in a 1 percent rise in the mortality rate due to an increase in the number and intensity of heat events.[37]

Hot temperatures can contribute to deaths from heart attacks, strokes, other forms of cardiovascular disease, renal disease, and respiratory diseases such as asthma and chronic obstructive pulmonary disorder. Human bodies cool themselves primarily through sweating and through increasing blood flow to body surfaces. Heat events thus increase stress on cardiovascular, renal, and respiratory systems, and may lead to hospitalization or death in the elderly and those with pre-existing diseases.

Massachusetts has a very high prevalence of asthma: approximately 1 out of every 11 people in

[35] Hattis, D. et al. 2012. The Spatial Variability of Heat-Related Mortality in Massachusetts. Applied Geography. 33(2012) pg 45-52. http://wordpress.clarku.edu/yogneva/files/2012/04/Hattis-et-al-2011-The-spatial-variability-of-heat-related-mortality-in-Massachusetts.pdf

[36] Madrigano J, Mittleman MA, Baccarelli A, Goldberg R, Melly S, von Klot S, Schwartz J.Temperature, myocardial infarction, and mortality: effect modification by individual- and area-level characteristics. Epidemiology. 2013 May;24(3):439-46.

[37] Shi L. et al. 2015. Impacts of temperature and its variability on mortality in New England. Nature Climate Change. Volume 5. November 2015.

the state currently has asthma. In Massachusetts, poor air quality often accompanies heat events, as increased heat increases the conversion of ozone precursors in fossil fuel combustion emissions to ozone. Particulate pollution may also accompany hot weather, as the weather patterns that bring heat waves to the region may carry pollution from other areas of the continent. Poor air quality can negatively affect respiratory and cardiovascular systems, and can exacerbate asthma and trigger heart attacks.

The rate of hospital admissions for heat stress under existing conditions is shown in Figure 3-29. Between 2002 and 2012, the annual average age-adjusted rate of hospital admission for heat stress was highest in Plymouth and Suffolk Counties. Franklin County ranked among the second highest rate of 0.12-0.13 admissions per 10,000 people. As displayed in Figure 3-30, Franklin County experienced the highest annual average age-adjusted hospital admissions for heart attacks (4.29 to 4.17 per 10,000 people) during this period, along with Plymouth, Bristol, and Berkshire Counties. Hamden County had the highest annual average age emergency department visits due to asthma (see Figure 3-31), while Franklin County's rate was statistically significantly lower.

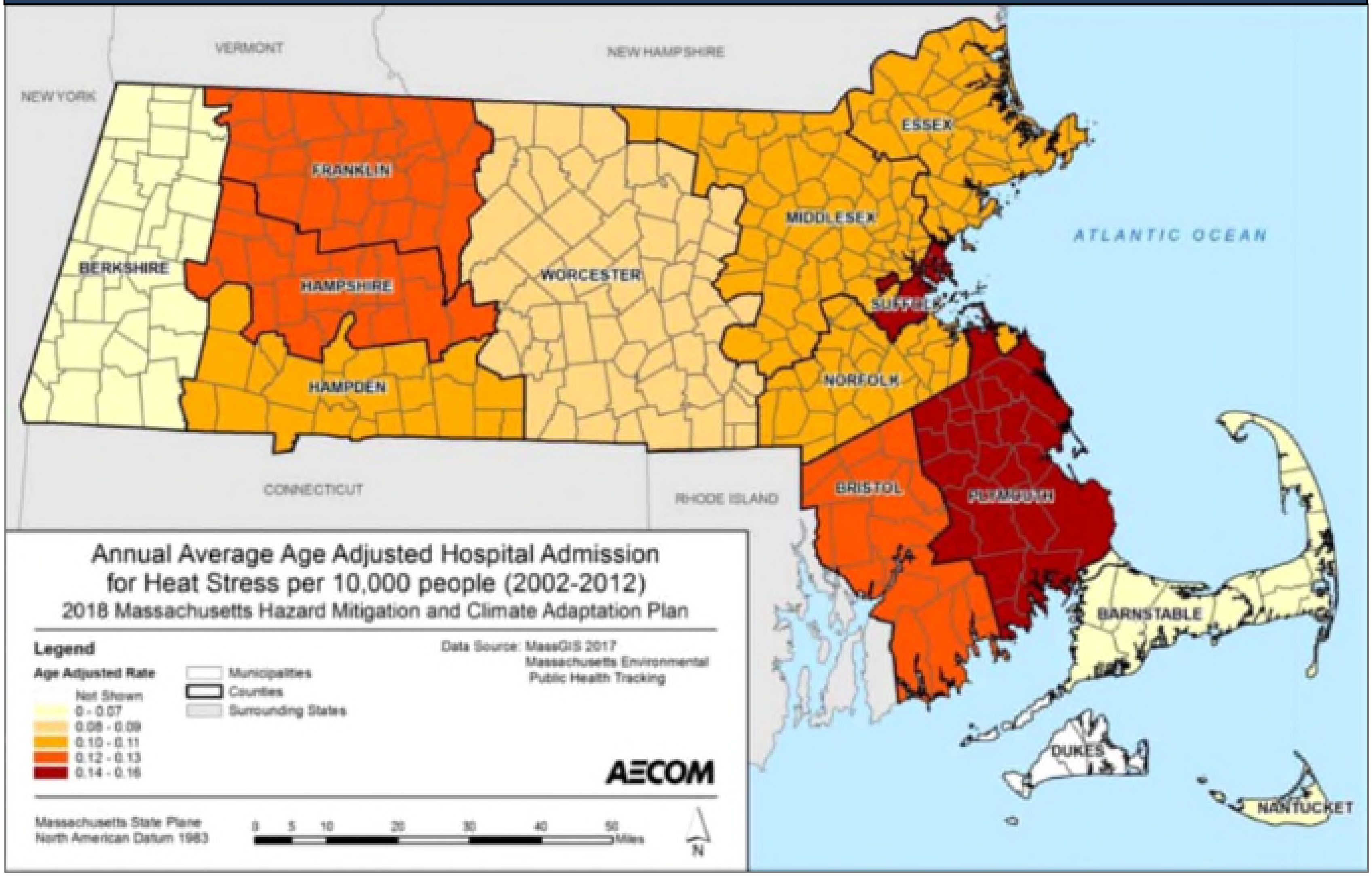
Some behaviors increase the risks of temperature-related impacts. These behaviors include voluntary actions, such as drinking alcohol or taking part in strenuous outdoor physical activities in extreme weather, but may also include necessary actions, such as taking prescribed medications that impair the body's ability to regulate its temperature or that inhibit perspiration.

Cold-weather events can also have significant health impacts. The most immediate of these impacts are cold-related injuries, such as frostbite and hypothermia, which can become fatal if exposure to cold temperatures is prolonged. Similar to the impacts of hot weather that have already been described, cold weather can exacerbate pre-existing respiratory and cardiovascular conditions. Additionally, power outages that occur as a result of extreme temperature events can be immediately life-threatening to those dependent on electricity for life support or other medical needs. Isolation of these populations is a significant concern if extreme temperatures preclude their mobility or the functionality of systems they depend on. Power outages during cold weather may also result in inappropriate use of combustion heaters, cooking appliances, and generators in indoor or poorly ventilated areas, leading to increased risk of carbon monoxide poisoning or fires.

Greenfield is fortunate to have official heating and cooling centers in town. The John Zon Senior Center and Greenfield Public Library provide heating and cooling during business hours. Overnight heating is available in seated areas at the Salvation Army Center for Worship &

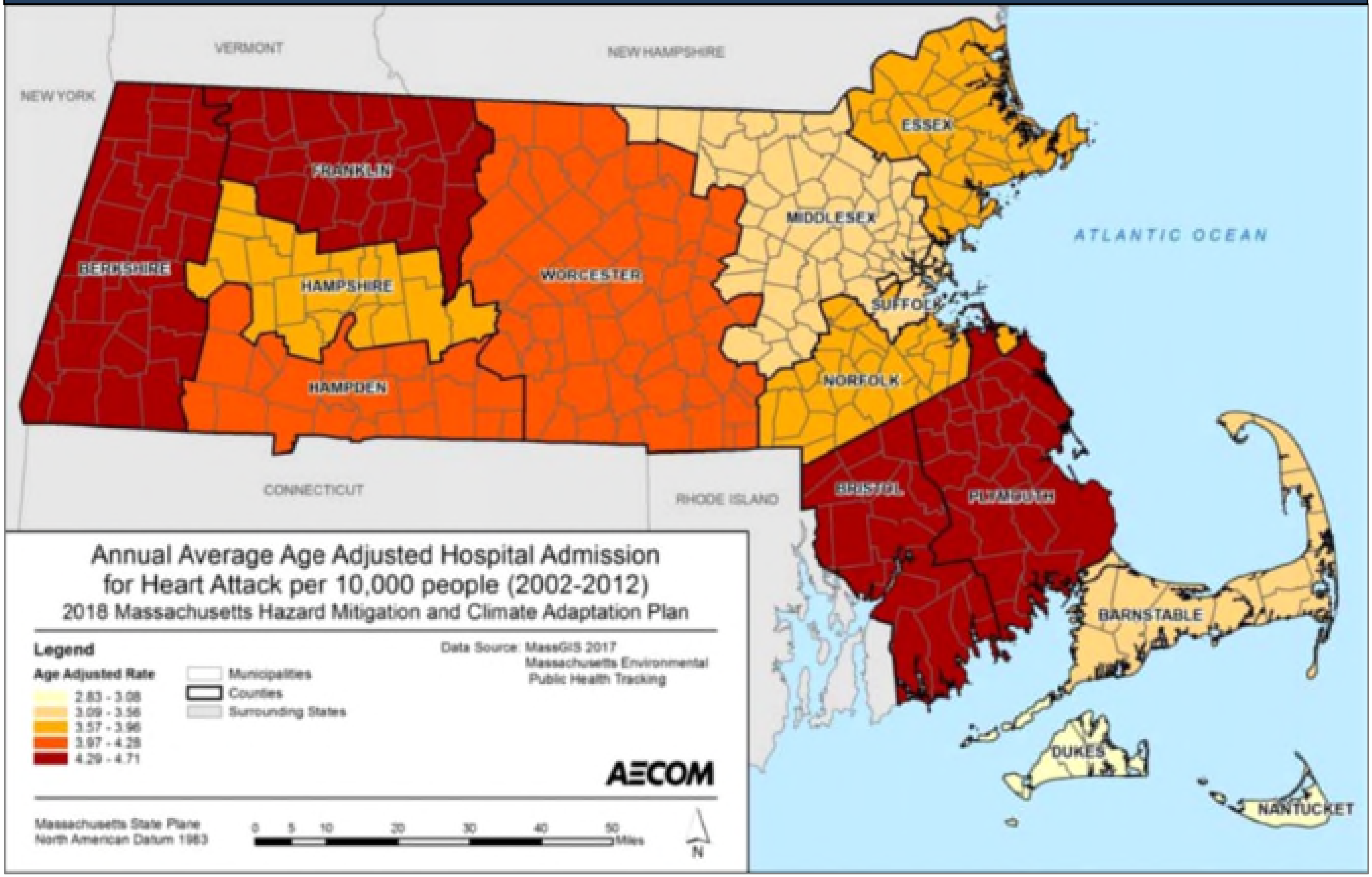
Service on Chapman Street.

Figure 3-29: Rates of Heat Stress-Related Hospitalization by County



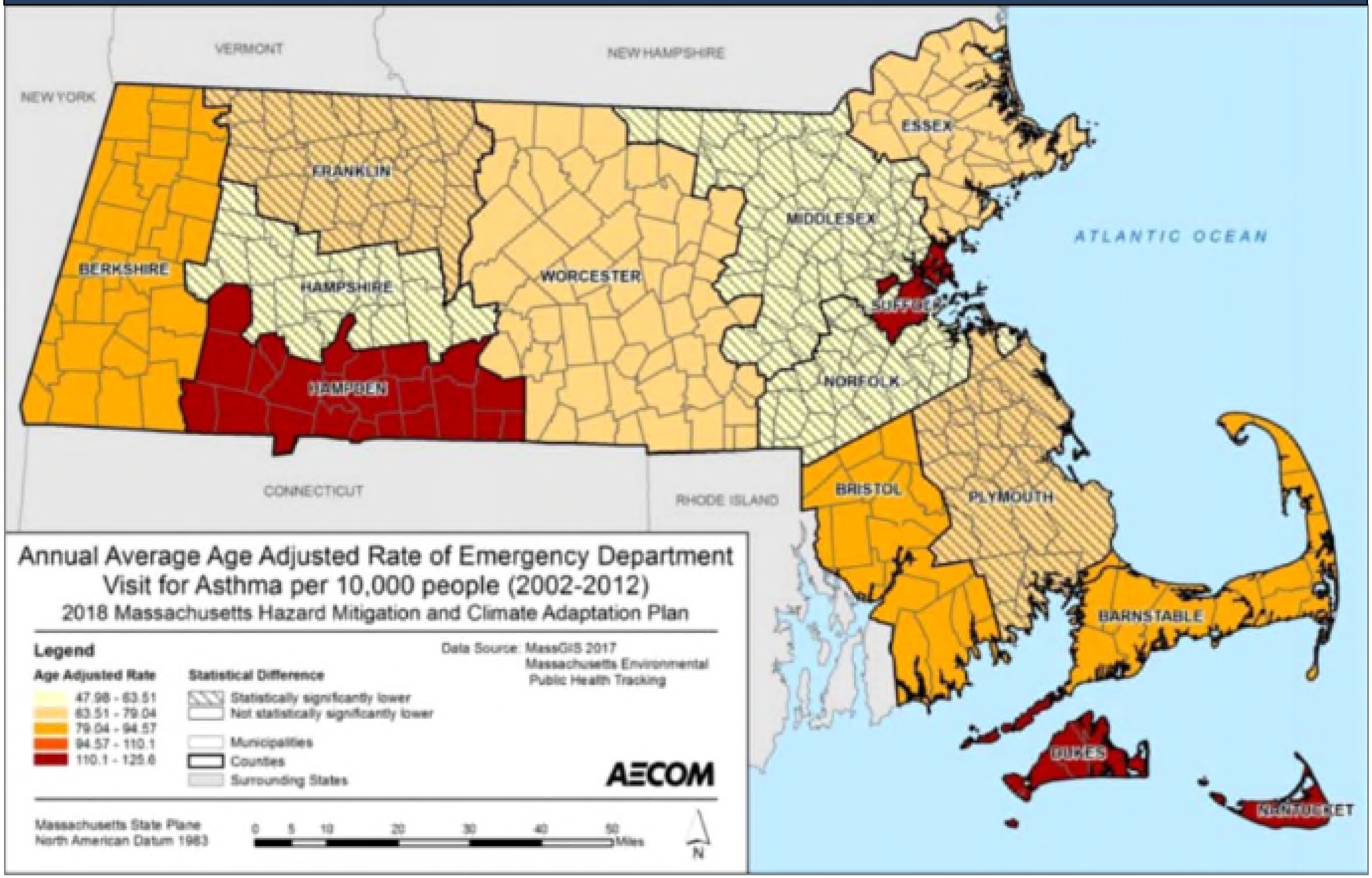
Source: Massachusetts Hazard Mitigation and Climate Adaptation Plan, September 2018.

Figure 3-30: Rates of Hospital Admissions for Heart Attacks by County



Source: Massachusetts Hazard Mitigation and Climate Adaptation Plan, September 2018.

Figure 3-31: Rates of Emergency Department Visits Due to Asthma by County



Source: Massachusetts Hazard Mitigation and Climate Adaptation Plan, September 2018.

Economic Impacts

Extreme temperature events also have impacts on the economy, including loss of business function and damage to and loss of inventory. Business owners may be faced with increased financial burdens due to unexpected building repairs (e.g., repairs for burst pipes), higher than normal utility bills, or business interruptions due to power failure (i.e., loss of electricity and telecommunications). Increased demand for water and electricity may result in shortages and a higher cost for these resources. Industries that rely on water for business (e.g., landscaping businesses) will also face significant impacts. There is a loss of productivity and income when the transportation sector is impacted and people and commodities cannot get to their intended destination. Businesses with employees that work outdoors (such as agricultural and construction companies) may have to reduce employees' exposure to the elements by reducing or shifting their hours to cooler or warmer periods of the day.

The agricultural industry is most directly at risk in terms of economic impact and damage due to extreme temperature and drought events. Extreme heat can result in drought and dry conditions, which directly impact livestock and crop production. Increasing average temperatures may make crops more susceptible to invasive species. Higher temperatures that result in greater concentrations of ozone negatively impact plants that are sensitive to ozone. Additionally, as described in the Environment sub-section, changing temperatures can impact the phenology.

Livestock are also impacted, as heat stress can make animals more vulnerable to disease, reduce their fertility, and decrease the rate of milk production. Additionally, scientists believe the use of parasiticides and other animal treatments may increase as the threat of invasive species and pests grows.

Infrastructure

All elements of the built environment are exposed to the extreme temperature hazard. The impacts of extreme heat on buildings include: increased thermal stresses on building materials, which leads to greater wear and tear and reduces a building's useful lifespan; increased air-conditioning demand to maintain a comfortable temperature; overheated heating, ventilation, and air-conditioning systems; and disruptions in service associated with power outages. Extreme cold can cause materials such as plastic to become less pliable, increasing the potential for these materials to break down during extreme cold events. In addition to the facility-specific impacts, extreme temperatures can impact critical infrastructure sectors of the built environment in a number of ways, which are summarized in the subsections that follow.

Agriculture

Above average, below average, and extreme temperatures are likely to impact crops—such as apples, peaches, and maple syrup—that rely on specific temperature regimes. Unseasonably warm temperatures in early spring that are followed by freezing temperatures can result in crop loss of fruit-bearing trees. Increasing heat stress days (above 90°F) may stress livestock and some crops. More pest pressure from insects, diseases and weeds may harm crops and cause farms to increase pesticide use. Farmers may have the opportunity to introduce new crops that are viable under warmer conditions and longer growing seasons; however, a transition such as this may be costly.[38]

Energy

In addition to increasing demand for heating and cooling, periods of both hot and cold weather can stress energy infrastructure. Electricity consumption during summer may reach three times the average consumption rate of the period between 1960 and 2000; more than 25 percent of this consumption may be attributable to climate change.[39] In addition to affecting consumption rates, high temperatures can also reduce the thermal efficiency of electricity generation.

Extended-duration extreme cold can lead to energy supply concerns, as the heating sector then demands a higher percentage of the natural gas pipeline capacity. When this occurs, New England transitions electricity generation from natural gas to oil and liquid natural gas. Limited on-site oil and liquid natural gas storage as well as refueling challenges may cause energy supply concerns if the events are colder and longer in duration.

Transportation

Extreme heat has potential impacts on the design and operation of the transportation system. Impacts on the design include the instability of materials, particularly pavement, exposed to high temperatures over longer periods of time, which can cause buckling and lead to increased failures.[40] High heat can cause pavement to soften and expand, creating ruts, potholes, and jarring, and placing additional stress on bridge joints. Extreme heat may cause heat stress in materials such as asphalt and increase the frequency of repairs and replacements. Roads are also vulnerable to rapid freeze and thaw cycles, which may cause damage to road surfaces. An increase in freeze and thaw cycles can also damage bridge expansion joints.[41]

Railroad tracks can expand in extreme heat, causing the track to “kink” and derail trains. Higher

[38] Resilient MA: http://resilientma.org/sectors/agriculture. Accessed March 4, 2019.

[39] Massachusetts Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee (EOEEA). 2011. Massachusetts Climate Change Adaptation Report.

[40] Massachusetts Department of Transportation (MassDOT). 2017. Assessment of Extreme Temperature Impacts on MassDOT Assets

[41] Resilient MA: http://resilientma.org/sectors/transportation. Accessed March 4, 2019.

temperatures inside the enclosure-encased equipment, such as traffic control devices and signal control systems for rail service, may result in equipment failure. Rail operations will also be impacted when mandatory speed reductions are issued in areas where tracks have been exposed to high temperatures over many days, resulting in increased transit travel time and operating costs as well as a reduction in track capacity. Finally, extreme temperatures also discourage active modes of transportation, such as bicycling and walking. This will have a secondary impact on sustainable transportation objectives and public health.

Operations are vulnerable to heat waves and associated power outages that affect electrical power supply to rail operations and to supporting ancillary assets for highway operations, such as electronic signing. Increased heat also impacts transportation workers, the viability of vegetation in rights-of-way, and vehicle washing or maintenance schedules.[42] Hot weather increases the likelihood that cars may overheat during hot weather, and also increases the deterioration rate of tires.

<u>Water Infrastructure</u>
Extreme temperatures do not pose as great a threat to water infrastructure as flood-related hazards, but changes in temperature can impact water infrastructure. For example, extreme heat that drives increases in air-conditioning demand can trigger power outages that disrupt water and wastewater treatment.[43] Hotter temperatures will also likely result in increased outdoor water consumption. Combined with other climate impacts such as an increase in surface water evapotranspiration, changing precipitation patterns, and groundwater recharge rates, increased water demand may challenge the capacity of water supplies and providers. Extreme heat can damage aboveground infrastructure such as tanks, reservoirs, and pump stations. Warmer temperatures can also lead to corrosion, water main breaks, and inflow and infiltration into water supplies. Extreme heat is likely to result in increased drought conditions, and this has significant implications for water infrastructure, as discussed in the Drought Section.

Extreme cold can freeze pipes, causing them to burst. This can then lead to flooding and mold inside buildings when frozen pipes thaw.

Environment

There are numerous ways in which changing temperatures will impact the natural environment.

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[42] Massachusetts Department of Transportation (MassDOT). 2017. Assessment of Extreme Temperature Impacts on MassDOT Assets
[43] Resilient MA: http://resilientma.org/sectors/water-resources. Accessed March 4, 2019.

Because the species that exist in a given area have adapted to survive within a specific temperature range, extreme temperature events can place significant stress both on individual species and the ecosystems in which they function. High-elevation spruce-fir forests, forested boreal swamp, and higher-elevation northern hardwoods are likely to be highly vulnerable to climate change. Higher summer temperatures will disrupt wetland hydrology. Paired with a higher incidence and severity of droughts, high temperatures and evapotranspiration rates could lead to habitat loss and wetlands drying out.[44] Individual extreme weather events usually have a limited long-term impact on natural systems, although unusual frost events occurring after plants begin to bloom in the spring can cause significant damage. However, the impact on natural resources of changing average temperatures and the changing frequency of extreme climate events is likely to be massive and widespread.

One significant impact of increasing temperatures may be the northern migration of plants and animals. Over time, shifting habitat may result in a geographic mismatch between the location of conservation land and the location of critical habitats and species the conserved land was designed to protect. One specific way in which average temperatures influence plant behavior is through changes in phenology, the pattern of seasonal life events in plants and animals. A recent study by the National Park Service found that of 276 parks studied, three-quarters are experiencing earlier spring conditions, as defined by the first greening of trees and first bloom of flowers, and half are experiencing an "extreme" early spring that exceeds 95% of historical conditions.[45] These changing seasonal cues can lead to ecological mismatches, as plants and animals that rely on each other for ecosystem services become "out of sync." For example, migratory birds that rely on specific food sources at specific times may reach their destinations before or after the species they feed on arrive or are in season. Additionally, invasive species tend to have more flexible phenologies than their native counterparts; therefore, shifting seasons may increase the competitiveness of present and introduced invasive species.

Wild plants and animals are also migrating away from their current habitats in search of the cooler temperatures to which they are accustomed. This is particularly pertinent for ecosystems that (like many in the northeastern U.S.) lie on the border between two biome types. For example, an examination of the Green Mountains of Vermont found a 299- to 390-foot upslope shift in the boundary between northern hardwoods and boreal forests between

[44] Manomet Center for Conservation Sciences (MCCS) and Massachusetts Division of Fisheries and Wildlife (DFW). 2010. Climate Change and Massachusetts Fish and Wildlife: Volume 3 Habitat Management.

[45] National Park System (NPS). 2016. Project Brief: Phenology and Climate Change. https://www.nps.gov/subjects/climatechange/upload/2016-10-26-NPS-Phen-Project-Brief.pdf

1964 and 2004.[46] Such a shift is hugely significant for the species that live in this ecosystem as well as for forestry companies or others who rely on the continued presence of these natural resources. Massachusetts ecosystems that are expected to be particularly vulnerable to warming temperatures include:

- Coldwater streams and fisheries
- Vernal pools
- Spruce-fir forests
- Northern hardwood (Maple-Beech-Birch) forests, which are economically important due to their role in sugar production
- Hemlock forests, particularly those with the hemlock wooly adelgid
- Urban forests, which will experience extra impacts due to the urban heat island effect

Additional impacts of warming temperatures include the increased survival and grazing damage of white-tailed deer, increased invasion rates of invasive plants, and increased survival and productivity of insect pests, which cause damage to forests.[47] As temperature increases, the length of the growing season will also increase.

Vulnerability Summary

Based on the above assessment, Greenfield has a "Medium" vulnerability to extreme temperatures. The following problem statements summarize Greenfield's areas of greatest concern regarding extreme temperatures.

[46] U.S. Global Change Research Program (USGCRP). 2014. Hatfield, J. et al., Ch. 6: Agri-culture. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., pp 150-174

[47] Manomet Center for Conservation Sciences (MCCS) and Massachusetts Division of Fisheries and Wildlife (DFW). 2010. Climate Change and Massachusetts Fish and Wildlife: Volume 3 Habitat Management.

Extreme Temperature Hazard Problem Statements
• Extreme cold temperatures combined with power outages, even short duration, can result in frozen and burst pipes for properties without back-up power.
• Residents may not be familiar with how to deal with or prevent diseases associated with increasing average temperatures (e.g., tick and mosquito borne diseases).
• Elderly, disabled and low-income residents are more vulnerable to extreme temperatures and may lack A/C or adequate heating systems in their homes.
• Extreme heat may worsen risk of wildfires and the availability of local water supplies for firefighting. Firefighters may already lack sufficient water volume, pressure, and/or infrastructure across town to fight wildfires. Also see wildfires problem statements.
• Extreme temperature changes during Spring and Fall can negatively affect crops. An improved process is needed for estimating and tracking local crop damage caused by a extreme temperatures.
• Extreme temperatures create a risk of "brown-outs" in the power grid, where electricity supply may dip due to excess demand on the system and can affect vulnerable populations and municipal operations dependent on a consistent and uninterrupted power supply.
• Changing climate has resulted in an annual decrease in days below freezing, a trend that will progress over the next century. Fewer days below freezing and deep frosts occurring later in the season are some of the contributing factors for larger tic and mosquito populations and longer seasons for both. This increases risk to Greenfield residents from insect borne diseases.

3.14 INVASIVE SPECIES

Potential Impacts of Climate Change

A warming climate may place stress on colder-weather species while allowing non-native species accustomed to warmer climates to spread northward. This northward trend is already well documented, and is expected to accelerate in the future. Another way in which climate change may increase the frequency of natural species threat is through the possibility of climate refugees. As populations move to escape increasingly inhospitable climates, they are likely to bring along products, food, and livestock that could introduce novel (and potentially invasive) species to the areas in which they settle.

Extreme winter temperatures are also critical limiting factors for many forest pests, and warming is expected to increase their survival and lead to expansions and outbreaks. For example, in Massachusetts, it's likely that winter temperatures have been limiting the impact of hemlock wooly adelgid (Adelges tsugae), as many infested forest stands are surviving while in more southerly ranges there is near complete mortality from this pest. But the adelgid has already expanded its range with warming winter temperatures and is likely to have increased survival and higher reproductive rates in the northern portion of its range as temperatures warm, likely leading to more significant impacts on forests.[48]

Figure 3-32: Impacts of Climate Change on Invasive Species

Potential Effects of Climate Change	
RISING TEMPERATURES ➔ WARMING CLIMATE	A warming climate may place stress on colder-weather species, while allowing non-native species accustomed to warmer climates to spread northward.
RISING TEMPERATURES AND CHANGES IN PRECIPITATION ➔ ECOSYSTEM STRESS	Changes in precipitation and temperature combine to create new stresses for Massachusetts' unique ecosystems. For example, intense rainfall in urbanized areas can cause pollutants on roads and parking lots to get washed into nearby rivers and lakes, reducing habitat quality. As rainfall and snowfall patterns change, certain habitats and species that have specific physiological requirements may be affected. The stresses experienced by native ecosystems as a result of these changes may increase the chances of a successful invasion of non-native species.

Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Hazard Description

"Invasives" are species recently introduced to new ecosystems that cause or are likely to cause significant harm to the environment, economy, or human health. Invasives compete with native plants and wildlife for resources, disrupt beneficial relationships, spread disease, cause direct

[48] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 4, 2019.

mortality, and can significantly alter ecosystem function. Some of the more common invasives in Massachusetts may already be familiar - problematic invasive plants include purple loosestrife (Lythrum salicaria), Japanese barberry (Berberis thunbergi), glossy buckthorn (Frangula alnus), multiflora rose (Rosa multiflora), Japanese knotweed (Fallopia japonica), garlic mustard (Alliaria petiolata) and black locust (Robinia pseudoacacia). Invasive animals include forest pests such as the hemlock woolly adelgid (Adelgis tsugae), Asian longhorn beetle (Anoplophora glabripennis), and the emerald ash borer (Agrilus planipennis). The zebra mussel (Dreissena polymorpha) is a particularly detrimental aquatic invasive species that has recently been detected in Western Massachusetts.[49]

The Massachusetts Invasive Plant Advisory Group (MIPAG), a collaborative representing organizations and professionals concerned with the conservation of the Massachusetts landscape, is charged by the Massachusetts Executive Office of Energy and Environmental Affairs to provide recommendations to the Commonwealth to manage invasive species. MIPAG defines invasive plants as "non-native species that have spread into native or minimally managed plant systems in Massachusetts, causing economic or environmental harm by developing self- sustaining populations and becoming dominant and/or disruptive to those systems." These species have biological traits that provide them with competitive advantages over native species, particularly because in a new habitat they are not restricted by the biological controls of their native habitat. As a result, these invasive species can monopolize natural communities, displacing many native species and causing widespread economic and environmental damage. MIPAG recognized 69 plant species as "Invasive," "Likely Invasive," or "Potentially Invasive."

Massachusetts has a variety of laws and regulations in place that attempt to mitigate the impacts of these species. The Massachusetts Department of Agricultural Resources (MDAR) maintains a list of prohibited plants for the state, which includes federally noxious weeds as well as invasive plants recommended by MIPAG and approved for listing by MDAR. Species on the MDAR list are regulated with prohibitions on importation, propagation, purchase, and sale in the Commonwealth. Additionally, the Massachusetts Wetlands Protection Act (310 CMR 10.00) includes language requiring all activities covered by the Act to account for, and take steps to prevent, the introduction or propagation of invasive species.

In 2000, Massachusetts passed an Aquatic Invasive Species Management Plan, making the Commonwealth eligible for federal funds to support and implement the plan through the federal Aquatic Nuisance Prevention and Control Act. MassDEP is part of the Northeast Aquatic

[49] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 4, 2019.

Nuisance Species Panel, which was established under the federal Aquatic Nuisance Species Task Force. This panel allows managers and researchers to exchange information and coordinate efforts on the management of aquatic invasive species. The Commonwealth also has several resources pertaining to terrestrial invasive species, such as the Massachusetts Introduced Pest Outreach Project, although a strategic management plan has not yet been prepared for these species.

Code of Massachusetts Regulation (CMR) 330 CMR 6.0(d) requires any seed mix containing restricted noxious weeds to specify the name and number per pound on the seed label. Regulation 339 CMR 9.0 restricts the transport of currant or gooseberry species in an attempt to prevent the spread of white pine blister rust. There are also a number of state laws pertaining to invasive species. Chapters 128, 130, and 132 of Part I of the General Laws of the state include language addressing water chestnuts, green crabs, the Asian longhorn beetle, and a number of other species. These laws also include language allowing orchards and gardens to be surveyed for invasive species and for quarantines to be put into effect at any time.

Identification and monitoring is an important element in mitigating impacts from invasive species. The Outsmart Invasive Species project is a collaboration between the University of Massachusetts Amherst, the Massachusetts Department of Conservation and Recreation (MA DCR) and the Center for Invasive Species and Ecosystem Health at the University of Georgia. The goal of the project is to strengthen ongoing invasive-species monitoring efforts in Massachusetts by enlisting help from citizens. The web- and smartphone-based approach enables volunteers to identify and collect data on invasive species in their own time, with little or no hands-on training. By taking advantage of the increasing number of people equipped with iPhone or digital camera/web technology, this approach will expand the scope of invasive-species monitoring, in an effort to help control outbreaks of new or emergent invasive species that threaten our environment.[50]

Location

The damage rendered by invasive species is significant. The massive scope of this hazard means that the entire City of Greenfield may experience impacts from these species. Furthermore, the ability of invasive species to travel far distances (either via natural mechanisms or accidental human interference) allows these species to propagate rapidly over a large geographic area. Similarly, in open freshwater ecosystems, invasive species can quickly spread once introduced, as there are generally no physical barriers to prevent establishment, outside of physiological tolerances, and multiple opportunities for transport to new locations (by boats, for example).

[50] https://masswoods.org/outsmart. Accessed March 5, 2019.

Extent

Invasive species are a widespread problem in Massachusetts and throughout the country. The geographic extent of invasive species varies greatly depending on the species in question and other factors, including habitat and the range of the species. Some (such as the gypsy moth) are nearly controlled, whereas others, such as the zebra mussel, are currently adversely impacting ecosystems throughout the Commonwealth. Invasive species can be measured through monitoring and recording observances.

Previous Occurrences

The terrestrial and freshwater species listed on the MIPAG website as “Invasive” (last updated April 2016) are identified in Table 3-41. The table also includes details on the nature of the ecological and economic challenges presented by each species as well as information on where the species has been detected in Massachusetts. Twenty-eight of the invasive species on the list have been observed in Greenfield since 2010.

Table 3-41: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Greenfield**
Acer platanoides L. (**Norway maple**)	A tree occurring in all regions of the state in upland and wetland habitats, and especially common in woodlands with colluvial soils. It grows in full sun to full shade. Escapes from cultivation; can form dense stands; out-competes native vegetation, including sugar maple; dispersed by water, wind and vehicles.	Y
Aegopodium podagraria L. (**Bishop's goutweed; bishop's weed; goutweed**)	A perennial herb occurring in all regions of the state in uplands and wetlands. Grows in full sun to full shade. Escapes from cultivation; spreads aggressively by roots; forms dense colonies in flood plains.	Y
Ailanthus altissima (P. Miller) Swingle (**Tree of heaven**)	This tree occurs in all regions of the state in upland, wetland, & coastal habitats. Grows in full sun to full shade. Spreads aggressively from root suckers, especially in disturbed areas.	Y
Alliaria petiolata (Bieb.) Cavara & Grande (**Garlic mustard**)	A biennial herb occurring in all regions of the state in uplands. Grows in full sun to full shade. Spreads aggressively by seed, especially in wooded areas.	Y
Berberis thunbergii DC. (**Japanese barberry**)	A shrub occurring in all regions of the state in open and wooded uplands and wetlands. Grows in full sun to full shade. Escaping from cultivation; spread by birds; forms dense stands.	Y
Cabomba caroliniana A.Gray (**Carolina fanwort; fanwort**)	A perennial herb occurring in all regions of the state in aquatic habitats. Common in the aquarium trade; chokes waterways.	N
Celastrus orbiculatus Thunb. (**Oriental bittersweet; Asian or Asiatic bittersweet**)	A perennial vine occurring in all regions of the state in uplands. Grows in full sun to partial shade. Escaping from cultivation; berries spread by birds and humans; overwhelms and kills vegetation.	Y
Cynanchum louiseae Kartesz & Gandhi (**Black swallow-wort, Louise's swallow-wort**)	A perennial vine occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to partial shade. Forms dense stands, out-competing native species: deadly to	Y

Table 3-41: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Greenfield**
	Monarch butterflies.	
Elaeagnus umbellata Thunb. (**Autumn olive**)	A shrub occurring in uplands in all regions of the state. Grows in full sun. Escaping from cultivation; berries spread by birds; aggressive in open areas; has the ability to change soil.	Y
Euonymus alatus (Thunb.) Sieb. (**Winged euonymus; Burning bush**)	A shrub occurring in all regions of the state and capable of germinating prolifically in many different habitats. It grows in full sun to full shade. Escaping from cultivation and can form dense thickets and dominate the understory; seeds are dispersed by birds.	Y
Frangula alnus P. Mill. (**European buckthorn; glossy buckthorn**)	Shrub or tree occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Produces fruit throughout the growing season; grows in multiple habitats; forms thickets.	Y
Hesperis matronalis L. (**Dame's rocket**)	A biennial and perennial herb occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Spreads by seed; can form dense stands, particularly in flood plains.	Y
Iris pseudacorus L. (**Yellow iris**)	A perennial herb occurring in all regions of the state in wetland habitats, primarily in flood plains. Grows in full sun to partial shade. Out-competes native plant communities.	Y
Lonicera japonica Thunb. (**Japanese honeysuckle**)	A perennial vine occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Rapidly growing, dense stands climb and overwhelm native vegetation; produces many seeds that are bird dispersed; more common in southeastern Massachusetts.	Y
Lonicera morrowii A.Gray (**Morrow's honeysuckle**)	A shrub occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Part of a confusing hybrid complex of nonnative honeysuckles commonly planted and	Y

Table 3-41: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Greenfield**
	escaping from cultivation via bird dispersal.	
Lonicera x bella Zabel [*morrowii* x *tatarica*] (**Bell's honeysuckle**)	This shrub occurs in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade. Part of a confusing hybrid complex of nonnative honeysuckles commonly planted and escaping from cultivation via bird dispersal.	Y
Lysimachia nummularia L. (**Creeping jenny; moneywort**)	A perennial herb occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Escaping from cultivation; problematic in flood plains, forests and wetlands; forms dense mats.	Y
Lythrum salicaria L. (**Purple loosestrife**)	A perennial herb or subshrub occurring in all regions of the state in upland and wetland habitats. Grows in full sun to partial shade. Escaping from cultivation; overtakes wetlands; high seed production and longevity.	Y
Myriophyllum heterophyllum Michx. (**Variable water-milfoil; Two-leaved water-milfoil**)	A perennial herb occurring in all regions of the state in aquatic habitats. Chokes waterways, spread by humans and possibly birds.	Y
Myriophyllum spicatum L. (**Eurasian or European water-milfoil; spike water-milfoil**)	A perennial herb found in all regions of the state in aquatic habitats. Chokes waterways, spread by humans and possibly birds.	Y
Phalaris arundinacea L. (**Reed canary-grass**)	This perennial grass occurs in all regions of the state in wetlands and open uplands. Grows in full sun to partial shade. Can form huge colonies and overwhelm wetlands; flourishes in disturbed areas; native and introduced strains; common in agricultural settings and in forage crops.	Y

Table 3-41: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Greenfield**
Phragmites australis (Cav.) Trin. ex Steud. subsp. australis (**Common reed**)	A perennial grass (USDA lists as subshrub, shrub) found in all regions of the state. Grows in upland and wetland habitats in full sun to full shade. Overwhelms wetlands forming huge, dense stands; flourishes in disturbed areas; native and introduced strains.	Y
Polygonum cuspidatum Sieb. & Zucc. (**Japanese knotweed; Japanese or Mexican Bamboo**)	A perennial herbaceous subshrub or shrub occurring in all regions of the state in upland, wetland, and coastal habitats. Grows in full sun to full shade, but hardier in full sun. Spreads vegetatively and by seed; forms dense thickets.	Y
Polygonum perfoliatum L. (**Mile-a-minute vine or weed; Asiatic tearthumb**)	This annual herbaceous vine is currently known to exist in several counties in MA, and has also has been found in RI and CT. Habitats include streamside, fields, and road edges in full sun to partial shade. Highly aggressive; bird and human dispersed.	Y
Potamogeton crispus L. (**Crisped pondweed; curly pondweed**)	A perennial herb occurring in all regions of the state in aquatic habitats. Forms dense mats in the spring and persists vegetatively.	Y
Ranunculus ficaria L. (**Lesser celandine; fig buttercup**)	A perennial herb occurring on stream banks, and in lowland and uplands woods in all regions of the state. Grows in full sun to full shade. Propagates vegetatively and by seed; forms dense stands especially in riparian woodlands; an ephemeral that outcompetes native spring wildflowers.	Y
Rhamnus cathartica L. (**Common buckthorn**)	A shrub or tree occurring in all regions of the state in upland and wetland habitats. Grows in full sun to full shade. Produces fruit in fall; grows in multiple habitats; forms dense thickets.	Y
Robinia pseudoacacia L. (**Black locust**)	A tree that occurs in all regions of the state in upland habitats. Grows in full sun to full shade. While the species is native to central portions of Eastern North America, it is not indigenous to Massachusetts. It has been planted throughout the state since the 1700's and is now widely naturalized. It behaves as an invasive species in areas with sandy soils.	Y

Table 3-41: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Greenfield**
Rosa multiflora Thunb. (**Multiflora rose**)	A perennial vine or shrub occurring in all regions of the state in upland, wetland and coastal habitats. Grows in full sun to full shade. Forms impenetrable thorny thickets that can overwhelm other vegetation; bird dispersed.	Y
Trapa natans L. (**Water-chestnut**)	An annual herb occurring in the western, central, and eastern regions of the state in aquatic habitats. Forms dense floating mats on water.	N

Source: Massachusetts Invasive Plant Advisory Group, https://www.massnrc.org/mipag/invasive.htm, and Franklin County Flora Group, 2019.

Although there are less clear-cut criteria for invasive fauna, there are a number of animals that have disrupted natural systems and inflicted economic damage on the Commonwealth, and may impact Greenfield (Table 3-42). One invasive species, the Zebra mussel, was first documented in Massachusetts in Laurel Lake in Greenfield and Warwick in 2009. Invasive fungi are also included in this table. Because of the rapidly evolving nature of the invasive species hazard, this list is not considered exhaustive.

Table 3-42: Invasive Animal and Fungi Species in Massachusetts

Species (Common Name)	Notes on Occurrence and Impact
Terrestrial Species	
Lymantria dispar dispar (**Gypsy moth** (insect))	This species was imported to Massachusetts for silk production, but escaped captivity in the 1860s. It is now found throughout the Commonwealth and has spread to parts of the Midwest. This species is considered a serious defoliator of oaks and other forest and urban trees; however, biological controls have been fairly successful against it.
Ophiostoma ulmi, Ophiostoma himal-ulmi, Ophiostoma novo-ulmi (**Dutch elm disease** (fungus))	In the 1930s, this disease arrived in Cleveland, Ohio, on infected elm logs imported from Europe. A more virulent strain arrived in the 1940s. The American elm originally ranged in all states east of Rockies, and elms were once the nation's most popular urban street tree. However, the trees have now largely disappeared from both urban and forested landscapes. It is estimated that "Dutch" elm disease has killed more than 100 million trees.
Adelges tsugae (**Hemlock woolly adelgid** (insect))	This species was introduced accidentally around 1924 and is now found from Maine to Georgia, including all of Massachusetts. It has caused up to 90% mortality in eastern hemlock species, which are important for shading trout streams and provide habitat for about 90 species of birds and mammals. It has been documented in about one-third of Massachusetts cities and Citys and threatens the state's extensive Eastern Hemlock groves.
Cryphonectria parasitica (**Chestnut blight** (fungus))	This fungus was first detected in New York City in 1904. By 1926, the disease had devastated chestnuts from Maine to Alabama. Chestnuts once made up one-fourth to one-half of eastern U.S. forests, and the tree was prized for its durable wood and as a food for humans, livestock, and wildlife. Today, only stump sprouts from killed trees remain.
Anoplophora glabripennis (**Asian long-horned beetle**)	This species was discovered in Worcester in 2008. The beetle rapidly infested trees in the area, resulting in the removal of nearly 30,000 infected or high-risk trees in just 3 years.

Table 3-42: Invasive Animal and Fungi Species in Massachusetts	
Species (Common Name)	**Notes on Occurrence and Impact**
Cronartium ribicola (**White pine blister rust** (fungus))	This fungus is an aggressive and non-native pathogen that was introduced into eastern North America in 1909. Both the pine and plants in the Ribes genus (gooseberries and currants) must be present in order for the disease to complete its life cycle. The rust threatens any pines within a quarter-mile radius from infected Ribes.
Aquatic Species	
Dreissena polymorpha (**Zebra mussel**)	The first documented occurrence of zebra mussels in a Massachusetts water body occurred in Laurel Lake in July 2009. Zebra mussels can significantly alter the ecology of a water body and attach themselves to boats hulls and propellers, dock pilings, water intake pipes and aquatic animals. They are voracious eaters that can filter up to a liter of water a day per individual. This consumption can deprive young fish of crucial nutrients.

Source: Chase et al., 1997; Pederson et al., 2005, CZM, 2013, 2014; Defenders of Wildlife; Gulf of Maine; EOEEA, 2013a, 2013b; as presented in the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan.

Probability of Future Events

Because the presence of invasive species is ongoing rather than a series of discrete events, it is difficult to quantify the frequency of these occurrences. However, increased rates of global trade and travel have created many new pathways for the dispersion of exotic species. As a result, the frequency with which these threats have been introduced has increased significantly. Increased international trade in ornamental plants is particularly concerning because many of the invasive plants species in the U.S. were originally imported as ornamentals.

More generally, a warming climate may place stress on colder-weather species while allowing non-native species accustomed to warmer climates to spread northward. The impacts of invasive species and climate change is discussed in more detail below.

Impact

The impacts of invasive species may interact with those of climate change, magnifying the negative impacts of both threats. Furthermore, due to the very traits that make them successful at establishing in new environments, invasives may be favored by climate change. These traits include tolerance to a broad range of environmental conditions, ability to disperse or travel long distances, ability to compete efficiently for resources, greater ability to respond to changes in the environment with changes in physical characteristics (phenotypic plasticity), high reproductive rates, and shorter times to maturity.

To become an invasive species, the species must first be transported to a new region, colonize and become established, and then spread across the new landscape. Climate change may impact each stage of this process. Globally, climate change may increase the introduction of invasive species by changing transport patterns (if new shipping routes open up), or by increasing the survival of invasives during transport. New ornamental species may be introduced to Massachusetts to take advantage of an expanded growing season as temperatures warm. Aquatic invasives may survive in ships' ballast waters with warmer temperatures. Extreme weather events or altered circulation patterns due to climate change could also allow the dispersal of invasive species to new regions via transportation of seeds, larvae and small animals.

Species may shift their ranges north as the climate warms and be successful in regions they previously had not colonized. Invasives may also be able to spread more rapidly in response to climate change, given their high dispersal rates and fast generation times. These faster moving species may be at a competitive advantage if they can move into new areas before their native competitors.

Here in the Northeast, warming conditions may be particularly concerning for some invasives because species ranges in temperate regions are often limited by extreme cold temperatures or snowfall. There is concern that aquatic species, such as hydrilla (Hydrilla verticillata) and water hyacinth (Eichhornia crassipes), may be able to survive and overwinter in Massachusetts with increased temperatures and reduced snowfall. Nutria (Myocastor coypus), large, non-native, semi-aquatic rodents that are currently established in Maryland and Delaware, are likely to move north with warming temperatures - perhaps as far as Massachusetts.

Extreme winter temperatures are also critical limiting factors for many forest pests, and warming is expected to increase their survival and lead to expansions and outbreaks. For example, in Massachusetts, it’s likely that winter temperatures have been limiting the impact of hemlock wooly adelgid (Adelges tsugae), as many infested forest stands are surviving while in more southerly ranges there is near complete mortality from this pest. But the adelgid has already expanded its range with warming winter temperatures and is likely to have increased survival and higher reproductive rates in the northern portion of its range as temperatures warm, likely leading to more significant impacts on forests.

Invasive species are often able to thrive or take advantage of areas of high or fluctuating resource availability such as those found in disturbed environments. For example, for invasive plants, insect outbreaks or storms often free up space in the forest allowing light to penetrate and nutrients and moisture balances to change, allowing invasive plants to move in. Climate change is likely to create these types of opportunities through increased disturbances such as storms and floods, coastal erosion and sea level rise.

Invasives may also be better able to respond to changing environmental conditions that free up resources or create opportunities. For example, greater plasticity in response to their environment may allow some invasive plants to respond faster to increases in spring temperature than native plants. These invasives are able to leaf-out earlier in warmer years, taking up available space, nutrients, and sunlight, and achieving a competitive advantage against native species. Increased carbon dioxide in the atmosphere may also benefit some weedy plant species, allowing them to compete for other resources (like water) more effectively than their native counterparts.

Species roles may change as the climate changes, further complicating the management and policy response. As species ranges shift and existing inter-species relationships are broken, there is the potential that some species, including native species, may become pests because the interspecies interactions (e.g., predation, herbivory) that used to keep their population numbers in check are no longer functional.[51]

Once established, invasive species often escape notice for years or decades. Introduced species that initially escaped many decades ago are only now being recognized as invasives. Because these species can occur anywhere (on public or private property), new invasive species often escape notice until they are widespread and eradication is impractical. As a result, early and coordinated action between public and private landholders is critical to preventing widespread damage from an invasive species.

Vulnerability

Because plant and animal life is so abundant in Greenfield, the entire City is considered to be exposed to the invasive species hazard. Areas with high amounts of plant or animal life may be at higher risk of exposure to invasive species than less vegetated areas; however, invasive species can disrupt ecosystems of all kinds.

Society

The majority of invasive species do not have direct impacts on human well-being; however, as described in the following subsections, there are some health impacts associated with invasive species.

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[51] This section excerpted from the MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 5, 2019.

Vulnerable Populations

Invasive species rarely result in direct impacts on humans, but sensitive people may be vulnerable to specific species that may be present in the state in the future. These include people with compromised immune systems, children under the age of 5, people over the age of 65, and pregnant women. Those who rely on natural systems for their livelihood or mental and emotional well-being are more likely to experience negative repercussions from the expansion of invasive species.

Health Impacts

Of particular concern to human health are species like the Asian tiger mosquito (Aedes albopictus). This invasive mosquito, originally from southeast and subtropical Asia has moved through the Eastern U.S. and has recently arrived in Massachusetts. Capable of spreading West Nile Virus, Equine Encephalitis, and numerous other tropical diseases, this aggressive mosquito is likely range-limited by cold winter temperatures, suitable landscape conditions (it prefers urban areas), and variation in moisture. As winter temperatures increase, the species is likely to become more prevalent in Massachusetts and throughout the Northeast, increasing the risk of serious illness for residents in summer months.[52]

Additional invasive species have negative impacts on human health. The Tree of Heaven (Ailanthus altissima) produces powerful allelochemicals that prevent the reproduction of other species and can cause allergic reactions in humans. Similarly, due to its voracious consumption, the zebra mussel accumulates aquatic toxins, such as polychlorinated biphenyls or polyaromatic hydrocarbons, in their tissues at a rapid rate. When other organisms consume these mussels, the toxins can accumulate, resulting in potential human health impacts if humans consume these animals.

Loss of urban tree canopy from invasive species and pests can lead to higher summertime temperatures and greater vulnerability to extreme temperatures. Health impacts from extreme heat exposure is discussed in the Extreme Temperature section.

Economic Impacts

Economic impacts include the cost to control invasive species on public and private land. Individuals who are particularly vulnerable to the economic impacts of this hazard include all groups who depend on existing ecosystems in Greenfield for their economic success. This includes all individuals working in forestry and agriculture-related fields, as well as those whose

[52] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 5, 2019.

livelihoods depend on outdoor recreation activities such as hunting, hiking, or aquatic sports. Businesses catering to visitors who come to a City for outdoor recreation opportunities can also suffer from loss of business. Additionally, homeowners whose properties are adjacent to vegetated areas or waterbodies experiencing decline from an invasive species outbreak could experience decreases in property value.

Infrastructure

The entire City of Greenfield is considered exposed to this hazard; however, the built environment is not expected to be impacted by invasive species to the degree that the natural environment is. Buildings are not likely to be directly impacted by invasive species. Amenities such as outdoor recreational areas that depend on biodiversity and ecosystem health may be impacted by invasive species. Facilities that rely on biodiversity or the health of surrounding ecosystems, such as outdoor recreation areas or agricultural/forestry operations, could be more vulnerable to impacts from invasive species.

Agriculture

The agricultural sector is vulnerable to increased invasive species associated with increased temperatures. More pest pressure from insects, diseases, and weeds may harm crops and cause farms to increase pesticide use. In addition, floodwaters may spread invasive plants that are detrimental to crop yield and health. Agricultural and forestry operations that rely on the health of the ecosystem and specific species are likely to be vulnerable to invasive species.

Public Health

An increase in species not typically found in Massachusetts could expose populations to vector-borne disease. A major outbreak could exceed the capacity of hospitals and medical providers to care for patients.

Transportation

Water transportation may be subject to increased inspections, cleanings, and costs that result from the threat and spread of invasive species. Species such as zebra mussels can damage aquatic infrastructure and vessels.

Water Infrastructure

Water storage facilities may be impacted by zebra mussels. Invasive species may lead to reduced water quality, which has implications for the drinking water supplies and the cost of treatment.

Environment

Greenfield is approximately 60% forested, and is therefore vulnerable to invasive species impacts to forests. Invasive plants can out-compete native vegetation through rapid growth and prolific seed production. Increased amounts of invasive plants can reduce plant diversity by dominating forests. When invasive plants dominate a forest, they can inhibit the regeneration of native trees and plants. This reduced regeneration further reduces the forest's ability to regenerate in a timely and sufficient manner following a disturbance event. In addition, invasive plants have been shown to provide less valuable wildlife habitat and food sources.

As discussed previously, the movement of a number of invasive insects and diseases has increased with global trade. Many of these insects and diseases have been found in New England, including the hemlock woolly adelgid, the Asian long-horned beetle, and beech bark disease. These organisms have no natural predators or controls and are significantly affecting our forests by changing species composition as trees susceptible to these agents are selectively killed.

Invasive species interact with other forest stressors, such as climate change, increasing their negative impact. Examples include:

- A combination of an earlier growing season, more frequent gaps in the forest canopy from wind and ice storms, and carbon dioxide fertilization will likely favor invasive plants over our native trees and forest vegetation.
- Preferential browse of native plants by larger deer populations may favor invasive species and inhibit the ability of a forest to regenerate after wind and ice storms.
- Warming temperatures favor some invasive plants, insects, and diseases, whose populations have historically been kept in check by the cold climate.
- Periods of drought weaken trees and can make them more susceptible to insects and diseases.[53]

Aquatic invasive species pose a particular threat to water bodies. In addition to threatening native species, they can degrade water quality and wildlife habitat. Impacts of aquatic invasive species include:

- Reduced diversity of native plants and animals
- Impairment of recreational uses, such as swimming, boating, and fishing
- Degradation of water quality
- Degradation of wildlife habitat
- Increased threats to public health and safety

[53] Catanzaro, Paul, Anthony D'Amato, and Emily Silver Huff. *Increasing Forest Resiliency for an Uncertain Future*. University of Massachusetts Amherst, University of Vermont, USDA Forest Service. 2016

- Diminished property values
- Local and complete extinction of rare and endangered species

Vulnerability Summary

Based on the above assessment, Greenfield has a "High" vulnerability to Invasive species. The following problem statements summarize Greenfield's areas of greatest concern regarding inasvive species.

Invasive Species Hazard Problem Statements
• The changing climate has resulted in fewer days below freezing, a trend that will progress over the next century. Fewer days below freezing and deep frosts occurring later in the season are some of the contributing factors that has resulted in a climate more suitable for invasive insects and other pests that can carry non-native diseases.
• Agriculture and forestry in Greenfield rely on biodiverse ecosystems and are experiencing negative impacts due to invasive species. The scope of successfully controlling invasives long-term is often beyond the reach of what residents, farmers, and foresters can manage on their own.
• Invasive species exacerbate stormwater flooding and erosion issues by dominating streambanks and altering the stability of river corridors.
• Residents may not be familiar with how to deal with or prevent vector-borne diseases spread by insects drawn by warmer temperatures.
• Education and outreach is needed to increase local awareness around invasive species and equip residents with appropriate control measure.

3.15 OTHER HAZARDS

In addition to the hazards identified above, the Committee reviewed the full list of hazards listed in the Massachusetts Hazard Mitigation and Climate Adaptation Plan. Due to the location and context of the City of Greenfield, coastal erosion, coastal flooding, and tsunamis were determined not to be a threat. Manmade hazards are not addressed in the State plan, but were addressed in the 2014 Greenfield Multi-Hazard Mitigation Plan, and are considered a risk to the City.

This plan does not address all manmade hazards that could affect Greenfield. A complete hazards vulnerability analysis was not within the scope of this update. For the purposes of the 2020 plan, the Committee discussed and updated the information from the 2014 Plan, where available, and discussed non-natural hazards that are of an accidental nature, including industrial transportation accidents and industrial accidents in a fixed facility. New to the 2020 plan is an evaluation of cyber-security, which has become a threat of greater concern in recent years.

MANMADE HAZARDS

Hazard Description

Most non-natural or manmade hazards fall into two general categories: intentional acts and accidental events, although these categories can overlap. Some of the hazards included in these two categories, as defined by MEMA, consist of intentional acts such as explosive devices, biological and radiological agents, arson and cyberterrorism and accidental events such as nuclear hazards, invasive species, infrastructure failure, industrial and transportation accidents. Accidental events can arise from human activities such as the manufacture, transportation, storage, and use of hazardous materials.

Hazardous materials in various forms can cause death, serious injury, long-lasting health effects, and damage to buildings, homes, and other property. Many products are shipped daily on the nation's highways, railroads, waterways, and pipelines. Chemical manufacturers are one source of hazardous materials, but there are many others, including service stations, hospitals, and hazardous materials waste sites. Hazardous materials come in the form of explosives, flammable and combustible substances, poisons, and radioactive materials. These substances are most often released as a result of transportation accidents or because of chemical accidents in plants.

Location and Extent

A release may occur at a fixed facility or in transit. Communities with a large industrial base, like Greenfield, may be more inclined to experience a hazardous materials release due to the number of facilities using such materials in their manufacturing process. Communities with several major roadways may be at a greater risk due to the number and frequency of trucks transporting hazardous materials passing through, with similar risks associated with the location of railways in a town.

<u>Industrial Accidents – Transportation</u>
Franklin County transportation systems include road, rail, and air. Accessible and efficient freight transportation plays a vital function in the economy of the region. Most freight and goods being transported to and from Franklin County are by truck; however, a significant amount of freight that moves through the county is being hauled over the three main rail lines. Given that any freight shipped via air needs first to be trucked to an airport outside the region, air transportation is not being evaluated in this plan.

The major trucking corridors in Franklin County are Interstate 91, running north/south, and Route 2, running east/west. These two highways also represent the busiest travel corridors in the region for non-commercial traffic. Safe and efficient transportation routes for trucks to and through the region are important to the region's economy and to the safety of its citizens. The safer the transportation routes are, the less likely a transportation accident will occur.

According to the Franklin County Hazardous Material Emergency Plan,[54] approximately 13 trucks per hour traveling through the region contain hazardous materials (Table 3-43). Most of these vehicles are on Interstate 91, which passes through Greenfield. However, approximately two vehicles per hour travel along Route 2 and up to one truck per hour may be carrying hazardous materials along Routes 5/10. Both of these roads cross through Greenfield. In addition, the HMEP notes that all roads in the county likely have vehicles carrying hazardous materials at varying intervals.

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[54] Franklin County Regional Emergency Planning Committee, Franklin County Hazardous Material Emergency Plan and Maps, 2006. Based on a one-time survey conducted in 2003.

Table 3-43: Estimated Levels of Hazardous Material Transported on Area Roadways	
Roadway	**Number of Tank or Van Trucks Carrying Hazardous Materials per hour**
Interstate 91	10
Route 2	2
Other major roadways *(Routes 5/10, 63, 47, 116,202, 8A, 78, 122, 142, and 2A)*	1 or 0

The hazardous materials regularly carried on these trucks passing through Greenfield include:

- Gasoline
- Fuel oil
- Kerosene
- Liquefied petroleum gas
- Propane
- Sodium aluminate
- Sulfuric acid
- NOS liquids 3082

Two to three trains per day travel on the Pan Am Systems Connecticut River Line which runs through Greenfield and 10-15 trains pass through the East Deerfield Rail Yard each day (Table 3-44). On the Connecticut River Line an average of two cars per train carry hazardous wastes, while at the Rail Yard and average of between two to five cars per train carry hazardous wastes. While there have been upgrades in the track systems in recent years and changes in switching processes, a Pan Am Railways representative reports that this has increased the speed with which trains move through Franklin County, but has not had a significant impact on the number of trains passing through.

The hazardous materials regularly carried on these trains passing through Greenfield include:

- Sulfuric acid
- Liquified petroleum gas
- Hydrochloric acid
- Chlorine
- Caustic soda
- Methanol
- Sodium chloride

Table 3-44: Estimated Level of Hazardous Material Transport on Area Train Lines			
Train Line	**Trains per Day (General Merchandise)**	**Average Number of Cars per Train**	**Average Number of Cars per Train with Hazardous Waste**
Main Freight Line, Pan Am Systems	10 to 24	50	4
Connecticut River Line, Pan Am Systems	2 to 3	30	2
East Deerfield Rail Yard, Pan Am Systems	10 to 15 trains passing through yard	n/a	2 to 5
New England Central	2	60	5

Industrial Accidents - Fixed Facilities

An accidental hazardous material release can occur wherever hazardous materials are manufactured, stored, transported, or used. Such releases can affect nearby populations and contaminate critical or sensitive environmental areas. Those facilities using, manufacturing, or storing toxic chemicals are required to report their locations and the quantities of the chemicals stored on-site to state and local governments.

The Toxics Release Inventory (TRI) tracks the management of over 650 toxic chemicals that pose a threat to human health and the environment. U.S. facilities in different industry sectors that manufacture, process, or otherwise use these chemicals in amounts above established levels must report how each chemical is managed through recycling, energy recovery, treatment, and environmental releases. *Note: a "release" of a chemical means that it is emitted to the air or water, or placed in some type of land disposal*. The information submitted by facilities to the EPA and states is compiled annually as the Toxics Release Inventory or TRI, and is stored in a publicly accessible database. TRI information helps support informed decision-making by industry, government, non-governmental organizations and the public. Note that TRI does not provide any safety or health information about these chemicals and compounds. TRI data, in conjunction with other information, can be used as a starting point in evaluating exposures that may result from industrial activities which involve toxic chemicals.[55]

It is important to note that inclusion on the TRI in no way indicates any issues with any of the sites, but rather is an inventory of those facilities meeting TRI reporting requirements. Table 3-45 lists these facilities located in Greenfield.

[55] https://www.epa.gov/enviro/tri-overview

Table 3-45: Toxics Release Inventory (TRI)	
Facility Name	**Facility Location**
Bete Fog Nozzle Inc.	50 Greenfield Street
Dumont Company LLC	289 Wells Street
JH Smith Company Inc.	330 Chapman Street
Kennametal Inc Greenfield Plant	34 Sanderson Street
Coco Cola; Greenfield Dept.	180 Silvi O Conte Drive

Source: TRI Search Results. EnviroFacts USPA. http://envior.epa.gov/enviro/ Accessed 12/31/19.

The Franklin County Regional Emergency Planning Committee (REPC) 2018 List of Tier II Facilities includes those listed in Table 3-46 for Greenfield. Facilities covered by the reporting requirements of the Federal Emergency Planning and Community Right-to-Know Act (EPCRA) must submit annual Tier II reports to their Emergency Planning Committee (EPC), and Local Fire Department, and the State Emergency Response Commission (SERC).

Table 3-46: Tier II Facilities in Greenfield	
A.R. Sandri, Inc. Bulk Facility Propane; Chapman Station	191 Cleveland St.
A.R. Sandri, Inc. Bulk Facility Propane; Cleveland Station	499 Chapman St.
Airgas USA - Greenfield Dept.	1159 Bernardston Rd.
Argotect 53 Silvio Dept.	53 Silvio O Conte Dr.
Baystate Franklin Medical Center	164 High St.
BJ's Wholesale Club	42 Colrain Rd.
Coco Cola; Greenfield Dept.	180 Silvi O Conte Dr.
Collins/Moylan Arena (FMC Ice Sports)	41 Barr Avenue
F.W. Webb Company	136 Silvio O Conte Dr.
Home Depot (Store #2619)	264 Mohawk Trail/Rt 2

Source: 2018 Franklin County REPC List of Tier II Facilities

Also worth consideration is that many farmers store agricultural chemicals on their properties. Given that much farmland is located in or near floodplains and their adjacent water bodies, the potential for an accidental hazardous materials spill to impact water quality is present. This plan does not include an in-depth evaluation of hazardous materials as they relate to farming. In many cases, famers do use and store pesticides, herbicides and fertilizers on their property. And in most cases, farmers are utilizing best management practices in the use and storage of agricultural chemicals and have undergone any required training and licensing if they are applying these chemicals to the land. Despite training and best management practices, an accidental release of hazardous materials can occur and potentially threaten human health and the environment. One approach that the City could take to help prepare for a hazardous materials spill on a farm, possibly through coordination with the Agricultural Commission, would be to become familiar with the types and quantities of chemicals stored on-site at the larger farms within the City.

Another potential source of contamination from hazardous materials stored and use on-site could be the many local public and private schools that maintain sports fields, often with the use of pesticides and herbicides. These sites and the chemicals that are stored there should be documented as well. These actions would assist first responders in being adequately prepared to protect human health and prevent contamination of the environment in the event of a major spill or other accidental release of hazardous materials.

Hazardous facilities located outside of City boundaries can potentially impact the City as well. The Vermont Yankee nuclear power plant is located on the Connecticut River in Vernon, Vermont, near the Vermont/Massachusetts border and approximately 33 miles from Greenfield. In January 2010, the facility notified the Vermont Department of Health that samples taken in November 2009 from a ground water monitoring well on site contained tritium. This finding signals an unintended release of radioactive material into the environment. Testing has shown that contaminated groundwater has leaked into the Connecticut River, though tritium levels in the river have remained below the lower limit of detection.[56]

On August 27, 2013, Entergy, then-owner of Vermont Yankee, announced that Vermont Yankee would cease operations at the end of 2014 for economic reasons. Vermont Yankee officially disconnected from the grid on December 29, 2014. The reactor was manually shut down without incident. Transfer of all Vermont Yankee spent fuel from the reactor to the spent fuel pool was completed on January 12, 2015. The transfer of all Vermont Yankee spent fuel to dry cask storage was completed on August 1, 2018. On December 6, 2018, the Vermont Public Utilities Commission (PUC) approved Entergy's sale of Vermont Yankee to subsidiaries of NorthStar Group Services, Inc., as a means of completing the decommissioning and site restoration on an accelerated schedule.[57]

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[56] Vermont Department of Health. http://healthvermont.gov/enviro/rad/vt_yankee.aspx
[57] Vermont Department of Public Service: https://publicservice.vermont.gov/content/nuclear_decommissioning_citizens_advisory_panel_ndcap/history. Accessed July 6, 2019.

The Yankee Atomic Electric Company (YAEC) stores spent nuclear fuel from the former Yankee Rowe nuclear facility, which operated for over three decades as a power generating facility until 1992. The plant was disassembled and officially decommissioned in 2007. However spent fuel from the plant's operation is still stored on site adjacent to the Sherman Reservoir on the Deerfield River, upstream from Greenfield. The fuel is stored in Nuclear Regulatory Commission – approved dry canisters and casks made of steel and concrete, which are placed on a concrete pad on the site. The stored fuel is monitored 24 hours a day. The fuel storage site is within the inundation zone for the Harriman Dam, which is located approximately 6.5 miles upstream from the site. According to the YAEC's website, the type of container that the fuel is stored in has been tested to withstand submersion under 50 feet of water for 8 hours, among other safety tests.[58]

The 2011 tsunami and earthquake in Japan that damaged a nuclear power plant demonstrates the potential vulnerability of these facilities to natural disasters, and the geographic extent that could be impacted by an accident.   City officials should stay abreast of proper evacuation procedures in the event of an accident at the Vermont Yankee or Yankee Rowe facilities.

Cyber Threats

A failure of networked computer systems could result in the interruption or disruption of City services (including public safety and other critical services), the disruption or interruption of the functioning of City departments, and the potential for loss or theft of important data (including financial information of the City and residents).

There are many possible causes of a network failure, but most either happen because of damage to the physical network/computer system infrastructure or damage to the network in cyberspace. Physical damages are incidents that damage physical telecommunications infrastructure or server/computer hardware. Examples are a water main break above a server room, fire/lighting strike that destroys equipment, construction accident damaging buried fiber line, or power outage and other issues effecting the Internet Service Provider (ISP) that interrupts access to the internet to the City.

Damage to the cyber infrastructure can be malicious attacks or critical software errors that affect computer systems, from individual computers to the entire network. These virtual hazards can cause lack of access to the network, permanent data loss, permanent damage to computer hardware, and impact the ability to access programs or systems on the network.

[58] Yankee Atomic Electric Company. http://www.yankeerowe.com/fuel_transportation.html.

When incidents are malicious attacks, they can impact:

- Confidentiality: protecting a user's private information.
- Integrity: ensuring that data is protected and cannot be altered by unauthorized parties.
- Availability: keeping services running and giving administration access to key networks and controls.
- Damage: irreversible damage to the computer or network operating system or "bricking" and physical, real world damages, caused by tampering with networked safety systems.
- Confidence: confidence of stakeholders in the organization who was victim of the attack.

Motives for cyber-attacks can vary tremendously, ranging from the pursuit of financial gain—the primary motivation for what is commonly referred to as "cyber-crimes" is for profit, retribution, or vandalism. Other motivations include political or social aims. Hacktivism is the act of hacking, or breaking into a computer system, for a political or social purpose. Cyber espionage is the act of obtaining secrets without permission of the holder of the information, using methods on the Internet, networks, or individual computers. [59] These threats are not only external; many acts of cyber-crime happened from current or former employees who were given network access legitimately.

For Greenfield, the most likely cyber-threat affecting the City and City departments comes from malware and social engineering. These crimes prey on the vulnerable and unprepared and every individual and organization that connects a device to the internet is a potential mark.

<u>Social Engineering:</u>
Social engineering involves obtaining confidential information from individuals through deceptive means by mail, email, over the phone, and increasingly through text messages.[60] These techniques are referred to as 'Phishing'.

<u>Malware</u>
Malware, or malicious software, is any program or file that is harmful to a computer user. Types of malware can include computer viruses, worms, Trojan horses, and spyware. These malicious programs can perform a variety of different functions such as stealing, encrypting or deleting sensitive data, altering or hijacking core computing functions and monitoring users' computer

[59] NYC Hazard Mitigation, Cyber Threats, https://nychazardmitigation.com/hazard-specific/cyber-threats/what-is-the-hazard/
[60] Cybersecurity Precautions, MA Executive Office of Technology Services & Security, 2017

activity without their permission. The most common way for malware to infect a City's network is through an employee opening an infected email attachment.

Previous Occurrences

Over the past few years a type of malware called ransomware has been targeted at local governments. Cyber-criminals will use social-engineering to infect a network, take control and block user access to that network, then request a ransom from the organization. Once the ransomware is on the network, it can be extremely expensive and time consuming to restore that network without paying the ransom. When the cost of the ransom is less than the cost of resorting the system, is when the cyber-criminals succeed.

In July 2019, school districts all across the United States were targeted by ransomware. Since 2013, there have been some 170 attacks against state and local governments and there is no sign that this trend is slowing. Unlike other hazards, cyber-threats are global. Cyber-criminals don't care where you are or how small your town is. Many cyber-crimes are not just lone criminals, they are more often than not committed by sophisticate criminal organizations and foreign governments who work around the clock looking to exploit small towns and big businesses alike.

The best way to prevent a cyber-attack is to follow best practices in cyber-security. Following these best practices will greatly mitigate the likelihood a cyber-attack is successful. MA Executive Office of Technology Services and Security (EOTSS)[61] is the chief MA State program that can assist local governments with cyber-security. There are educational opportunities available throughout the region that aim to assist municipalities learn and implement these best practices.

Active Shooter

Every year, Greenfield hosts several popular, multi-day events that draw large crowds to recreational and music venues in the City. These include the Green River Festival, which takes place at Greenfield Community College in mid-July, and Wormtown Music Festival at Camp KeeWanee. The Emergency Management Director expressed concern about mass gatherings and planned events like these because they draw large crowds of people and could be a potential target for active/mass shootings. The EMD reported that these productions have preemptively increased security at these events increased in recent years to help ensure safety. Additional concerns were expressed about evacuation of large crowds, particularly Wormtown because there is only one road in and out of Camp KeeWanee. Both of these fesitvals are held

[61] https://www.mass.gov/cybersecurity

during times of the year when hazards such as extreme temperatures (heat) and heavy rain and wind events (thunderstorms/microbursts) typically happen.

Manmade hazards were assessed at the local level for the first time in the 2014 Multi-Hazard Mitigation Plan. The 2020 Plan adds to this work but is still just a preliminary assessment of Greenfield's vulnerability to these hazards. The potential for these types of manmade hazards to impact the City, its critical infrastructure and its residents is medium to high.

Manmade Hazard Problem Statements
• Greenfield is vulnerable to a spill of hazardous materials and/or hazardous waste transported on Interstate 91, Route 5/10, Route 2, or on the rail lines through town.
• Greenfield is vulnerable to a spill of hazardous materials and/or hazardous waste at one of several facilities in town that use and store hazardous materials. These facilities and/or hazardous materials storage may be in the 100-year floodplain and mapped river corridor.
• Cyber-attacks on local government is a growing threat. Keeping up with current best practices in cyber security can be challenging for communities.
• Greenfield hosts several popular events that draw large crowds to recreational and music venues annually, which could be targeted for active/mass shootings. These events also occur during times of the year when heat, flooding and wind hazards could impact these crowds. Evacuations could be problematic at Wormtown due to one access road.
• Continue participating in table top exercises for responding to transportation and fixed facility accidents.

4 MITIGATION CAPABILITIES & STRATEGIES

4.1 NATURE-BASED SOLUTIONS FOR HAZARD MITIGATION & CLIMATE RESILIENCY

Nature-Based Solutions are actions that work with and enhance nature to help people adapt to socio-environmental challenges. They may include the conservation and restoration of natural systems, such as wetlands, forests, floodplains and rivers, to improve resiliency. NBS can be used across a watershed, a City, or on a particular site. NBS use natural systems, mimic natural processes, or work in tandem with engineering to address natural hazards like flooding, erosion and drought.

The 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan and the Commonwealth's Municipal Vulnerability Preparedness (MVP) program both place great emphasis on NBS, and multiple state and federal agencies fund projects that utilize NBS. For this plan, Low Impact Development (LID) and Green Infrastructure (GI) are included under the blanket term of NBS. Following are examples of how NBS can mitigate natural hazards and climate stressors, and protect natural resources and residents:

- Restoring and reconnecting streams to floodplains stores flood water, slows it down and reduces infrastructure damage downstream
- Designing culverts and bridges to accommodate fish and wildlife passage also makes those structures more resilient to flooding, allowing for larger volumes of water and debris to safely pass through
- Managing stormwater with small-scale infiltration techniques like rain gardens and vegetated swales recharges drinking water supplies, reduces stormwater runoff, and reduces mosquito habitat and incidents of vector-borne illness by eliminating standing pools of water following heavy rain events
- Planting trees in developed areas absorbs carbon dioxide, slows and infiltrates stormwater, and provides shade, reducing summertime heat, lowering energy costs for village residents and improving air quality by reducing smog and particulate matter
- Vegetated riparian buffers absorb and filter pollutants before they reach water sources, and reduce erosion and water velocity during high flow events

This update of the Greenfield Multi-Hazard Mitigation Plan incorporates Nature-Based Solutions into mitigation strategies where feasible.

4.2 EXISTING AUTHORITIES POLICIES, PROGRAMS, & RESOURCES

One of the steps of this Hazard Mitigation Plan update process is to evaluate all of the City's existing policies and practices related to natural hazards and identify potential gaps in protection.

Greenfield has most of the no cost or low cost hazard mitigation capabilities in place. Land use zoning, subdivision regulations and an array of specific policies and regulations that include hazard mitigation best practices, such as limitations on development in floodplains, stormwater management, tree maintenance, etc. Greenfield has appropriate staff dedicated to hazard mitigation-related work for a community its size, including a Mayor, Planning & Development Director, Emergency Management Director, Department of Public Works, and a Tree Warden. In addition to City staff, Greenfield has an experienced Planning Board which reviews all proposed developments and assures that buildings are built to the current zoning requirements.

Greenfield has some recommended plans in place, including a 2014 Comprehensive Sustainable Master Plan and an Open Space and Recreation Plan, which will be updated in 2020. The City also has very committed and dedicated volunteers who serve on Boards and Committees and in other volunteer positions. The City collaborates closely with surrounding communities and is party to Mutual Aid agreements through MEMA. Greenfield is also a member community of the Franklin Regional Council of Governments, and participates in the Franklin County Regional Emergency Planning Committee (REPC).

Overview of Mitigation Strategies by Hazard

An overview of the general concepts underlying mitigation strategies for each of the hazards identified in this plan is as follows:

Flooding

The key factors in flooding are the water capacity of water bodies and waterways, the regulation of waterways by flood control structures, and the preservation of flood storage areas (like floodplains) and wetlands. As more land is developed, more flood storage is demanded of the City's water bodies and waterways. FEMA has identified no flood control structures within the City of Greenfield. Floods on the Connecticut River and portions of its major tributaries that are prone to backwater effects are controlled by nine flood control reservoirs located upstream in Massachusetts, New Hampshire, and Vermont.

The City of Greenfield has adopted several land use regulations that serve to limit or regulate development in floodplains, to manage stormwater runoff, and to protect groundwater and wetland resources, the latter of which often provide important flood storage capacity. These regulations are summarized in Table 4-1.

Infrastructure like dams and culverts are also in place to manage the flow of water. However, some of this infrastructure is aging and in need of replacement, or is undersized and incapable of handling heavier flows our region is experiencing due to climate change. The FRCOG has assisted the city with assessing and mapping high-risk culverts at road-stream crossings to prioritize upgrades.

Severe Snowstorms / Ice Storms

Winter storms can be especially challenging for emergency management personnel even though the duration and amount of expected amount of snowfall usually is forecasted. The Massachusetts Emergency Management Agency (MEMA) serves as the primary coordinating entity in the statewide management of all types of winter storms and monitors the National Weather Service (NWS) alerting systems during periods when winter storms are expected.

To the extent that some of the damages from a winter storm can be caused by flooding, flood protection mitigation measures also assist with severe snowstorms and ice storms. The City has adopted the State Building Code, which ensures minimum snow load requirements for roofs on new buildings. There are no restrictions on development that are directly related to severe winter storms, however, there are some Subdivision Rules and Regulations that could pertain to severe winter storms, summarized in Table 4-1.

Severe snowstorms or ice storms can often result in a small or widespread loss of electrical service. Should a natural hazard cause a power outage, Greenfield residents would be vulnerable to losing domestic heat and water supplies reliant on electricity.

Hurricanes and Tropical Storms

Hurricanes provide the most lead warning time of all identified hazards, because of the relative ease in predicting the storm’s track and potential landfall. MEMA assumes “standby status” when a hurricane’s location is 35 degrees North Latitude (Cape Hatteras) and “alert status” when the storm reaches 40 degrees North Latitude (Long Island). Even with significant warning, hurricanes cause significant damage – both due to flooding and severe wind.

The flooding associated with hurricanes can be a major source of damage to buildings, infrastructure and a potential threat to human lives. Flood protection measures can thus also be considered hurricane mitigation measures. The high winds that often accompany hurricanes can also damage buildings and infrastructure, similar to tornadoes and other strong wind events. For new or recently built structures, the primary protection against wind-related damage is construction according to the State Building Code, which addresses designing buildings to withstand high winds.

Severe Thunderstorms / Winds / Microbursts and Tornadoes

Most damage from tornadoes and severe thunderstorms come from high winds that can fell trees and electrical wires, generate hurtling debris and, possibly, hail. According to the Institute for Business and Home Safety, the wind speeds in most tornadoes are at or below design speeds that are used in current building codes, making strict adherence to building codes a primary mitigation strategy. In addition, current land development regulations, such as restrictions on the height and setbacks of telecommunications towers, can also help prevent wind damages.

Wildfires / Brushfires

Sixty percent of Greenfield is forested. A signifigant portion of the City is therefore at risk of fire. Wildfire and brushfire mitigation strategies involve educating people about how to prevent fires from starting, controlling burns within the City, as well as managing forests for fire prevention. The City of Greenfield currently has a Forestry Management Program for City owned forested lands, which helps to mitigate wildfire risks.

The Greenfield Fire Department has several ongoing educational programs to educate residents on fire safety, including fire drills in the schools. The Greenfield Fire Department is responsible for overseeing the dispensation of burn permits for the City. Residents must appear in person in order to obtain a permit, at which point the Fire Department will provide the applicant with information on safe burn practices. Each permit is issued on a case-by-case situation according to several factors including where the property is located and any past problems with burning on that property. The Fire Chief monitors permitted properties on a daily basis. Specific burn permit guidelines are established by the state, such as the burning season and the time when a burn may begin on a given day.

There are currently no restrictions on development based on the need to mitigate wildfires.

Earthquakes

Although there are five mapped seismological faults in Massachusetts, there is no discernible pattern of previous earthquakes along these faults nor is there a reliable way to predict future earthquakes along these faults or in any other areas of the state. Consequently, earthquakes are arguably the most difficult natural hazard for which to plan. Most buildings and structures in the state were constructed without specific earthquake resistant design features. In addition, earthquakes precipitate several potential devastating secondary effects such as building collapse, utility pipeline rupture, water contamination, and extended power outages. Therefore, many of the mitigation efforts for other natural hazards identified in this plan may be applicable during the City's recovery from an earthquake.

Dam Failure

Dam failure is an extremely infrequent occurrence, but a severe incident could prove catastrophic. In addition, dam failure most often coincides with flooding, so its impacts can be multiplied, as the additional water has nowhere to flow. The only mitigation measures currently in place are the state regulations governing the construction, inspection, and maintenance of dams. This is managed through the Office of Dam Safety at the Department of Conservation and Recreation. Owners of dams are responsible for hiring a qualified engineer to inspect their dams and report the results to the DCR. Owners of High Hazard Potential dams and certain Significant Hazard Potential dams are also required to prepare, maintain, and update Emergency Action Plans. Potential problems may arise if the ownership of a dam is unknown or contested. Additionally, the cost of hiring an engineer to inspect a dam or to prepare an Emergency Action Plan may be prohibitive for some owners.

Drought

The Northeast is generally considered to be a moist region with ample rain and snow, but droughts are not uncommon. Widespread drought has occurred across the region as recently as 2016, and before that in the early 2000s, 1980s, and mid-1960s. More frequent and severe droughts are expected as climate change continues to increase temperatures, raise evaporation rates, and dry out soils - even in spite of more precipitation and heavier rainfall events.[62]

The Greenfield Public Water Supply relies on both groundwater and surface water resources, and can also use water from the Green River during peak demands. Additionally, the City has identified a potential new well site between Leyden and Green River Roads that could contribute to a backup supply.

Forest landowners in City can be encouraged to conserve and manage their forests for climate resiliency. Strategies for promoting a resilient forest include increasing the diversity of tree species and age of trees in a forest, and promoting trees not currently threatened by pests or diseases that will thrive in a warming climate.[63]

[62] MassWildlife Climate Action Tool: https://climateactiontool.org/content/drought. Accessed March 8, 2019.
[63] Catanzaro, Paul, Anthony D'Amato, and Emily Silver Huff. *Increasing Forest Resiliency for an Uncertain Future*.

Extreme Temperatures

A primary mitigation measure for extreme temperatures is establishing and publicizing warming or cooling centers in anticipation of extreme temperature events. Getting the word out to vulnerable populations, especially the homeless and elderly, and providing transportation is particularly important but can be challenging. The City has warming and cooling centers to help residents cope with extreme temperatures. Locations include the Senior Center and Library during business hours. The Salvation Army Center for Worship & Service provides heating overnight. The City's Council on Aging has their own van to transport the elderly in the event of a hazard or emergency.

Planting and maintaining shade trees in villages and developed areas of Citys can help mitigate extreme heat in these areas. Roofs and paving absorb and hold heat from the sun, making developed areas hotter during the summer than surrounding forested areas. Trees that shade these surfaces can significantly lower the temperature in a neighborhood, making it easier to be outside and reducing cooling costs for homeowners.

Invasive Species

The spread of invasive species is a serious concern as species ranges shift with a changing climate. People can also be a carrier of invasive plant species. Installing boot brushes at hiking entrances can help slow the spread of invasive species by removing seeds being carried in soil on hiking boots. Landowners can learn the top unwanted plants and look for them when out on their land, and can be encouraged to work with neighbors to control invasive exotic plants.

Before implementing any forest management, landowners should be sure to inventory for invasive exotic species. They will need to be controlled before harvesting trees and allowing sunlight into the forest, which will trigger their growth and spread. Also, the timber harvester should be required to powerwash their machines before entering the woods. Financial assistance may be available to landowners through the USDA NRCS Environmental Quality Incentives Program (EQIP) to address invasive species.[64]

In addition, Greenfield can require only native, non-invasive species be used in new development and redevelopment.

University of Massachusetts Amherst, University of Vermont, USDA Forest Service. 2016

[64] MassWildlife Climate Action Tool: https://climateactiontool.org/content/maintain-or-restore-soil-quality-limit-recreational-impacts. Accessed March 8, 2019.

All Hazards

Greenfield Middle School is a designated shelter for the City in the event of a storm, hazard event, or emergency. It is also a regional shelter that alternates with Turner Falls High School to provide emergency shelter during events that impact the broader region. Greenfield Middle School has backup power and a limited inventory of emergency supplies. A regional sheltering plan that identifies regional shelter sites was completed for Franklin County with funds from the Western Region Homeland Security Advisory Council (WRHSAC). The Franklin County REPC is now working on operationalizing the plan by creating Shelter Management Teams and cost sharing agreements between Citys. Greenfield officials can participate in this process to ensure its residents have clear guidance on where to shelter during an emergency.

Primary and secondary evacuation routes are shown on the Critical Infrastructure map for Greenfield. Interstate 91 and Route 5&10 are heavily traveled highways, and accidents on these road can cut off the City from nearby hospitals and other communities.

A regional disaster debris management plan was created for Franklin County in 2015. The Franklin County REPC is currently working to verify the sites identified in the plan and complete agreements between municipalities for use of the regional sites. Towns may need to identify a site within their own borders if regional agreements cannot be made.

Existing Mitigation Capabilities

The City of Greenfield had numerous policies, plans, practices, programs and regulations in place, prior to the creation of this plan, that were created to mitigate the impact of natural hazards in the City. These various initiatives are summarized, described and assessed on the following pages and have been evaluated in the "Effectiveness" column.

Table 4-1: Existing Mitigation Capabilities

Strategy	Capability Type	Description	Hazards Mitigated	Effectiveness / Improvements
Floodplain Overlay District	Regulation - Zoning Ordinance	Special Flood Hazard Areas (Zones A, A 1-30) to indicate the 100-year floodplain. Permitted uses are allowed if they do not require structures, fill or storage of materials. No encroachment allowed within the 100-year floodplain without a Special Permit. Special permit conditions require no decrease in flood storage capacity or increase in flood levels. Use must not substantially affect the water table, water quality or drainage patterns.	Flooding	Effective for regulating new development within the 100-year floodplain. Consider limiting all new development within the 100-year floodplain.
Greenfield Wetlands Ordinance	General Regulation Chapter 195	Chapter 195 Greenfield Wetlands Protection Ordinance (adopted August 2016) establishes an additional minimum 25 foot No-Disturb Zone around all wetland resources areas, prohibits all outdoor storage of automobiles, hazardous materials, storage tank, or any potential pollutants or debris within the 100 year flood plain, requires 100% compensatory storage for all new work within the 100-year floodplain, and requires an alternatives analysis for wetland crossings.	Flooding	Evaluate alternative models of flooding vulnerability to incorporate in addition to the 100-year FEMA floodplain.
Performance Standards	Regulation - Zoning Ordinance	Standard (6.8.3.8) addresses the impacts of uncontrolled surface water runoff and sedimentation of surface waters.	Flooding	Effective for mitigating localized flooding by regulating stormwater runoff.
Earth Removal Regulation - Chapter 368 of the General Code	Regulation - Zoning Ordinance	Earth Removal: Regulates the removal of soil, loam, sand & gravel through a permitting process and exempts existing sand and gravel operations, and	Flooding	This Ordinance does not include a purpose and was written to address safety, aesthetics, and potential traffic impacts associated

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		disturbances due to building construction and landscaping activities.		with soil removal. Not Effective for controlling localized flooding. Add reducing or eliminating the potential for localized flooding events as a Purpose of the Ordinance. This Ordinance does not specifically address the potential for localized flooding that soil removal can cause. Require mitigation of potential impacts from flooding. Add a reference to the City's stormwater regulations.
Open Space and Cluster Development Section	Regulation – Zoning Ordinance	Major Development Review: Requires an Impact Statement for certain types of development. The Impact Statement must include an evaluation of the impact of stormwater, runoff, flooding, erosion, sedimentation, grading changes, increased impervious surface, discharges to groundwater, pumping of groundwater, wetlands disruption, and changes to vegetative cover. The Impact Statement must describe proposed mitigation measures for identified impacts. Regulations list the Environmental Standards for Impact Statements that address flooding: specifically, the project shall not cause erosion or flooding of the site.	Flooding	Effective for mitigating flooding and flood-related impacts for certain types of large-scale developments. Continue to work on the addition of Low Impact Development (LID) requirements.
Open Space and Cluster Development Section	Regulation – Subdivision Rules & Regulations	Site Plan Review: Project proponent must submit information regarding measures to prevent flooding and increased runoff and prevent erosion and sedimentation. Required for all uses that require a Special Permit, any business, commercial, industrial or institutional use (except certain home	Flooding	Effective for preventing flooding and uncontrolled stormwater runoff. Continue to work on the addition of Low Impact Development (LID) requirements.

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		occupations) and any site containing more than one (1) principal use.		
Definitive Plan	Subdivision Rules & Regulations	Proposed layout (including cross sections and profiles) of sewerage, storm drainage and water supply, including invert elevations, slopes, capacity, and velocity and stormwater management plan.	Flooding	Effective for mitigating localized flooding of roads and other infrastructure. Continue to work on the addition of Low Impact Development (LID) requirements.
Erosion Control	Subdivision Rules & Regulations	An erosion control plan, indicating the erosion control measures to be employed, including description of locations of temporary stockpiles, spoil areas, temporary drainage systems, slope stabilization techniques, sediment basins, etc., and narrative description of how erosion from individual lots onto streets and into drainage systems is proposed to be controlled.	Flooding	Effective for mitigating localized flooding of roads and other infrastructure.
Wetlands Protection Act and Chapter 195 Greenfield Wetlands Protection Ordinance	Regulation	Guidelines establish that the development must be in compliance with the WPA and the applicant shall obtain approval from the Conservation Commission prior to any construction activity in the affected areas.	Flooding	Effective for mitigating localized flooding of roads and other infrastructure and for preventing filling of flood storage areas.
Design Requirements	Subdivision Rules & Regulations	Requires design to reduce where possible, the volume of cut and fill; the area over which existing vegetation will be disturbed, especially if within 200 feet of a river, pond, or stream, or having a slope of more than 15%;the number of mature trees removed; the extent of waterway altered or relocated; the erosion and siltation; and flood damage.	Flooding, Landslides	Effective for mitigating localized flooding of roads and other infrastructure and for preventing filling of flood storage areas.
Easements, Flood Hazard Areas, and Protection of Natural Features and Open Space,	Subdivision Rules & Regulations	Should contain design requirements that can reduce the potential for flooding. Requires that any portion of a proposed subdivision which is located within the 100-year floodplain shall meet the following requirements:	Flooding	Somewhat effective for mitigating localized flooding of roads and other infrastructure and for preventing filling of flood storage areas. Consider adding

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		All requirements of § 200-4.13 Floodplain District (F) of the Greenfield Zoning Ordinance. The subdivision, including utilities and drainage, shall be designed to be consistent with the needs to minimize flood damage and provide adequate drainage. Subdivisions shall include base flood elevation data.		prevention of flooding as an explicitly stated purpose for this requirement. Continue to work on the addition of Low Impact Development (LID) requirements.
Stormwater System Regulation	Regulations	Regulations require a permit for all new connections to the stormwater system and any increases in volume from existing development. Stormwater Management Plans are required for all nonresidential uses. Regulations include stormwater management standards, design criteria and mandate coordination with the Greenfield Conservation Commission.	Flooding	Effective for mitigating or preventing localized flooding of roads and other infrastructure and for controlling impacts from stormwater runoff. Outreach/Education needed to encourage resident action in voluntary program. Continue to work on the addition of Low Impact Development (LID) requirements.
High-risk culvert inventory	City Plan	The FRCOG has assessed and mapped high-risk culverts to inform replacement prioritization planning.	Flooding	Effective for mitigating localized flooding of roads and other infrastructure.
Water Supply Protection District	Regulation – Zoning Ordinance	Regulations protect and preserve existing and potential sources of groundwater supply and recharge and watershed areas. Areas identified on the Zoning Map.	Flooding, Drought	Effective for mitigating the potential for localized flooding by preserving open space in the watershed and regulating stormwater runoff.
Greenfield Open Space and Recreation Plan	City Plans	Inventories natural features and environments in the City, including many that contain floodplain areas such as wetlands, aquifer recharge areas, farms, rivers, streams and brooks.	Flooding, Drought, Landslides	Effective in identifying sensitive resource areas, including floodplains and encourages thinking on a “watershed scale”. Prioritizes protecting areas along the Green River and recommends that the City take a proactive role in preserving farmland, much of which lies within the floodplain. Plan update scheduled for

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
				2020.
Greenfield Master Plan, 2014 Sustainable Master Plan	City Plans	Provides a framework for guiding development in City.	Multiple Hazards	Effective in establishing priorities for environmentally sensitive development that will mitigate flooding impacts.
Participation in the National Flood Insurance Program	National Plan	As of 2018, there are 43 National Flood Insurance Policies in force[65]. Areas identified by the FEMA maps.	Flooding	Effective
State Building Code	State Regulation	The City of Greenfield has adopted the Massachusetts State Building Code.	Multiple Hazards	Effective
River Corridor Toolkit	Land Protection, Easements	Provides help with delineating and managing river corridors to promote river restoration and protection, create climate resilient land uses, and reduce the harm to land, water, habitat, people, and infrastructure caused by increasingly severe and frequent flood events.	Flooding	Effective in raising awareness of flooding hazards and potential negative impacts of uncontrolled development (loss of open space, farmland, and floodplains). Will encourage thinking on a watershed scale and protective, proactive and land use strategies.
Driveway Regulation	Regulation - Zoning Ordinance	Standards include street grade regulations (six to 10 percent maximum).	Flooding, Severe Winter Storms	Effective
Shelters	City Plan	Shelters for victims of natural hazards in Greenfield have been identified. City Hall, Middle School and High Schools have generators.	Multiple Hazards	Effective
Zoning regulations for wireless communications facilities	Regulation - Zoning Ordinance	Requires a special permit from the Zoning Board of Appeals and a building permit from the Inspector of Buildings before a facility can be erected. Applicant must provide plans for anchoring and supporting the structure. The Ordinance also establishes a "fall zone" for the structure in	Hurricanes, Tornados, Thunderstorms, Microbursts and High-wind events	Effective

65 National Flood Insurance Program (NFIP) Statistics as of December 18, 2018

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		relation to property lines and road right-of-ways. Add safety and prevention of wind-related damage as a stated purpose.		
Zoning Regulations Prohibiting new mobile homes	Regulation - Zoning Ordinance	City of Greenfield Zoning Ordinance prohibits the siting of new mobile homes.	Hurricanes, Tornados, Thunderstorms, Microbursts and High-wind events	Effective in reducing the potential for loss of life and property damage. Existing mobile homes are "grandfathered" and can be replaced. Replacements must meet standards of current building code. Ensure that replacement mobile homes be tied down to reduce the damaging impacts of high winds.
Burn Permits	Regulation	Residents are required to appear in person to obtain burn permits. Fire Department personnel provide information on safe burn practices.	Wildfire	Effective
Subdivision Review	Subdivision Rules & Regulations	The Fire Department is involved in the review of subdivision plans.	Wildfire	Effective
Public Education and Outreach	Program	The Fire Department has an ongoing educational program in the schools.	Wildfire	Effective
Forestry Management	Practice	The City has a Forestry Management Program for City-owned forested lands.	Wildfire	Somewhat Effective. The plan should implement practices that identify and implement climate resilient practices that reduce the risk of fire hazards in City-owned forested areas that are at higher risk for wildfire.
Permits required for new dam construction	State Regulation	State law requires a permit for the construction of any dam.	Dam Failure	Effective. Ensures dams are adequately designed.
Dam Inspections	State Regulation	DCR has an inspection schedule that is based on the hazard rating of the dam (low, significant, high hazard).	Dam Failure	Very Low. The state passed a law in 2002 to shift responsibility for inspections from the state

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
				to the dam owner. The regulations have not been issued so DCR continues to inspect only the High Hazard dams. It is highly likely that the remaining dams are not being inspected according to the required schedule. Repeal the state law requiring dam owners pay for inspections. Adequate staff and resources should be given to DCR to ensure the inspection schedules are maintained. Map dams and Inundation Areas. Evaluate the need for Dam Inspections by the City. Incorporate Dam Safety into Development Review process.
Zoning	Regulation - Zoning Ordinance	Special Permit and/or Order of Conditions required for dams in Floodplain district or wetlands. Floodplain areas and those under the jurisdiction of the Conservation Commission.	Dam Failure	Effective

4.3 HAZARD MITIGATION GOAL STATEMENTS AND ACTION PLAN

As part of the multi-hazard mitigation planning process undertaken by the Greenfield Multi-Hazard Mitigation Plan Update Committee, existing gaps in protection and possible deficiencies were identified and discussed. The Committee then developed general goal statements and mitigation action items that, when implemented, will help to reduce risks and future damages from multiple hazards. The goal statements, action items, City department(s) responsible for implementation, and the proposed timeframe for implementation for each category of hazard are described below. It is important to note that the City of Greenfield may be limited by resources (both funding and staffing). Efforts by the City to expand and improve upon existing policies and programs may be limited without additional technical assistance and funding.

Hazard Mitigation Goals

Based on the findings of the Risk Assessment, public outreach, and a review of previous City plans and reports, Greenfield has developed the following goals to serve as a framework for mitigating the hazards identified in this plan:

- To provide adequate shelter, water, food and basic first aid to displaced residents in the event of a natural disaster.
- To provide adequate notification and information regarding evacuation procedures, etc., to residents in the event of a natural disaster.
- To minimize the loss of life, damage to property, and the disruption of governmental services and general business activities due to natural hazards.

Prioritization of Hazards

The Committee examined the results of the Risk Assessment (see Section 3) and used the results to prioritize the identified hazards. The Committee evaluated the natural hazards that can impact the City based on probability of occurrence, severity of impacts, and area of occurrence. The Committee also reviewed the town’s Existing Mitigation Strategies (Table 4-1) and the work completed since the 2014 plan (Table 4-4) to determine the Priority Level for each hazard.

The Committee developed problem statements and/or a list of key issues for each hazard to summarize the vulnerability of Greenfield’s structures, systems, populations and other community assets identified as vulnerable to damage and loss from a hazard event. These problem statements were used to identify the City’s greatest vulnerabilities that will be addressed in the mitigation strategy (Section 4). For the most part, those hazards receiving the highest Overall Hazard Vulnerability Rating were also assigned a Priority Level of High, as shown in Table 4-2.   There are exceptions, notably Severe Winter Storms (the City and its residents are generally well prepared) and Invasive Species (more information about this hazard is needed before allocating scarce resources) .

Table 4-2: Greenfield Hazard Priority Level Rating		
Natural Hazard	**Overall Hazard Vulnerability Rating**	**Priority Level**
Severe Winter Storms	High	Low-Medium
Flooding	High	High
Tornadoes	Medium	Medium
Dam Failure (Leyden Glen and FERC High Hazard dams)	Low	Low
Dam Failure (all other dams)	Low	Low
Hurricanes / Tropical Storms	High	High
Severe Thunderstorms / Wind / Microbursts	High	High
Extreme Temperatures	Medium	Medium
Earthquakes	Low	Low
Landslides	Medium	Medium
Drought	Medium	Low
Wildfires	Medium	Low
Invasive Species	High	Low

Prioritization of Action Items

The Committee identified several strategies that are currently being pursued, and other strategies that will require additional resources to implement. Strategies are based on the work of the Committee, as well as the hazard identification and risk assessment (Section 3) and the information in Tables 4-1, 4-2 and 4-4 of this plan.

Prioritization Methodology

The Committee reviewed and prioritized a list of mitigation strategies using the following criteria:

- **Application to high priority or multiple hazards** – Strategies are given a higher priority if they assist in the mitigation of hazards identified as high priorities (Table 4-2) or apply to several natural hazards.

- **Time required for completion** – Projects that are faster to implement, either due to the nature of the permitting process or other regulatory procedures, or because of the time it takes to secure funding, are given higher priority.

- **Estimated benefit** – Strategies which would provide the highest degree of reduction in loss of property and life are given a higher priority. This estimate is based on the Hazard Identification and Risk Assessment Chapter, particularly with regard to how much of each hazard's impact would be mitigated.

- **Cost effectiveness** – In order to maximize the effect of mitigation efforts using limited funds, priority is given to low-cost strategies. For example, regular tree maintenance is a relatively low-cost operational strategy that can significantly reduce the length of time of power outages during a winter storm. Strategies that have identified potential funding streams, such as the Hazard Mitigation Grant Program, are also given higher priority.

The following categories are used to define the priority of each mitigation strategy:

- **Low** – Strategies that would not have a significant benefit to property or people, address only one or two hazards, or would require funding and time resources that are impractical.

- **Medium** – Strategies that would have some benefit to people and property and are somewhat cost effective at reducing damage to property and people.

- **High** – Strategies that provide mitigation of high priority hazards or multiple hazards and have a large benefit that warrants their cost and time to complete.

- **Very High** – extremely beneficial projects that will greatly contribute to mitigation of high priority and multiple hazards and the protection of people and property. These projects are also given a numeric ranking within the category.

Cost Estimates

Each of the following implementation strategies is provided with a cost estimate. Projects that already have secured funding are noted as such. Where precise financial estimates are not currently available, categories were used with the following assigned dollar ranges:

- **Low** – cost less than $25,000
- **Medium** – cost between $25,000 – $100,000
- **High** – cost over $100,000

Cost estimates take into account the following resources:

- City staff time for grant application and administration (at a rate of $25 per hour)
- Consultant design and construction cost (based on estimates for projects obtained from town and general knowledge of previous work in the city)
- City staff time for construction, maintenance, and operation activities (at a rate of $25 per hour)

Project Timeline

The timeframe for implementation of the action items are listed in the Action Plan as Year 0-1, which is the first year following plan adoption, and subsequent years after plan adoption through the 5 year life of the plan (Year 2, Year 3, Year 4 and Year 5). The Committee recognized that many mitigation action items have a timeframe that is ongoing due to either funding constraints that delay complete implementation and/or the action item should be implemented each of the five years of the plan, if possible. Therefore, a category of Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate was added.

Even when the political will exists to implement the Action Items, the fact remains that Greenfield is a small city that relies heavily on a small number of paid staff, many of whom have multiple responsibilities, and a dedicated group of volunteers who serve on town boards.

However, some Action Items, when implemented by City staff and volunteers, result in a large benefit to the community for a relatively small cost.

For larger construction projects, the City has limited funds to hire consultants and engineers to assist them with implementation. For these projects, the Greenfield may seek assistance through the Franklin Regional Council of Governments (FRCOG). However, the availability of FRCOG staff can be constrained by the availability of grant funding.

The 2020 Greenfield Multi-Hazard Mitigation Prioritized Action Plan is shown in Table 4-3. Potential funding sources for mitigation action items are listed when known. Other potential funding sources are listed in Table 5-1 of this plan. When City funds are listed as a source to fund hazard mitigation projects or activities, either in part (match) or in full, these funds would be obtained from the Greenfield's "general fund".

The 2020 Greenfield Multi-Hazard Mitigation Prioritized Action Plan is shown in Table 4-3. Potential funding sources for mitigation action items are listed when known. Other potential funding sources are listed in Table 5-1 of this plan. When City funds are listed as a source to fund hazard mitigation projects or activities, either in part (match) or in full, these funds would be obtained from the City's "general fund".

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	Action Description	Hazards Addressed	Responsible Department / Board	Estimated Cost	Potential Funding Source	Estimated Timeframe	Benefits: Society (S) Infrastructure (I) Environment (E)	Priority 2014 2020	Status
Critical Facilities & Infrastructure	Install backup generator to provide standby power to the Corrosion Control Building and Millbrook Well #2 and provide a reliable backup power source for those facilities to ensure that there is no interruption in potable water service and treatment during hazard events that impact the City of Greenfield.	Multiple Hazards	Department of Public Works (DPW)	High	HMPG	Year 0-1 with construction anticipated to be complete by Year 2	S, I	**2014 High** **2020 Very High**	The City has a pending application with FEMA's HMGP
Critical Facilities & Infrastructure Education & Awareness	Continue efforts to separate domestic sump pump outfall from municipal sewer system to reduce pressure on municipal wastewater treatment facilities and to comply with DEP/EPA regulations.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	DPW	High	City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, I, E	**Very High**	New Action Item The City currently working to separate domestic sump drainage from WWTP system by offering $500 reimbursement for connections to municipal drainage systems and $1,500 reimbursements for on-site storage and infiltration systems. The City also using smoke tests to prioritize storm sewer separation.
Critical Facilities & Infrastructure	Hire a consultant to update existing cost estimates and engineering solutions (now over 15 years old) for replacement and rehabilitation of the existing Maple Brook Culvert. Work should incorporate NBS and be segmented by priority. Specific areas of concern include: Spring Terrace, Crescent Street, Medicine Circle, Green and Cooke Streets and Greenway Lane, and Hastings, Haywood and Riddell Streets neighborhoods where the Maple Brook Culvert backs up during heavy rain events, including near 34 Riddell Street, which is the proposed location of the new Fire Station.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	DPW	High	HMGP, MVP, MassDEP, City	Year 0-1 and ongoing	S, I, E	**2014 High** **2020 Very High**	This work has been identified as a critical need since the 2005 Plan. Repair work was done to the Solon Street interceptor following Tropical Storm Irene in 2011. Repair work is ongoing, but on a site by site basis. The entire Maple Brook culvert, which was constructed in the 1930's and involved burying the Maple Brook, drains approximately 1,000 acres of the City's most urbanized landscape. The culvert is severely undersized. The construction of the City's new

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
									Fire Station at 34 Riddell Street is contingent upon these repairs. This Action Item has been updated and carried forward to the 2020 Plan.
Critical Facilities & Infrastructure	To safeguard secondary access to Leyden Glen Reservoir and Dam, hire a consultant to provide designs and cost estimates for stormwater management solutions for the southern Leyden Glen Reservoir Access Road to improve drainage and to mitigate erosion and rutting caused by stormdrains upslope that discharge large volumes of water from Leyden Road. Coordinate work with the Town of Leyden.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	DPW	Medium - High	HMGP, MVP, City	Year 2	S, I, E	**2014 Medium** **2020 High**	To maintain safe vehicular access to the reservoir and dam, the City has worked to improve cross-drains and adjust the crown and pitch of Leyden Glen Reservoir Access Road but there is additional work that needs to be done. The north access road has become the primary access road. However, there are erosion and stormwater runoff problems with the north access road, too, fill is added annually to address erosion problems. Action Item description has been updated and carried over from 2014 plan.
Critical Facilities & Infrastructure	Continue efforts to upgrade the City's aging storm sewer and waste water conveyance infrastructure to reduce Inflow and Infiltration pressure on municipal wastewater treatment facilities and to reduce the risk of combined waste water and storm water hazard events.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts, Manmade Hazards	DPW	High	MVP, City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, I, E	**High**	New Action Item DPW has worked with a contractor to complete structural inspections and this work is ongoing. DPW has used smoke tests to identify and prioritize storm sewer separation projects in the City. Areas addressed include Wells Street and School

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
									Street.
Critical Facilities & Infrastructure	Hire a consultant to prepare final designs and cost estimates for climate resiliency projects identified in the *Green River Corridor Mapping and Management Report* (2019) and to expand River Corridor mapping to tributaries of the Green River.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	Planning Department, Conservation Commission	Medium - High	HMGP, MVP, MassDEP, Land Trusts, City	Year 2	S, I, E	**Medium**	New Action Item
Critical Facilities & Infrastructure	Hire a consultant to evaluate and prioritize localized stormwater flooding problem areas within the City, data from high-risk culvert inventory prepared by FRCOG, abandoned or tax lien properties, and River Corridor Mapping and develop conceptual designs and cost estimates for stormwater management and flood resilience options, including: infrastructure replacement and upgrades, and nature-based solutions (NBS) such as daylighting streams and creating retention basins to attenuate flood flows, especially in flood-prone areas of the City.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	DPW, Planning Department	High	HMGP, MVP, MassDEP, City	Year 3	S, I, E	**Medium**	New Action Item
Critical Facilities & Infrastructure	Improve the process for residents to report situations in which private property is negatively impacted by municipal stormwater infrastructure or flooding issues related to surface drainage and for reports to be handled by the DPW.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	DPW	Low	City	Year 2	S, I, E	**Medium**	New Action Item
Critical Facilities & Infrastructure	Hire a hydraulic engineer to conduct a feasibility study of retrofits for the Wastewater Treatment Plant that would allow the building to be safely inundated by floodwaters as a necessary flood resilience strategy in addition to having raised the flood doors to maximum possible elevation (144.3 ft.).	Flooding, Dam Failure	Department of Public Works	High	MVP, HMGP, City	Year 3	S, I, E	**Medium**	New Action Item Flood doors were installed to an elevation of 144.3 feet in 2014.

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
Critical Facilities & Infrastructure	Hire a structural engineering consultant to assess the integrity of the concrete retaining walls on the streambanks of the Green River along Deerfield Street and Meridian Streets and to develop conceptual designs and cost estimates to repair and/or replace the retaining walls.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts, Dam Failure, Landslides	DPW	Medium - High	MVP, City	Year 3	S, I, E	**Medium**	New Action Item
Critical Facilities & Infrastructure	Complete an inventory of locations in the City, especially within the Green River Corridor, where critical infrastructure, including roads, buildings and utilities, are vulnerable to fluvial erosion hazards and landslides. Use GIS to analyze soils vs. slope and to identify these potential landslide hazard areas on a map. Indicate where soil borings are needed for more accurate data at significant sites. Hire a consultant to identify retrofitting measures and cost estimates for projects to prevent roadway damage, traffic disruptions, and damage to other critical infrastructure from fluvial erosion hazards and landslides. Update the City's land use regulations to reflect this risk analysis, as appropriate.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts, Landslides	DPW, Planning Department, Conservation Commission	High	MVP, City	Year 3	S, I, E	**2014 Medium** / **2020 Medium**	Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.
Critical Facilities & Infrastructure	Hire a tree service and coordinate with the Town of Leyden for work needed on Oak Hill Access Road to the municipal water supply filtration plant where overgrown red pines are top heavy and encroaching on road shoulder. Needed cutting ranges 15-25' from road sides and crosses into the Town of Leyden in some places.	Tornados, Microbursts, Hurricanes, Thunderstorms, Severe Winter Storms	DPW	Medium - High	MVP, City	Year 1	S, I	**Medium**	New Action Item
Critical Facilities & Infrastructure	Hire a consultant to update the feasibility study, design, and cost estimates for the West Side Water Project. This project would construct a new 1-3.5 million gallon water storage tank on the west side of City and a 20-inch water transmission main to Main Street to address poor pressure and flows (especially critical for firefighting) as well as provide a backup for	Wildfire, Drought	DPW, Planning Department	High	City Bond, Grant(s)	Year 4	S, I, E	**Medium**	This Action Item was carried over from the 2005 and 2014 plans but had not been assigned a priority level. This 2020 Action Item is an update and a more realistic approach. The existing studies for this project are now >40 years

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
	the Rocky Mountain Storage tank. This project has been needed since the 1970's and is identified in the 2016 *Water Supply Master Plan*.								old. The DPW has upgraded some 4-inch water mains to support fire fighting. The upgrades included the water mains on West Street and Philips Street, which are side streets near the downtown area.
Local Plans & Regulations	Continue to participate in the Franklin County Regional Emergency Planning Committee (REPC), which is currently working to complete and operationalize the Debris Management Plan. Coordinate with state and regional agencies to identify a location(s) in the City for the temporary storage of contaminated and/or hazardous flood debris.	Multiple Hazards	DPW , Franklin County REPC	Low	MVP, City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, E	**2014 High** **2020 Very High**	Action Item description has been updated and carried over from 2014 plan.
Local Plans & Regulations	Continue to review and update, as appropriate, City land use regulations to include climate resiliency provisions such as Best Management Practices for River Corridor areas (FRCOG's River Corridor Toolkit), further restricting or limiting new development within the 100-year floodplain and River Corridor, Low Impact Development (LID) stormwater practices, etc.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	Planning Department, Conservation Commission	Low	City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, I, E	**2014 High** **2020 HIgh**	The City Planning Board has been reviewing previous recommendations that include LID stormwater management practices. Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.
Local Plans & Regulations	Using Assessors' data and the GIS mapping developed for the 2020 Plan, update the Vulnerability Assessment for properties located within the 100-year floodplain and include properties in the mapped Green River Corridor that are vulnerable to flooding and fluvial erosion. Include information on crop damages, if available.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	Planning Department, City Assessors	Low	MVP, City	Year 2	S, I, E	**2014 High** **2020 HIgh**	The City participated in the FRCOG's project to map the Green River Corridor. Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
Local Plans & Regulations	Share FRCOG's River Corridor Toolkit and high-risk culverts/stormwater flooding inventory with all City Boards and Committees. Encourage use by the Planning and Construction Committee when siting new municipal buildings.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts	Planning Board Planning Department, Conservation Commission, DPW	Low	City	Year 1	S, I, E	**High**	New Action Item
Local Plans & Regulations	Hire a consultant to develop Standard Operating Procedures (SOPs) and checklists of materials, etc. for each City Department to plan for response and evacuating residents, including SOPs to address street closings and sheltering needs. Develop "Rip and Run" task sheets to efficiently delegate emergency management across City Departments during hazard events.	Multiple Hazards	Emergency Management Director, Police Department, Fire Department	Medium - High	MVP, City	Year 2	S	**High**	New Action Item
Local Plans & Regulations	Examine strategies for improving the City's existing hazard tree program, which currently completes tree work for residents outside of utility areas. Look for ways to improve the process of identifying tree hazards and to minimize conflict between the DPW and residents. Encourage coordination between City departments and the Greenfield Tree Warden to foster safe and effective care of the City's trees, including selecting and planting new trees with the guidance of the *Greenfield Tree Planting Plan* (2019).	Tornados, Microbursts, Hurricanes, Thunderstorms, Severe Winter Storms	DPW, Greenfield Tree Warden	Low	City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, I, E	**High**	New Action Item
Local Plans & Regulations	Identify City-owned forested areas that are at higher risk for wildfires (near industrial manufacturing, residential areas, high-wire utilities, etc.) to implement climate resilient forest management practices that reduce the risk of fire hazards (such as the removal of slash). Coordinate with utility company for tree clearing work.	Wildfire	Conservation Commission, Planning Department, Fire Department	Low-Medium	MVP, City, DCR	Year 3	S, I, E	**2014 Medium** / **2020 Medium**	Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.
Local Plans & Regulations	Hire a consultant to assess vulnerability to earthquake damage of the City's existing critical facilities and infrastructure, and determine appropriate retrofitting measures to reduce the risk of damage from earthquakes.	Earthquakes	Emergency Management Director, Building Inspector,	Medium-High	MVP, HMGP, City	Year 5	I	**2014 Medium** / **2020 Low**	Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 / 2020**	**Status**
			DPW, Planning Department						
Education & Awareness	Continue outreach to residents to improve household disaster preparedness and fire safety. Inform residents and businesses located within flood and dam inundation areas about how to prepare for flooding and safely evacuate. Distribute updated emergency information packets through City Boards and City Council, hold an annual forum at the Council on Aging to better reach vulnerable populations, including seniors and disabled residents, and promote access to the City's Emergency Management website where residents can find out if they line in a flood-prone area and enroll in Greenfield Alert (Emergency Notifications). Utilize the City's website and Cable TV to disseminate information.	Multiple Hazards	Emergency Management Director, Fire Department	Low	MVP, City	Year 0-1, to be reviewed annually and implemented in subsequent years (Years 2-5), as appropriate.	S, I	**2014 High** / **2020 High**	The City's Emergency Management Department and Fire Departments each maintain a page on the City's website. Information is regularly posted and includes disaster preparedness information for residents such as "Helpful Links for Disaster Preparedness", "Greenfield Alert (Emergency Notifications)", and "Local Weather Forecast-Link". Also links to Emergency Management PDF files, "Family Disaster Planning", and "Emergency Management Special Needs Survey". Related Action Items from the 2014 Plan have been consolidated and the Action Item description updated for the 2020 plan.
Education & Awareness	Establish secure storage areas and containers for household hazardous waste at designated municipal collection sites, as well as funding for additional staff to operate and increase outreach for the City's existing household hazardous waste collection program to reduce risk of hazardous spills and contamination.	Flooding, Manmade Hazards	Emergency Management Director, Department of Public Works, Health Department	Low - Medium	MVP, City	Year 2	S, I, E	**High**	New Action Item
Education & Awareness	Educate homeowners about the risk of wildfires and brushfires and how to reduce the risk by adopting general fire safety techniques.	Wildfires	Fire Department	Low	City	Year 0-1, to be reviewed annually and implemented	S, I, E	**2014 Medium**	The City's Fire Department maintains a page on the City's website. Information can be posted there. On-line Burn

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan									
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Estimated Timeframe**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority 2014 2020**	**Status**
						in subsequent years (Years 2-5), as appropriate.		**2020 Medium**	Permits are available through the Fire Department. The application process includes information for safe practices and a caution that the permit holder will be responsible for up to $500 of fire suppression costs if the burn pile gets out of control. Action Item carried over from 2014 Plan and is still relevant.

Table 4-4: Completed or Obsolete 2014 Hazard Mitigation Actions								
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority in Past Plan**	**Current Status**
Local Plans & Regulations	Enforce the State Building Code and provide training to the Building Inspector, as needed, to ensure new buildings are designed and constructed to reduce the risk of damage from high winds.	Multiple Hazards	Building Inspector	Low – Medium	City	S, I	High	Completed Enforcement of the State Building Code is underway and ongoing. The Local Project Team determined that it is not necessary to include this as an Action Item in the 2020 Plan.
Critical Facilities & Infrastructure	Inventory City trees and work with the utility companies to prune or remove trees/limbs to reduce risk to property and infrastructure from high wind events.	Tornados, Microbursts, Hurricanes, Thunderstorms	Department of Public Works	Low - Medium	City, Utility Company	S, I, E	High	Completed and Ongoing, as needed Substantial trimming along powerlines completed by Eversource. City Tree program has active and ongoing work orders outside of utility areas.
Local Plans & Regulations	Research, update and amend Section 200-7.14 of the Greenfield Zoning Ordinance that regulates wireless communication facilities to include provisions related to preventing wind-related damage in fall zone areas to reduce the risk to life and property from high winds associated with microbursts and other high wind events.	Tornados, Microbursts, Hurricanes, Thunderstorms	Planning Department	Low	City	S, I	High	Completed
Local Plans & Regulations	Encourage the construction of new homes with basements or crawl spaces or "safe rooms" to provide shelter during a microburst, hurricane or other storm event with high winds.	Tornados, Microbursts, Hurricanes, Thunderstorms	Building Inspector	Low	City	S	Low	Obsolete except in site-specific cases where appropriate. Initiative should be voluntary.
Critical Facilities & Infrastructure	To increase resilience of the City's water supply infrastructure, repair damage from TS Irene and make improvements to retentional area and dam structures at Green River Pumping Station Impoundment.	Flooding, Microbursts, Hurricanes, Thunderstorms	Department of Public Works	High	FEMA Disaster Recovery Funds, City	S, I, E	Relevant Action Not in Past Plan	Completed in 2013-2014, the City rebuilt the retention area at Green River Pumping Station Impoundment. The retaining wall was extended and keyed concrete into ledge, and soil on either side of the berm was solidified with a concrete block mat giving it a stronger base.
Critical Facilities & Infrastructure	Fortify and flood-proof the Wastewater Treatment Plant to an elevation of 144.3 feet (previously at 140 feet).	Flooding, Microbursts, Hurricanes, Thunderstorms	Department of Public Works	High	FEMA Disaster Recovery Funds, City	S, I, E	Relevant Action Not in Past Plan	Completed in 2014 with flood doors installed to 144.3 ft.

Table 4-4: Completed or Obsolete 2014 Hazard Mitigation Actions								
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority in Past Plan**	**Current Status**
Local Plans & Regulations	In order to reduce the risk and potential loss of life from dam failure, prepare a GIS map of areas within the City that are likely to be flooded in the event of a dam failure at Leyden Glen Dam and FERC High Hazard dams upstream of the City and distribute to all municipal public safety officials.	Flooding, Dam Failure	Planning Department, Planning Board	High	Dam owners	S, I, E	High	Completed Updated Dam Inundation Area mapping for the FERC High Hazard dams (Harriman Dam on the Deerfield River and Moore Dam on the Connecticut River) was completed in 2018 and provided to the City. These areas and the the Leyden Glen Dam Inundation Area is shown on the maps for the 2020 Plan. Greenfield Public Safety Officials have the inundation mapping.
Local Plans & Regulations	Support local and regional, watershed-wide open space protection efforts, particularly in floodplain areas.	Flooding, Microbursts, Hurricanes, Thunderstorms	Planning Department, City Council	High	MassDEP 319 grant program, EEA	S, I, E	High	Completed and Ongoing, as needed The City participated in the related planning work conducted by FRCOG, including the *Deerfield River Watershed Based Plan(2017), A Framework for Resilience: Responding to Climate Change in the Deerfield River Watershed (2019), and the River Corridor Management Toolkit (2019).*
Local Plans & Regulations	Conduct a fluvial geomorphological assessment of erosion and erosion hazards along the banks of the Green River.	Flooding	Department of Public Works, Planning Department, Emergency Management Director	High	MassDEP 319 grant program, EEA	S, I, E	Medium	Completed River Corridor mapped for the Green River. River Corridor mapping needed for tributaries.
Local Plans & Regulations	Ensure compliance with the Massachusetts State Building Code. Provide training to the Building Inspector, as needed, to ensure that all new construction complies with the appropriate seismic requirements of the State Building Code. Participate in trainings offered by FEMA's National Earthquake Technical Assistance Program (NETAP). NETAP is designed to help state, local, and tribal governments obtain the knowledge, tools, and support that they need to plan and implement effective	Earthquakes	Building Inspector	Low	City	S, I	Medium	Completed Enforcement of the State Building Code is underway and ongoing. The Local Project Team determined that it is not necessary to include this as an Action Item in the 2020 Plan.

Table 4-4: Completed or Obsolete 2014 Hazard Mitigation Actions								
Action Type	**Action Description**	**Hazards Addressed**	**Responsible Department / Board**	**Estimated Cost**	**Potential Funding Source**	**Benefits: Society (S) Infrastructure (I) Environment (E)**	**Priority in Past Plan**	**Current Status**
	earthquake mitigation strategies.							
Critical Facilities & Infrastructure	Conduct inspections of the Mill and Meridian Street dams, which were identified by the Committee as possibly being in poor condition.	Dam Failure	Department of Public Works, Planning Department, City Engineer	Medium	City	S, I	High	Completed This work is ongoing. Mill Street, Leyden Glen and Meridian Street Dams are on a 5 year inspection cycle.
Critical Facilities & Infrastructure	Purchase and install backup generators for the DPW, emergency facilities, and critical public utilities where still needed.	Multiple Hazards	Department of Public Works	High	City, FEMA	S, I	High	Completed City Hall, Fire Station, Wastewater Pump Stations, DPW at 209 Wells Street, and the Middle School and High Schools now have backup generators. Public drinking water supply still needs backup power to operate the facility and remain in compliance with water quality standards during power outages. See Table 4-3 above.

5 PLAN ADOPTION AND MAINTENANCE

5.1 PLAN ADOPTION

The Franklin Regional Council of Governments (FRCOG) provided support to the Greenfield Multi-Hazard Mitigation Plan Update Committee as they underwent the planning process. City staff and the other members of the Committee were invaluable resources to the FRCOG and provided background and policy information and municipal documents, which were crucial to facilitating completion of the plan.

When the preliminary draft of the Greenfield 2020 Multi-Hazard Mitigation Plan was completed, copies were disseminated to the Committee for comment and approval. The Committee was comprised of representatives of City boards and departments who bear the responsibility for implementing the action items and recommendations of the completed plan (see the list of Committee members on the front cover).

Copies of the Final Review Draft of the 2020 Multi-Hazard Mitigation Plan for the City of Greenfield were distributed to City boards and officials, and to surrounding towns for review. Copies were made available at the City Hall and the Library, and a copy of the plan was also posted on the City website for public review. Once reviewed and approved by MEMA, the plan was sent to the Federal Emergency Management Agency (FEMA) for their approval. FEMA approved the plan pending adoption by the Greenfield City Council. The Council voted to adopt the plan on April 16, 2020. FEMA issued the final approval letter on April 28, 2020.

5.2 PLAN MAINTENANCE PROCESS

The implementation of the Greenfield Multi-Hazard Mitigation Plan will begin following its approval by MEMA and FEMA and formal adoption by the Greenfield City Council. Specific City departments and boards will be responsible for ensuring the development of policies, bylaw revisions, and programs as described in the Action Plan (Table 4-3). The Greenfield Multi-Hazard Mitigation Plan Update Committee will oversee the implementation of the plan.

Monitoring, Evaluating, and Updating the Plan

The measure of success of the Greenfield Multi-Hazard Mitigation Plan will be the number of identified mitigation strategies implemented. In order for the City to become more disaster resilient and better equipped to respond to natural disasters, there must be a coordinated effort between elected officials, appointed bodies, City employees, regional and state agencies involved in disaster mitigation, and the general public.

Implementation Schedule

Annual Meetings

The Greenfield Multi-Hazard Mitigation Committee will meet on an annual basis or as needed (i.e., following a natural or other disaster) to monitor the progress of implementation, evaluate the success or failure of implemented recommendations, and brainstorm for strategies to remove obstacles to implementation. Following these discussions, it is anticipated that the Committee may decide to reassign the roles and responsibilities for implementing mitigation strategies to different City departments and/or revise the goals and objectives contained in the plan. At a minimum, the Committee will review and update the plan every five years. The meetings of the Committee will be organized and facilitated by the Greenfield Director of Planning & Development and the Emergency Management Director.

Bi-Annual Progress Report

The Emergency Management Director will prepare and distribute a biannual progress report in years two and four of the plan. Members of the Committee will be polled on any changes or revisions to the plan that may be needed, progress and accomplishments for implementation, failure to achieve progress, and any new hazards or problem areas that have been identified. Success or failure to implement recommendations will be evaluated differently depending on the nature of the individual Action Items being addressed, but will include, at a minimum, an analysis of the following: 1) whether or not the item has been addressed within the specified time frame; 2) whether actions have been taken by the designated responsible parties; 3) what funding sources were utilized; 4) whether or not the desired outcome has been achieved; and 4) identified barriers to implementation. This information will be used to prepare the bi-annual progress report which may be attached as an addendum, as needed, to the local hazard mitigation plan. The progress report will be distributed to all of the local implementation group members and other interested local stakeholders. The Emergency Management Director and the Committee will have primary responsibility for tracking progress and updating the plan.

Five-Year Update Preparation

During the fourth year after initial plan adoption, the Emergency Management Director will convene the Committee to begin preparations for an update of the plan, which will be required by the end of year five in order to maintain approved plan status with FEMA. The team will use the information from the annual meetings and the biannual progress reports to identify the needs and priorities for the plan update.

Updated Local Hazard Mitigation Plan – Preparation and Adoption

FEMA's approval of this plan is valid for five years, by which time an updated plan must be approved by FEMA in order to maintain the City's approved plan status and its eligibility for FEMA mitigation grants. Because of the time required to secure a planning grant, prepare an updated plan, and complete the approval and adoption of an updated plan, the local Multi-Hazard Mitigation Plann Update Committee should begin the process by the end of Year 3. This will help the City avoid a lapse in its approved plan status and grant eligibility when the current plan expires.

The Committee may decide to undertake the update themselves, request assistance from the Franklin Regional Council of Governments, or hire another consultant. However the Committee decides to proceed, the group will need to review the current FEMA hazard mitigation plan guidelines for any changes. The updated Greenfield Multi-Hazard Mitigation Plan will be forwarded to MEMA and to FEMA for approval.

As is the case with many Franklin County municipalities, Greenfield's government relies on a few public servants filling many roles, upon citizen volunteers and upon limited budgets. As such, implementation of the recommendations of this plan could be a challenge to the Committee. As the Committee meets regularly to assess progress, it should strive to identify shortfalls in staffing and funding and other issues which may hinder Plan implementation. The Committee can seek technical assistance from the Franklin Regional Council of Governments to help alleviate some of the staffing shortfalls. The Committee can also seek assistance and funding from the sources listed in Table 5-1.

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
National Flood Insurance Program	Pre-disaster insurance	Rolling	DCR	Property Owner, FEMA
Community Assistance Program	State funds to provide assistance to communities in complying with NFIP requirements	Annually	DCR	FEMA/NFIP
Community Rating System (Part of the NFIP)	Flood insurance discounts	Rolling	DCR	Property Owner
Flood Mitigation Assistance (FMA) Program	Cost share grants for pre-disaster planning & projects	Annual	MEMA	75% FEMA/ 25% non-federal
Hazard Mitigation Grant Program (HMGP)	Post-disaster cost-share Grants	Post Disaster	MEMA	75% FEMA/ 25% non-federal
Pre-Disaster Mitigation (PDM) Program	National, competitive grant program for projects & planning	Annual	MEMA	75% FEMA/ 25% non-federal
Small Business Administration Disaster Loans	Post- disaster loans to qualified applicants	Ongoing	MEMA	Small Business Administration
Public Assistance Program	Post-disaster aid to state and local governments	Post Disaster	MEMA	FEMA/ plus a non-federal share
Dam & Seawall Repair & Removal Program	Grant and loan funds for design, permitting, and construction of repair or removal of dams	Annual	EEA	Dam and Seawall Repair or Removal Fund

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
Emergency Management Performance Grant (EMPG)	Funding to assist local emergency management departments in building and maintaining an all-hazards emergency preparedness system, including planning; organizational support; equipment; training; and exercises	When funds are available	MEMA	
Volunteer Fire Assistance (VFA) Program	Grants and materials to Citys with less than 10,000 population for technical, financial and other assistance for forest fire related purposes, including training, Class A foam, personal protective gear, forestry tools, and other fire suppression equipment	Annual	DCR	USDA Forest Service
Federal 604b Water Quality Management Planning Grant	Funding for assessment and planning that identifies water quality problems and provides preliminary designs for Best Management Practices to address the problems	Annual	MA DEP	EPA Clean Water Act
Section 319 Nonpoint Source Competitive Grant Program	Provides grants for wide variety of activities related to non-point source pollution runoff mitigation	Annual	MassDEP	EPA
Economic Development Administration Grants and Investment	Provides grants for community construction projects, which can include mitigation activities	Rolling	FRCOG	U.S. Department of Commerce, EDA
Emergency Watershed Protection	A disaster recovery program made available in emergency situations when neither the state nor the local community is able to repair a damaged watershed	Post-Disaster	NRCS MA	USDA NRCS
Agricultural Management Assistance	Funding for producers to develop or improve sources of irrigation water supply, construct new or reorganize irrigation delivery systems on existing cropland to mitigate the risk of drought	Rolling	NRCS MA	USDA NRCS

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
Conservation Stewardship Program	Agricultural producers and forest landowners earn payments for actively managing, maintaining, and expanding conservation activities – like cover crops, rotational grazing, ecologically-based pest management, buffer strips, and pollinator and beneficial insect habitat – while maintaining active agricultural production	Rolling	NRCS MA	USDA NRCS
Environmental Quality Incentives Program (EQIP)	Provides technical and financial assistance to forestry & agricultural producers to plan and install conservation practices that address natural resource concerns including water quality degradation, water conservation, reducing greenhouse gases, improving wildlife habitat, controlling invasive plant species, and on-farm energy conservation and efficiency.	Rolling	NRCS MA	USDA NRCS
Agricultural Lands Conservation Program (ACEP)	Provides financial and technical assistance to help conserve agricultural lands and wetlands.	Rolling	NRCS MA	USDA NRCS
Forest Stewardship Program	Supports private landowners and municipalities to manage woodlands for timber, soil and water quality, wildlife and fish habitat, and recreation	Rolling	DCR / MA Woodlands Institute	USDA Forest Service
Community Forest Stewardship Implementation Grants for Municipalities	Municipalities that manage a City forest or have water supply land currently enrolled in the Forest Stewardship Program apply for 75-25 matching reimbursement grants to implement their forest stewardship plan	Rolling as funding permits	DCR	USDA Forest Service
USDA Community Facilities Direct Loan & Grant	Provides grants and loans for infrastructure and public safety development and enhancement in rural areas	Annual	USDA Rural Development MA	USDA Rural Development

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
Transportation Improvement Program	Prioritized, multi-year listing of transportation projects in a region that are to receive Federal funding for implementation. Projects are limited to certain roadways and are constrained by available funding for each fiscal year. Any transportation project in Franklin County that is to receive federal funding must be listed on the TIP.	Rolling	Franklin County Transportation Planning Organization / FRCOG	80% Federal / 20% State
Chapter 90 Program	Funds maintaining, repairing, improving and constructing City and county ways and bridges which qualify under the State Aid Highway Guidelines	Annual	Mass DOT	State Transportation Bond
Culvert Replacement Municipal Assistance Grant	Funds replacement of undersized, perched, and/or degraded culverts located in an area of high ecological value with better designed crossings that meet improved structural and environmental design standards and flood resiliency criteria	Annual	MA Division of Ecological Restoration	State Appropriation
MassWorks Infrastructure Program	Funds for public infrastructure such as roadways, streetscapes, water, and sewer	Annual	EOHED	State Appropriation
Municipal Small Bridge Program	5 year program (FY17 – FY21) to assist cities and Citys with replacing or preserving bridges with spans between 10' and 20'	Bi-Annual	MassDOT	State Appropriation
Municipal Vulnerability Preparedness (MVP) Planning and Action Grant Programs	Funding to support cities and Citys to begin the process of planning for climate change resiliency and implement priority projects; projects proposing nature-based solutions that rely on green infrastructure or conservation and enhancement of natural systems to improve community resilience are given priority for implementation funding through the MVP Action Grant	Annual	EEA	State Appropriation
Land and Water Conservation Fund Grant Program	Funding for municipalities for the acquisition of parkland, development of a new park, renovation of an existing park, development of trails in an existing conservation or recreation area, or the acquisition of conservation land	Annual	EEA	National Park Service

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
Drinking Water Supply Protection Grant	Provides financial assistance to public water systems and municipal water departments for the purchase of land in existing Department of Environmental Protection (DEP)-approved drinking water supply protection areas, or land in estimated protection areas of identified and planned future water supply wells or intakes	Annual	EEA	EEA
Landscape Partnership Grant	Funding for large-scale (min. 500 acres), joint conservation projects completed in partnership with federal, state, and local governments, and non-profits	Annual	EEA	EEA
Conservation Partnership Grant	Funds acquisition of conservation or recreation land by non-profit entities	Annual	EEA	EEA
LAND – Local Acquisitions for Natural Diversity	Funding for municipal conservation and agricultural commissions to acquire interests in land that will be used for conservation and passive recreation purposes	Annual	EEA	EEA
PARC - Parkland Acquisitions and Renovations for Communities	Funding for municipalities to acquire parkland, build a new park, or to renovate an existing park	Annual	EEA	EEA
Table Acronym Key: DCR = MA Department of Conservation & Recreation; FEMA = Federal Emergency Management Agency; MEMA = MA Emergency Management Agency; EEA = MA Executive Office of Energy & Environmental Affairs; USDA = U.S. Department of Agriculture; NRCS = Natural Resource Conservation Service; EDA = U.S. Economic Development Administration; EPA = U.S. Environmental Protection Agency; FRCOG = Franklin Regional Council of Governments; MassDOT = MA Department of Transportation; EOHED = MA Executive Office of Housing & Economic Development				

Incorporating the Plan into Existing Planning Mechanisms

<u>2014 Multi-Hazard Mitigation Plan</u>
The City of Greenfield has taken steps to implement findings from the 2014 Multi-Hazard Mitigation Plan into the following policy, programmatic areas and plans: the 2014 Sustainable Master Plan, ongoing work of the Planning Board to update the City's land use regulations with stormwater management best practices, such as Low Impact Development (LID). The City participated in the FRCOG's project to map the Green River Corridor.

<u>2020 Multi-Hazard Mitigation Plan</u>
Upon approval of the Greenfield Multi-Hazard Mitigation Plan by FEMA, the Committee will provide all interested parties and implementing departments with a copy of the plan, with emphasis on Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan. The Committee should also consider initiating a discussion with each department on how the plan can be integrated into that department's ongoing work. At a minimum, the plan should be distributed to and reviewed with the following entities:

- Fire Department
- Emergency Management Director
- Police Department
- Public Works Department
- Planning Board
- Zoning Board of Appeals
- Conservation Commission
- Franklin County Regional Emergency Planning Committee
- Building Inspector
- City Council

Some possible planning mechanisms for incorporating the 2020 Greenfield Multi-Hazard Mitigation Plan into existing planning mechanisms to the fullest extent possible could include:

- Incorporation of relevant Hazard Mitigation and climate change information into the update of the City's Open Space and Recreation Plan. There are opportunities to discuss findings of the hazard mitigation plan and incorporate them into the Environmental Inventory and Analysis section of the OSRP and to include appropriate action items from the hazard mitigation plan in the OSRP Action Plan. The plan update project has commenced and will finish by June 30, 2021.

- Any future update of the City's Sustainable Master Plan could incorporate relevant material from this plan into sections such as the Natural Resources section and any action plans.
- When the Final Draft 2020 Multi-Hazard Mitigation Plan for the City of Greenfield is distributed to the City boards for their review, a letter asking each board to endorse any action item that lists that board as a responsible party would help to encourage completion of action items.
- The Planning Board could include discussions of the Multi-Hazard Mitigation Plan Action Items in one meeting annually and assess progress. Ongoing work of the Planning Board to update the City's Subdivision Rules and Regulations and Zoning Ordinance could be updated by the Planning Board based upon the recommendations of this plan. For example, the City could consider adapting the Model River Corridor Protection Zoning Overlay District to protect and manage the Green River Corridor. Technical assistance from the FRCOG may be available to assist in the modification of Greenfield's current ordinances.
- The River Corridor Mapping for the Green River can be used by the Conservation Commission, the Agricultural Commission and other City departments in their permitting and decision-making processes.
- The City was awarded a Municipal Vulnerability Preparedness (MVP) program planning grant in 2018 and will be working to become designated a MVP Community. This 2020 Multi-Hazard Mitigation Plan is a good foundation for the MVP planning effort, including the Community Resilience Building Workshop scheduled for Fall 2020.

Continued Public Involvement

The City of Greenfield is dedicated to continued public involvement in the hazard mitigation planning and review process. During all phases of plan maintenance, the public will have the opportunity to provide feedback. The 2020 Plan will be maintained and available for review on the City website through 2025. Individuals will have an opportunity to submit comments for the Plan update at any time. Any public meetings of the Committee will be publicized. This will provide the public an opportunity to express their concerns, opinions, or ideas about any updates/changes that are proposed to the Plan.

APPENDIX A - Public Participation

City of Greenfield
Multi-Hazard Mitigation Plan Update Underway
April 8, 2019

The Greenfield Multi-Hazard Mitigation Plan Committee is currently updating the Multi-Hazard Mitigation Plan for Greenfield, in partnership with the Franklin Regional Council of Governments (FRCOG) Planning Department. Once the updated Plan is approved by FEMA and adopted by the City, the City will be eligible for state and Federal grant monies to fund pre- and post-disaster mitigation projects.

The purpose of this Multi-Hazard Mitigation Plan update is to identify natural and other hazards that may affect the community; conduct a risk assessment to identify infrastructure at the highest risk for being damaged by hazards; inventory and assess current City hazard mitigation policies, programs, and regulations; and identify action steps to prevent damage to property and loss of life.

The Greenfield Multi-Hazard Mitigation Planning Committee will meet several times to compile new and updated information for the Plan. All meetings of the Committee are open to the public; meeting notices and agendas can be found at the Greenfield City Offices located at 20 Sanderson Street, Room 203, Greenfield, MA or on the City's website at https://greenfield-ma.gov/p/29/Department-of-Planning--Development.

To find out more about this project and how you can become involved, please contact Eric Twarog, Director, Greenfield Department of Planning & Development at (413) 772-1549 or eric.twarog@greenfield-ma.gov.

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
William B. Allen 1st Floor Meeting Room
12 Olive Street
Greenfield, MA 01301
Tuesday, April 16, 2019
1:00 p.m. – 2:30 p.m.

1. Introductions
2. Overview of Project and Timeline
3. Overview of Hazards and Climate Change Stressors
4. Discussion of Greenfield's Risk to Each Hazard Based on the Location, Extent, Probability, and Severity of Hazards
    a. Review of Draft Critical Facilities & Infrastructure Map
    b. Review of Environmental Resources Map
5. Schedule Next Meeting

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
FRCOG Offices
2nd Floor
12 Olive Street
Greenfield, MA 01301
Tuesday, June 4, 2019
9:30 a.m. – 11:00 a.m.

1. Introductions
2. Discussion of Draft River Corridor Mapping Completed for the Green River and the Relationship to Flood Hazard Mitigation
3. Review and Discuss Status of Action Items from 2014 Multi-Hazard Mitigation Plan (see attached)
4. Project Schedule Update and MVP Planning Grant
5. Schedule Next Meeting

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
1st Floor Allen Meeting Room
12 Olive Street
Greenfield, MA 01301
Tuesday, July 16, 2019
10:00 a.m. – 11:30 a.m.

1. Introductions
2. Follow-up Discussion from June 4th Meeting on River Corridor Maps and Flood Hazard Mitigation. Review maps to update Critical Facilities/Vulnerable Areas
3. Review and Discuss Status of Action Items from 2014 Multi-Hazard Mitigation Plan (see attached)
4. Project Schedule Update and MVP Planning Grant
5. Schedule Next Meeting

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
1st Floor Allen Meeting Room
12 Olive Street
Greenfield, MA 01301
Tuesday, August 27, 2019
10:00 a.m. – 11:30 a.m.

1. Introductions
2. Continue the Review and Discussion of the Status of Action Items from 2014 Multi-Hazard Mitigation Plan (attached)
3. Review and Update Existing Mitigation Measures Tables from 2014 Multi-Hazard Mitigation Plan (attached)
4. Discuss and Plan MVP Workshop to be held on October 15, 2019
5. Schedule Next Meeting

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
2nd Floor FRCOG Library
12 Olive Street
Greenfield, MA 01301
Thursday, September 19, 2019
10:00 a.m. – 11:30 a.m.

1. Introductions
2. Discuss and Plan MVP Workshop to be held on October 15, 2019
3. Review and Update Existing Mitigation Measures Tables from 2014 Multi-Hazard Mitigation Plan (copies will be distributed at the meeting)
4. Schedule Next Meeting

MEETING AGENDA

CITY OF GREENFIELD

MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
1st Floor Allen Meeting Room
12 Olive Street
Greenfield, MA 01301
Tuesday, October 15, 2019
9:30 a.m. – 11:30 a.m.

1. Introductions
2. Review and Integrate Committee Feedback into Prioritized Action Plan (Table 4-3), and Completed or Obsolete 2014 Hazard Mitigation Actions (Table 4-4), from 2019 Multi-Hazard Mitigation Plan (copies will be distributed at the meeting)
3. Review Updated Existing Mitigation capabilities (Table 4-1), from 2019 Multi-Hazard Mitigation Plan (copies will be distributed at the meeting)
4. Review Flooding Hazard Section and Problem Statements
5. Schedule Next Meeting

MEETING AGENDA

City of Greenfield

Multi-Hazard Mitigation Plan Update Project

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
1st Floor Allen Meeting Room
12 Olive Street
Greenfield, MA 01301
Thursday, October 31, 2019
9:30 a.m. – 11:30 a.m.

1. Introductions
2. Review and Integrate Committee Feedback into Prioritized Action Plan (Table 4-3), and Completed or Obsolete 2014 Hazard Mitigation Actions (Table 4-4), from 2019 Multi-Hazard Mitigation Plan (copies will be distributed at the meeting)
3. Review Updated Existing Mitigation capabilities (Table 4-1), from 2019 Multi-Hazard Mitigation Plan (copies will be distributed at the meeting)
4. Review Flooding Hazard Section and Problem Statements
5. Schedule Next Meeting

MEETING AGENDA

City of Greenfield

Multi-Hazard Mitigation Plan Update Project

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION

J.W. Olver Transit Center
Library in FRCOG Offices, Suite 2
12 Olive Street
Greenfield, MA 01301
Thursday, November 14, 2019
9:30 a.m. – 11:30 a.m.

1. Introductions
2. Finalize 2020 Prioritized Action Plan (Table 4-3) and Completed or Obsolete 2014 Hazard Mitigation Actions (Table 4-4). Updated copies will be distributed at the meeting.
3. Review Finalized 2020 Existing Mitigation capabilities (Table 4-1). Copies will be distributed at the meeting.
4. Complete initial review of Flooding Hazard Section and Problem Statements.
5. Review additional Hazard Sections as time permits.
6. Schedule Next Meeting

MEETING AGENDA

City of Greenfield

Multi-Hazard Mitigation Plan Update Project

Project Facilitator: Franklin Regional Council of Governments

MEETING LOCATION
J.W. Olver Transit Center

FRCOG Offices
2nd Floor Meeting Room
12 Olive Street
Greenfield, MA 01301

Thursday, December 19, 2019
9:30 a.m. – 11:30 a.m.

1. Introductions.
2. Review Final Drafts of the 2020 Prioritized Action Plan (Table 4-3) and Completed or Obsolete 2014 Hazard Mitigation Actions (Table 4-4).
3. Review and update Hazard Problem Statements.
4. Discuss questions/information needed for other plan sections as time permits.
5. Schedule next meeting.

Greenfield Multi-Hazard Mitigation Plan Update Meeting

Thursday, December 19, 2019, 9:30-11:30 p.m.

FRCOG Offices, Suite 2, John Olver Transit Center, Greenfield, MA

Name	Affiliation	Contact
Kimberly MacPhee	FRCOG	kmacphee@frcog.org
Ian Hodgdon	CITY OF GREENFIELD	ian.hodgdon@greenfield-ma.gov
Eric Twarog	City of Greenfield	eric.twarog@greenfield-ma.gov
Robert Strahan	City of Greenfield	robert.strahan@greenfield-ma.gov
Ginny DeSorgher	Planning Board	ginnydoll4@yahoo.com
CAROLE COLLINS	CITY OF GREENFIELD	carole.collins@green-field-ma.gov

Greenfield Multi-Hazard Mitigation Plan Update Meeting

Thursday, November 14, 2019, 9:30-11:30 p.m.

FRCOG Offices, Suite 2, John Olver Transit Center, Greenfield, MA

Name	Affiliation	Contact
Ian Hodgdon	City of Greenfield	ian.hodgdon@greenfield-ma.gov
Mark Holley	City of GFLD	Mark.Holley@Greenfield-ma.gov
Eric Twarog	City of Greenfield	eric.twarog@greenfield-ma.gov
Ginny Desorgher	Planning Board	ginnydoll4@yahoo.com
Kimberly MacPhee	FRCOG	kmacphee@frcog.org

Greenfield Multi-Hazard Mitigation Plan Update
Project Meeting
October 31, 2019
Sign-in Sheet
Please Print Clearly

Name	Affiliation	Mailing Address/ Email	Phone Number
Eric Twarog	Greenfield	eric.twarog@greenfield-ma.gov	(413) 772-1549
Ian Hodgdon	Greenfield	ian.hodgdon@greenfield-ma.gov	413-772-1528 x6102
Rachel Lindsay	Greenfield Con Com	rwlindsay@gmail.com	(516) 270-6703
Helena Farrell	FRCOG	hfarrell@frcog.org	
Ginny Desorgher	Planning	ginnydoll4@yahoo.com	5083143772

Greenfield Multi-Hazard Mitigation Meeting

Tuesday, October 15, 2019, 9:30-11:30 a.m.

FRCOG, 12 Olive Street, Greenfield, MA 01301

Name	Affiliation	Contact
Kimberly MacPhee	FRCOG	kmacphee@frcog.org
Eric Twarog	Greenfield	eric.twarog@greenfield-ma.gov
Ian Hodgdon	Greenfield	ian.hodgdon@greenfield-ma.gov
Rachel Lindsay	Greenfield Con. Com.	rwlindsay@gmail.com
Robert Strahan	Greenfield EMD	robert.strahan@greenfield-ma.gov
Ginny DeSorgher	Planning Board	ginnydoll9@yahoo.com
Carole Collins	Greenfield	carole.collins@greenfield-ma.gov
Mark Holley	GFID WPCF	mark.holley@greenfield-ma.gov

Greenfield Multi-Hazard Mitigation Plan Update
Project Meeting
September 19, 2019
Sign-in Sheet
Please Print Clearly

Name	Affiliation	Mailing Address/ Email	Phone Number
Eric Twarog	Greenfield	eric.twarog@greenfield-ma.gov	(413) 772-1549
Ian Hodgdon	City of Greenfield	ian.hodgdon@greenfield-ma.gov	(413) 772-1528
Helena Farrell	FRCOG	hfarrell@frcog.org	
Kimberly MacPhee		kmacphee@frcog.org	
Rachel W Lindsay		rachel@rdgland.com	(516) 270-6703
Nathaniel Hussey	Gfld Ag Com	nhussey@antioch.edu	413-325-7060
Mark Holley	GFLD DPW	MARK.Holley@GreenfieldMA.GOV	413-834-5080

Greenfield Multi-Hazard Mitigation Plan Update Meeting

Tuesday, August 27, 2019 10:00 a.m.

The FRCOG, 12 Olive Street, Greenfield, MA 01301

Name	Affiliation	Contact
Ian A. Hodgdon	City of Greenfield DPW	413-772-1528 x6102 ian.hodgdon@greenfield-ma.gov
Rachel Lindsay	Vice Chair Conservation Commission	516-370-6763 ~~rlindsay~~ rachel@rdgland.com
Mark Holley	City of Greenfield DPW	413-834-5080 mark.holley@greenfield-ma.gov
Eric Twarog	City of Greenfield, Planning	eric.twarog@greenfield-ma.gov
Nathaniel Hussey	Greenfield Agricultural Commission	nhussey@antioch.edu
Ginny DeSorgher	Planning Board Disability Access	ginnydsl14@yahoo.com
Kimberly MacPhee	FRCOG	kmacphee@frcog.org

Greenfield Multi-Hazard Mitigation Plan Update

Project Meeting

July 16, 2019

Sign-in Sheet

Please Print Clearly

Name	Affiliation	Mailing Address/ Email	Phone Number
Ian Hodgdon	DPW	189 Wells St. ian.hodgdon@greenfield-ma.gov	413-772-1528
Eric Twarog	Planning & Development	eric.twarog@greenfield-ma.gov	413-772-1549
Robert Strahan	GFD/FMO	robert.strahan@greenfield-ma.gov	774-4737
Kimberly MacPhee	FRCOG	kmacphee@frcog.org	774-3167 x130
Nathaniel Hussey	Citizen/Ag Commission	nattyhussey@gmail.com	413-325-7060
Virginia (Ginny) DeSorgher	Planning	ginnydoll4@yahoo.com	5083143176

Greenfield Multi-Hazard Mitigation Plan Update
Project Meeting
June 4, 2019
Sign-in Sheet
Please Print Clearly

Name	Affiliation	Mailing Address/ Email	Phone Number
Eric Twarog	Greenfield	eric.twarog@greenfield-ma.gov	(413) 772-1549
Ian Hodgdon	Greenfield	ian.hodgdon@greenfield-ma.gov	(413) 772-1528
Nicolas Miller	Field Geology Services	nicolas.miller1@gmail.com	207-491-4002
Robert Strahan	Greenfield Fire	robert.strahan@greenfield-ma.gov	413-774-4737
Ginny DeSorgher	Planning Board	ginnydoll4@yahoo.com	508-314-3776
CAROLE COLLINS	GREENFIELD	carole.collins@greenfield-ma.gov	772-1412
Kimberly MacPhee	FRCOG	kmacphee@frcog.org	

Greenfield Multi-Hazard Mitigation Plan Update
Project Meeting
April 16, 2019
Sign-in Sheet
Please Print Clearly

Name	Affiliation	Mailing Address/ Email	Phone Number
Nathaniel Hussey	Resident Committee Member	114 Birch St 412 Main St nhussey@antioch.edu	413 325 7060
Robert Strahan	GFD/EMD	~~1600 Bernardston~~ robert.strahan@greenfield-ma.gov	413-834-5080
Mark Holley	GFD/DPW/Water Sewer	14 Court Sq. Mark.Holley@Greenfield-MA.GOV	
Eric Twarog	Greenfield/Planning Dept	14 Court Sq. eric.twarog@greenfield-ma.gov	413-772-1528
Ian Hodgdon	GFLD/DPW/Engineering	189 Wells St. ian.hodgdon@greenfield-ma.gov	
Carole Collins	Greenfield Energy Dept.	14 Court Square 01301 carole.collins@greenfield-ma.gov	
Ginny DeSorgher	Greenfield Planning/Disability	43 Silvercrest LA Greenfield, MA ginny do114@yahoo.com	508 314 3776
Kimberly MacPhee	FRCOG	kmacphee@frcog.org	413-774-3167 x130
Helena Farrell	FRCOG	hfarrell@frcog.org	413.774.3167x134

City of Greenfield
Multi-Hazard Mitigation Plan
DRAFT AVAILABLE for REVIEW
January 6, 2020

The Greenfield Multi-Hazard Mitigation Plan Update Committee, in partnership with the Franklin Regional Council of Governments (FRCOG) Planning Department, has prepared a draft 2020 Multi-Hazard Mitigation Plan that is ready for public review. Once the 2020 Plan is approved by FEMA and adopted by the City, Greenfield will be eligible for state and Federal grant monies to fund pre- and post-disaster mitigation projects. The purpose of this Multi-Hazard Mitigation Plan update is to identify natural and other hazards that may impact the community; conduct a risk assessment to identify infrastructure at the highest risk for being damaged by hazards; inventory and assess current City hazard mitigation policies, programs, and regulations; and identify action steps to prevent damage to property and loss of life.

A Public Forum will be held on Thursday, January 16th from 6-8 p.m. at the John Zon Community Center, 35 Pleasant Street, Greenfield to present the draft plan and solicit feedback from stakeholders.

The draft plan is available at https://greenfield-ma.gov/files/Greenfield_Hazard_Mitigation_Plan_Public_Review_DRAFT_1-6-20_c2.pdf and a paper copy is available at the Planning Offices, 20 Sanderson Street, Room 203 and the Greenfield Public Library.

Public Comment Period to run until January 24, 2020

Comments can be submitted to:
Eric Twarog, AICP
Director of Planning & Development
City of Greenfield
eric.twarog@greenfield-ma.gov
413-772-1549

GREENFIELD RECORDER

(https://www.recorder.com)

News > Local (/News/Local/)

Greenfield seeks input on Multi-Hazard Mitigation Plan

Flooding on Nash's Mill Road in Greenfield, as the Green River overflowed its banks in October 2017. Staff File Photo/Paul Fra

» Buy this Image

(/byline?byline=) Published: 1/13/2020 5:48:10 PM

Staff Report Modified: 1/13/2020 5:47:24 PM

GREENFIELD — The Multi-Hazard Mitigation Plan Update Committee, in partnership with the Franklin Regional Council of Governments (FRCOG) Planning Department, has prepared a draft of the 2020 Multi-Hazard Mitigatior Plan that is ready for public review.

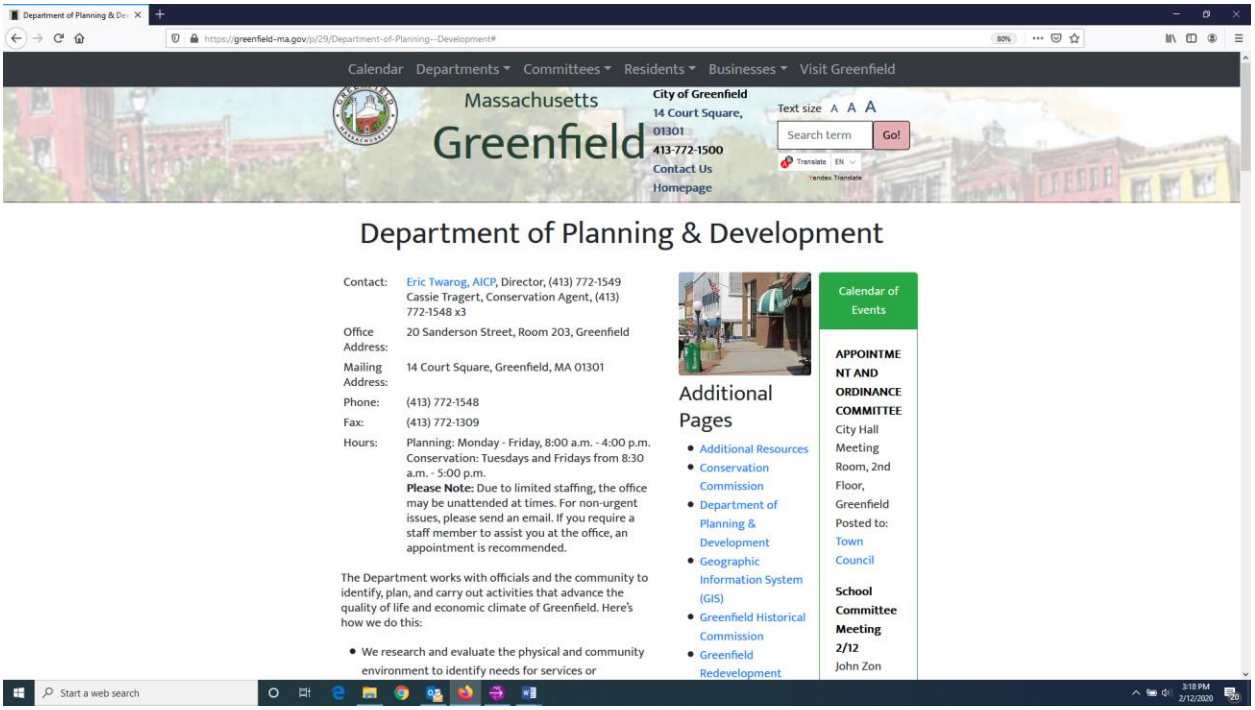
A public forum will be held Thursday from 6 to 8 p.m. at the John Zon Community Center, 35 Pleasant St., to present the draft plan and solicit feedbac from stakeholders, according to a press release from Mayor Roxann Wedegartne office.

Once the 2020 plan is approved by the Federal Emergency Management Agency (FEMA) and adopted by the city, Greenfield will be eligible for state and federal grant funding for pre- and post-disaster mitigation projects.

According to the release, the purpose of the Multi-Hazard Mitigation Plan upda is to identify natural and other hazards that may impact the community; condu a risk assessment to identify infrastructure at the highest risk for being damage by hazards; inventory and assess current city hazard mitigation policies, prograi and regulations; and identify action steps to prevent damage to property and los of life.

The draft plan is available online at bit.ly/2FLPyaL (https://bit.ly/2FLPyaL).

PROJECT POSTINGS TO CITY OF GREENFIELD WEBSITE



Calendar Departments Committees Residents Businesses Visit Greenfield

Massachusetts Greenfield

City of Greenfield
14 Court Square,
01301
413-772-1500
Contact Us
Homepage

Text size A A A

Search term Go!

Department of Planning & Development

Contact: Eric Twarog, AICP, Director, (413) 772-1549
Cassie Tragert, Conservation Agent, (413) 772-1548 x3

Office Address: 20 Sanderson Street, Room 203, Greenfield

Mailing Address: 14 Court Square, Greenfield, MA 01301

Phone: (413) 772-1548

Fax: (413) 772-1309

Hours: Planning: Monday - Friday, 8:00 a.m. - 4:00 p.m.
Conservation: Tuesdays and Fridays from 8:30 a.m. - 5:00 p.m.
Please Note: Due to limited staffing, the office may be unattended at times. For non-urgent issues, please send an email. If you require a staff member to assist you at the office, an appointment is recommended.

The Department works with officials and the community to identify, plan, and carry out activities that advance the quality of life and economic climate of Greenfield. Here's how we do this:

- We research and evaluate the physical and community environment to identify needs for services or

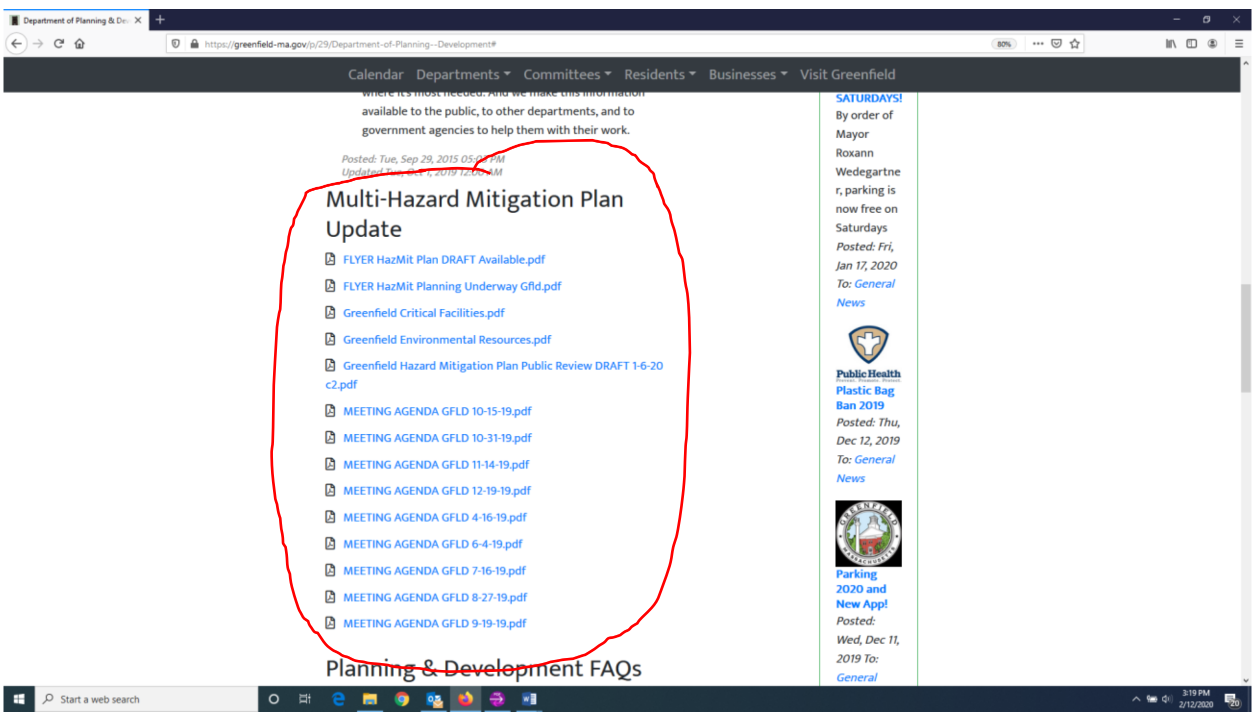
Additional Pages

- Additional Resources
- Conservation Commission
- Department of Planning & Development
- Geographic Information System (GIS)
- Greenfield Historical Commission
- Greenfield Redevelopment

Calendar of Events

APPOINTMENT AND ORDINANCE COMMITTEE
City Hall Meeting Room, 2nd Floor, Greenfield
Posted to: Town Council

School Committee Meeting 2/12
John Zon



Calendar Departments Committees Residents Businesses Visit Greenfield

available to the public, to other departments, and to government agencies to help them with their work.

Posted: Tue, Sep 29, 2015 05:00 PM
Updated Tue, Oct 1, 2019 12:00 AM

Multi-Hazard Mitigation Plan Update

- FLYER HazMit Plan DRAFT Available.pdf
- FLYER HazMit Planning Underway Gfld.pdf
- Greenfield Critical Facilities.pdf
- Greenfield Environmental Resources.pdf
- Greenfield Hazard Mitigation Plan Public Review DRAFT 1-6-20 c2.pdf
- MEETING AGENDA GFLD 10-15-19.pdf
- MEETING AGENDA GFLD 10-31-19.pdf
- MEETING AGENDA GFLD 11-14-19.pdf
- MEETING AGENDA GFLD 12-19-19.pdf
- MEETING AGENDA GFLD 4-16-19.pdf
- MEETING AGENDA GFLD 6-4-19.pdf
- MEETING AGENDA GFLD 7-16-19.pdf
- MEETING AGENDA GFLD 8-27-19.pdf
- MEETING AGENDA GFLD 9-19-19.pdf

Planning & Development FAQs

SATURDAYS!
By order of Mayor Roxann Wedegartner, parking is now free on Saturdays
Posted: Fri, Jan 17, 2020 To: General News

Public Health Plastic Bag Ban 2019
Posted: Thu, Dec 12, 2019 To: General News

Parking 2020 and New App!
Posted: Wed, Dec 11, 2019 To: General

HazMit Plan Update Stakeholders

Name	Representation	Email Address	Phone Number
Hope Macary	Council On Aging	hope.macary@greenfield-ma.gov	413-772-1517 x2
Greenfield Business Association	Greenfield Business Association		
Diana Szynal, Executive Director	Franklin County Chamber of Commerce	diana@franklincc.org	
Lisa Holt, Chief Operations Officer	The Arbors Assisted Living		
Buckley- Greenfield Healthcare Center	Nursing Home		
Charlene Manor Extended Care Facility	Nursing Home		
Poet's Seat Health Care	Nursing Home/Kathleen Stewart	administrator@pshcc.com	
GCC President	Greenfield Community College	President@gcc.mass.edu	
Jordana Harper	Greenfield Public Schools Superintendent	supergps@gpsk12.org	
Tina Cote	Franklin Regional Transit Authority (FRTA)	tina@frta.org	413-774-2262 x104
Daniel Finn	Greenfield Housing Authority	dan@greenfieldhousing.org	
The Community Builders	Leyden Woods Apartments		
	Franklin County Fairgrounds/Agricultural Society	nfo@fcas.com	
Susan K. Emond, Clerk of Courts	Franklin County Superior Court		
Christopher J. Donelan, Sheriff	Franklin County Sheriff's Office		
Joe Graveline	The Nolumbeka Project, Inc.	nolumbekaproject@gmail.com	
Tina Newton, Executive Assistant		tnewton@ymcaingreenfield.org	413-773-3646 x411
	Greenfield Country Estates - Mobile Home Park		
Karen Renaud	Greenfield City Council President	Councilor.renaud@greenfield-ma.gov	
William Martin, Mayor	Mayor's Office	mayor.ofgreenfield@greenfield-ma.gov	
Charles Roberts, Chair	Planning Board	cwr4@comcast.net	
Mark Maloney, Chair	Zoning Board of Appeals	cmmark911@hotmail.com	
John Griffin, Chair	Conservation Commission	griffin.jrg@gmail.com	
John Passiglia, Chair	Historical Commission	ironjohnny@msn.com	
Nathaniel Hussey, Chair	Agricultural Commission	nattyhussey@gmail.com	
Kelly Dixon, MSN, RN, Chair	Board of Health	valerie.bird@greenfield-ma.gov	
Lori Krikorian, Licensing Coordinator	Board of License Commissioners	lori.krikorian@greenfield-ma.gov	
Lynne Kelley, Chair/virginia Desorgher	Commission on Disability Access	ginnydoll4@yahoo.com	
Loreen A. Flockerzie, Chair/Lindsay Rowe, Staff Contact	Human Rights Commission	lindsay.rowe@greenfield-ma.gov	
Linda McInerney	Local Cultural Council	lmciner@gmail.com	
Sebastian Gutwein, Chair/Lindsay Rowe, Staff Contact	Parking and Traffic Commission	lindsay.rowe@greenfield-ma.gov	
Jean Wall, Chair/Lindsay Rowe, Staff Contact	Planning and Construction Committee	lindsay.rowe@greenfield-ma.gov	
Doris Cowdrey, Chair	Public Library Board of Trustees	dcowdrey1@verizon.net	
Butch Hawkins, Chair	Public Safety Commission	butch.hawkins@greenfield-ma.gov	
Christy Moore, Recreation Director	Recreation Commission	christy.moore@greenfield-ma.gov	
Adam Provost, Chair/MJ Adams, Staff Contact	Redevelopment Authority	mj.adams@greenfield-ma.gov	413-772-1548 x3102
Nancy Hazard, Chair	Sustainable Greenfield Implementation Committee	nhazard@worldsustain.net	
Lindsay Rowe, Staff Contact	Youth Commission	lindsay.rowe@greenfield-ma.gov	

Greenfield Multi-Hazard Mitigation Plan Update Project

HazMit Planning Local Project Team (2019)			
Name	**Representation**	**Email Address**	**Phone Number**
Eric Twarog	Planning & Development	eric.twarog@greenfield-ma.gov	413-772-1549
Robert Strahan	Fire Department	robert.strahan@greenfield-ma.gov	413-774-4323
Ian Hodgdon	Public Works	ian.hodgdon@greenfield-ma.gov	413-772-1528 x6102
Carole Collins	Energy & Sustainability	carole.collins@greenfield-ma.gov	413-772-1412
Mark Holley	Water Facilities Superintendent	mark.holley@greenfield-ma.gov	413-772-1540
Virginia Desorgher	Planning Board Member/Volunteer	ginnydoll4@yahoo.com	508-314-3776
Nathaniel Hussey	Antioch University Student/Volunteer	nhussey@antioch.edu	
Rachel Lindsay	Conservation Commission Member/Volunteer	rachel@regenerativedesigngroup.com	(516) 270-6703
Nancy Hazard	Greening Greenfield/Volunteer	nhazard@worldsustain.net	413-774-5667

Abutting Towns

Town	Email Address	Phone Number
Town of Bernardston		413-648-5401
Town of Colrain		413-624-3454
Town of Deerfield		413-665-1400
Town of Gill		413-863-9347
Town of Leyden		413-774-4111
Town of Montague		413-863-3200
Town of Shelburne		413-625-0300

Address
38 Church Street, Bernardston, MA 01337
55 Main Road, Colrain, MA 01340
8 Conway Street, South Deerfield, MA 01373
325 Main Road, Gill, MA 01354
16 W. Leyden Road, Leyden, MA 01337
1 Avenue A, Turners Falls, MA 01376
51 Bridge Street, Shelburne, MA 01370

City of
GREENFIELD, MASSACHUSETTS

PLANNING & DEVELOPMENT DEPARTMENT

Roxann Wedegartner
Mayor

City Hall ● 14 Court Square ● Greenfield, MA 01301
Phone 413-772-1549 ● Fax 413-772-1309
eric.twarog@greenfield-ma.org ● www.greenfield-ma.gov

January 6, 2020

Dear Stakeholder:

Increasingly, we find ourselves responding to more unpredictable and severe weather events that damage the City of Greenfield's infrastructure, natural resources, and local economy, and threaten the health and welfare of residents. The costs and impacts to the City remind us that we need to continue working to reduce our risk and increase our resilience to these extreme storm events. The Greenfield Multi-Hazard Mitigation Plan Update Committee, in partnership with the Franklin Regional Council of Governments (FRCOG) Planning Department, has prepared a draft 2020 Multi-Hazard Mitigation Plan that is ready for public review. Once the 2020 Plan is approved by FEMA and adopted by the City, Greenfield will be eligible for state and Federal grant monies to fund pre- and post-disaster mitigation projects. The purpose of this Multi-Hazard Mitigation Plan update is to identify natural and other hazards that may impact the community; conduct a risk assessment to identify infrastructure at the highest risk for being damaged by hazards; inventory and assess current City hazard mitigation policies, programs, and regulations; and identify action steps to prevent damage to property and loss of life.

A Public Forum will be held on Thursday, January 16th from 6-8 p.m. at the John Zon Community Center, 35 Pleasant Street, Greenfield to present the draft plan and solicit feedback from stakeholders.

The draft plan is available at https://greenfield-ma.gov/files/Greenfield_Hazard_Mitigation_Plan_Public_Review_DRAFT_1-6-20_c2.pdf and a paper copy is available at the Planning Offices, 20 Sanderson Street, Room 203 and the Greenfield Public Library. A Public Comment Period will be open until January 24, 2020. Comments can be submitted to: Eric Twarog, AICP, Director of Planning & Development, 14 Court Square, Greenfield, MA 01301 or eric.twarog@greenfield-ma.gov or 413-772-1549.

Thank you for your assistance with this important project.

Sincerely,

Eric Twarog

Eric Twarog, AICP
Director of Planning & Development

City of Greenfield
Multi-Hazard Mitigation Plan Update
Public Forum

January 16, 2019, 6:00 pm
John Zon Community Center

SIGN IN PLEASE

Name	Affiliation	Email
Allison Gage	FRCOG	agage@frcog.org
Robert Strahan	GFld	robert.strahan@greenfield-ma.gov
Eric Twarog	GFLD	eric.twarog@greenfield-ma.gov
Kimberly MacPhee	FRCOG	kmacphee@frcog.org
Norm Hirschfeld	GF council	nhms41@comcast.net
CAROLE COLLINS	GREENFIELD	carole.collins@greenfield-ma.gov
Rachel Lindsay	Con Com	~~[illegible]~~rachel@rdgland.com
NANCY HAZARD	Green Greenfield + SGIC	Nancy.Hazard@WorldSustain.Net

PUBLIC FORUM AGENDA

CITY OF GREENFIELD
MULTI-HAZARD MITIGATION PLAN UPDATE PROJECT

John Zon Community Center
35 Pleasant Street
Greenfield, MA 01301
Thursday, January 16, 2020
6:00 p.m. – 8:00 p.m.

1. Overview of Hazard Mitigation Planning Process
2. Review of Climate Change Impacts and Hazard Risk Assessment Results
3. Review of Draft Actions and Action Item Prioritization
4. Next Steps

GREENFIELD HAZARD MITIGATION PLAN UPDATE PUBLIC FORUM

John Zon Community Center
35 Pleasant Street, Greenfield MA
Thursday, January 16, 2019

Multi-Hazard Mitigation Plan

- The purpose of hazard mitigation is to reduce potential losses from future disasters.
- Mitigation plans identify the natural hazards that impact communities, identify actions to reduce losses from those hazards, and establish a coordinated process to implement the plan.

Greenfield Multi-Hazard Mitigation Plan 2014

- Inventoried *historic* hazard events – frequency, magnitude and damages
- Vulnerability assessment for flooding was prepared based on damages from *past* events and location in 100 year floodplain
- Prioritized all hazards and included action items for each hazard

2014 Multi-Hazard Mitigation Plan
Hazard ID & Vulnerability Assessment

Potential Hazards Identified for Greenfield
Dam Failure
Severe Winter Storm/Ice Storm
Earthquake
Hurricane
Wind Storms, Microbursts, etc.
Tornado
Ice Jam
Flood
Wild Fire/Brush Fire
Landslide
Manmade Hazards
Drought
Extreme Temperatures
Invasive Species

A changing climate is exposing us to greater risk.

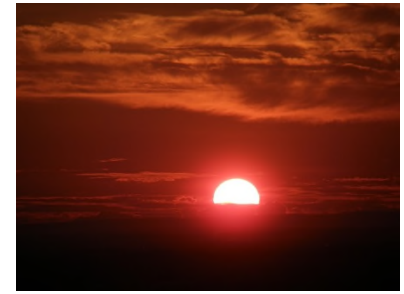
Massachusetts’ Changing Climate

- **Changing weather**
  - Higher temperatures
  - Shorter winters
  - More frequent & intense storms
  - Droughts
- **Amplifies existing risks**
  - Community and regional infrastructure
  - Local and regional economies
  - Public health
  - Natural resources and our environment

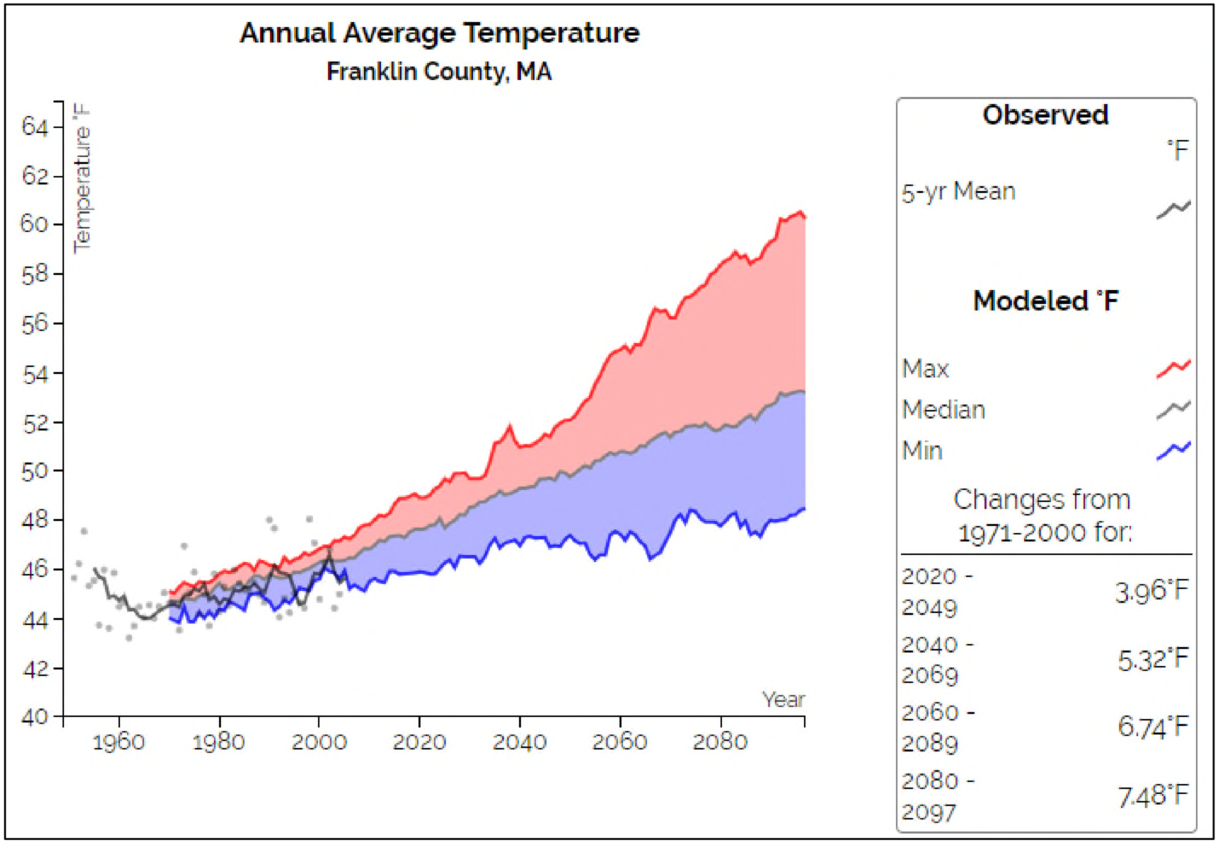
Goal for Building Resilience to a Changing Climate:

Protect life, property, natural resources and the economy

Higher Temperatures



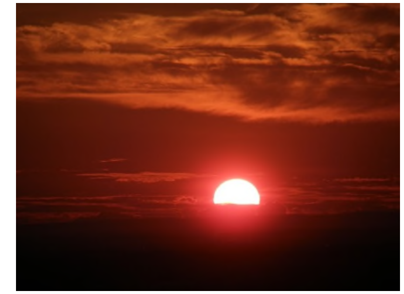
Projected Annual Average Temperature



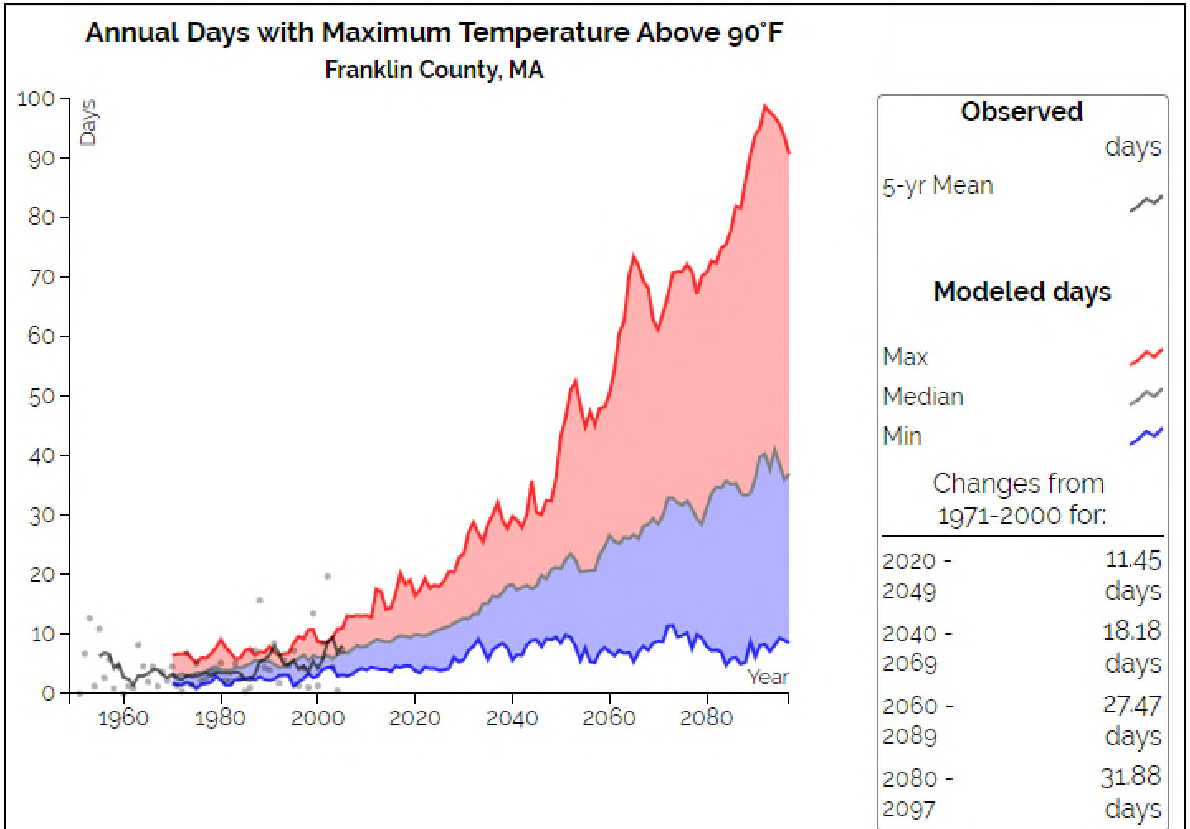
The average annual temperature is projected to increase from 45.3°F to 50.6°F (5.32°F change) by mid-century, and to 52.8°F (7.48°F change) by the end of this century

Source: Resilient MA, 2018

Extreme Temperatures



Projected Annual Days with a Maximum Temperature Above 90°F

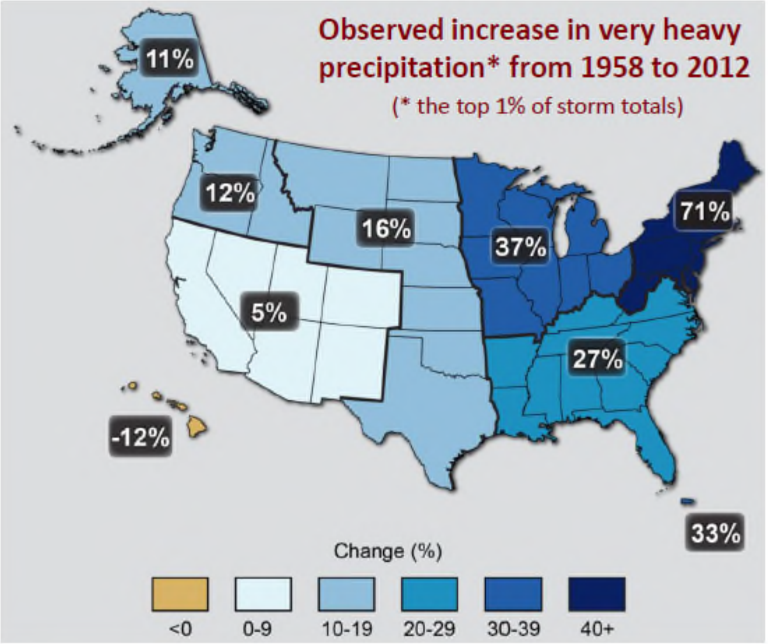


- Projected to increase by 18 days by the 2050s, and by 32 days by the end of the century for a total of 36 days over 90°F
- 1971 to 2000 average of 4 days per year

Source: Resilient MA, 2018

Changes in Precipitation

Observed Increase in Heavy Precipitation



- Total annual precipitation is projected to increase by 3 inches by mid-century, and by 4 inches by the end of this century
- Less snow / more rain in winter
- Heavier precipitation events overall

Source: Resilient MA, 2018

Extreme Weather Events

- Tropical storms
- Tornadoes
- Thunderstorms
- Snow storms
- Drought

The frequency, intensity, duration and geographic extent of these extreme storms is likely to increase.

2020 Hazard Identification & Risk Analysis

- **Identify Past, Current and Future Hazards**
- **Determine Top Priority Hazards**
  - Which hazards pose the greatest threat to the town currently and in the future?

Flooding on Nash's Mill Road

2020 Hazard Identification & Risk Analysis

Hazard Vulnerability Rating Key

1 – High Risk
2 – Medium Risk
3 – Low Risk

Table 3-4: Greenfield Hazard Identification and Risk Analysis

Type of Hazard	**Location of Occurrence**	**Impact**	**Overall Hazard Vulnerability Rating**
Severe Winter Storms	Large	Limited	1
Flooding	Large	Catastrophic	1
Tornadoes	Medium	Catastrophic	2
Dam Failure *Leyden Glen and FERC High Hazard Dams*	Medium	Catastrophic	3
Dam Failure *All other dams*	Medium	Critical	3
Hurricanes / Tropical Storms	Large	Catastrophic	1
Severe Thunderstorms / Wind / Microbursts	Large	Critical	1
Extreme Temperatures	Large	Limited-Critical	2
Earthquakes	Large	Minor-Catastrophic	3
Landslides	Isolated	Limited	2
Drought	Large	Limited	2
Wildfires	Medium	Limited	2
Invasive Species	Large	Critical	1

Vulnerability Assessment

- For each hazard, the following information is included:
  - Potential Impacts of Climate Change on the Hazard
  - A Description of the Hazard, including:
    - Location
    - Extent
    - Previous Occurrences
    - Probability of Future Events, and
    - Impacts
  - Discussion of the vulnerability of the town:
    - Society (including Vulnerable Populations)
    - Health Impacts
    - Economic Impacts
    - Infrastructure Impacts
    - Environmental Impacts

Table 3-18: Estimated Vulnerable Populations in Greenfield

Vulnerable Population Category	Number	Percent of Total Population*
Population Age 65 Years and Over	3,498	20%
Population with a Disability	2,761	16%
Population who Speak English Less than "Very Well"	1,186	6.8%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	2,882	37%
Householder Age 65 Years and Over Living Alone	1,439	18%
Households Without Access to a Vehicle	847	11%

*Total population = 17,474; Total households = 7,884

Note: Individuals and households may be counted under multiple categories.

Mitigation Strategies

- **Hazard Problem Statements**
- Evaluation of Current Mitigation Strategies
- Status of 2014 Action Plan Items
- 2020 Action Plan

Flood Hazard Problem Statements
• The City needs additional staff and funding to continue its program to separate domestic sump pump outfall from the municipal sewer system to reduce pressure on municipal wastewater treatment facilities and to comply with DEP/EPA.
• Funding is needed to prepare final design and cost estimates for climate resiliency projects identified in the *Green River Corridor Mapping and Management Report* (2019) and to expand River Corridor mapping to tributaries of the Green River. Restoration projects that address fluvial erosion on Greenfield's waterways persisting from previous flood events, restore floodplain access, and conserve land identified as attenuation assets should be developed and implemented.
• Beaver activity is occurring in proximity to residential settlement, commercial buildings and facilities, and municipal infrastructure. Continued monitoring and risk assessment is needed to mitigate damage from a potential beaver dam failure.
• Although the City has "Greenfield Alerts", a Reverse 911 Warning System, there is a need to expand the system and increase subscription among residents and businesses. Education and outreach are needed to ensure that all residents are aware of emergency situations and have access to evacuation and sheltering instructions, including options for residents with specialized medical needs, and pet sheltering options.
• Additional funding and infrastructure is needed to expand existing programming to promote and increase household disaster preparedness City wide, specifically the voluntary removal and safe disposal of hazardous materials.
• Culvert maintenance is continuously needed throughout the City, especially in the Maple Brook Culvert drainage system, to mitigate erosion, debris, and flooding hazards in and around developed areas. Culvert replacements have been prioritized at multiple locations. Green Infrastructure assessments in local flooding hot spots as well as options for daylighting urban streams in key areas are needed to equip the DPW and Planning Departments with alterative strategies to make streets and neighborhoods more flood resilient.

Mitigation Strategies

- Hazard Problem Statements
- Evaluation of Current Mitigation Strategies
- Status of 2014 Action Plan Items
- **2020 Action Plan**

Table 4-3: 2020 Greenfield Hazard Mitigation Prioritized Action Plan

Action Type	Action Description	Hazards Addressed	Responsible Department / Board	Estimated Cost	Potential Funding Source	Estima Timefra
Critical Facilities & Infrastructure	Hire a structural engineering consultant to assess the integrity of the concrete retaining walls on the streambanks of the Green River along Deerfield Street and Meridian Streets and to develop conceptual designs and cost estimates to repair and/or replace the retaining walls.	Flooding, Hurricanes, Tropical Storms, Severe Thunderstorms, Microbursts, Dam Failure, Landslides	DPW	Medium - High	MVP, City	Year

Next Steps

- Review the 2020 Action Items and identify any actions that are missing
- Provide comments on the plan by January 24, 2020. The plan is available on the Greenfield website: https://greenfield-ma.gov/files/Greenfield_Hazard_Mitigation_Plan_Public_Review_DRAFT_1-6-20_c2.pdf
- Comments may be submitted to Eric Twarog, Director of Planning & Development, City of Greenfield
- Participate in the upcoming MVP Workshop

THANK YOU!

APPENDIX B – FEMA Plan Review Tool

LOCAL MITIGATION PLAN REVIEW TOOL
City of Greenfield, 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: City of Greenfield, MA	**Title of Plan:** City of Greenfield Hazard Mitigation Plan	**Date of Plan:** February 12, 2020

Single or Multi-jurisdictional Plan? Single jurisdiction	**New Plan or Plan Update?** Plan Update
Regional Point of Contact: Kimberly Noake MacPhee, P.G., CFM **Title:** Land Use & Natural Resources Planning Program Manager **Agency/Address:** Franklin Regional Council of Governments 12 Olive Street, Suite 2 Greenfield, MA 01301 **Phone Number:** 413-774-3167 x130 Fax: 413-774-3169 **Email:** KMacPhee@frcog.org	**Local Point of Contact:** Eric Twarog, AICP **Title:** Director of Planning & Development **Agency/Address:** City of Greenfield Department of Planning & Development 14 Court Square Greenfield, MA 01301 **Phone Number:** (413) 772-1549 **Email:** eric.twarog@greenfield-ma.gov

State Reviewer:	**Title:**	**Date:**
Jeffrey Zukowski	Hazard Mitigation Planner	2/14/2020

FEMA Reviewer:	**Title:**	**Date:**
Sean Loughlin Brigitte Ndikum-Nyada Jay Neiderbach	FEMA Community Planner FEMA Community Planner FEMA Community Planner	2/20/2020 - 3/10/2020 3/10/2020 – 3/20/2020 4/28/2020 – 4/28/2020
Date Received in FEMA Region I	2/14/20	
Plan Not Approved		
Plan Approvable Pending Adoption	3/20/2020	
Plan Adopted	4/16/2020	
Plan Approved	4/28/2020	

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))	Section 1; pages 1-6	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))	Section 1; pages 4-6	X	
A3. Does the Plan document how the public was involved in the planning process during the drafting stage? (Requirement §201.6(b)(1))	Section 1; pages 5-6	X	
A4. Does the Plan describe the review and incorporation of existing plans, studies, reports, and technical information? (Requirement §201.6(b)(3))	Section 1; pages 5- 6	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))	Section 5; pages 245-247; 254	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))	Section 5; pages 245-247	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))	Section 3; pages 21-214	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))	Section 3; pages 21-214	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))	Section 3; pages 21-214	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))	Section 2; pages 10-11 Section 3; pages 57-58	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))	Section 4; pages 216-228	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))	Section 2; pages 10-11, 34-35 Section 3; pages 57-58	X	
C3. Does the Plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? (Requirement §201.6(c)(3)(i))	Section 4; page 229	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))	Section 4; pages 234-241	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))	Section 4; pages 229-241	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))	Section 5; pages 253-254	X	
ELEMENT C: REQUIRED REVISIONS			
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))	Section 2; pages 7-10, pg. 34-35, 49	X	

1. REGULATION CHECKLIST **Regulation** (44 CFR 201.6 Local Mitigation Plans)	**Location in Plan** (section and/or page number)	**Met**	**Not Met**
D2. Was the plan revised to reflect progress in local mitigation efforts? (Requirement §201.6(d)(3))	Section 4; pages, 49 216-228; pages 242-244	X	
D3. Was the plan revised to reflect changes in priorities? (Requirement §201.6(d)(3))	Section 4; pages 49, 234-241	X	
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 B	X	
E2. For multi-jurisdictional plans, has each jurisdiction requesting approval of the plan documented formal plan adoption? (Requirement §201.6(c)(5))			
ELEMENT E: REQUIRED REVISIONS			
ELEMENT F. ADDITIONAL STATE REQUIREMENTS (OPTIONAL FOR STATE REVIEWERS ONLY; NOT TO BE COMPLETED BY FEMA)			
F1.			
F2.			
ELEMENT F: 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.

Recommend Corrections:

• The adoption resolution/certificate (p. 257) uses a different title of the plan than the one identified on the front cover. This should be corrected to avoid confusion of which document is being adopted and to ensure accurate record keeping. Be consistent throughout the document, by using the same title throughout.

• Review the page numbering after Appendix A. There are unnumbered pages between pages 255 and 256.

• A good number of jurisdictions tend to celebrate the successful completion of their Hazard Mitigation Plans through inserting the final adoption certificate on page 2 or 3 of the copy of FEMA formal approved HMP. This also increased visibility and local ownership. We encourage you consider.

Element A: Planning Process

***Strengths*:**

• The plan integrates the MA Municipal Vulnerability Preparedness (MVP) program into the HMP planning process. The City is also working with the FRCOG on regional planning which is benefitting the collaboration and integration of these hazard mitigation planning elements.
• The planning process is well documented and includes a detailed schedule of the events and meetings that contributed to the development of the plan. A total of nine (9) meetings were held, as well as opportunities for neighboring communities to provide input, and opportunities for public input on the City web site.
• A range of existing studies, reports and plans were reviewed and incorporated, resulting in a plan that is comprehensive and current.
• The City does a good job of describing future annual (or as needed) plan maintenance meetings and developing a biennial progress report on the HMP.
• The City does a good job incorporating current, best available, i.e. MassGIS new land cover/land use dataset and stating its limitation.
• Great job describing the city's Natural, Cultural and Historic Resources.
• Great pictures from Tropical Storm Irene-2011.
• As the community continues to fortify and put in place real mitigation actions/projects, the need and costs for preparedness, response, and recovery from the impacts of natural hazards will be greatly reduced.

***Opportunities for Improvement*:**

• While the plan was posted online for input, another option for consideration is posting online surveys to gather input from citizens and stakeholders.
• Expand the supporting documentation of the planning process by including meeting summaries. Recording the planning team's discussion and decision-making process will be useful during plan updates.
• It is recommended to include the academia community in Greenfield to expand the stakeholder base. There are the Greenfield Community College, the Greenfield Community College Foundation, and the Nahman-Watson Library at Greenfield Community College.

Element B: Hazard Identification and Risk Assessment

***Strengths*:**

• Hazard profiles provide detailed information about the context of the hazards and the risk they present to the community.

• The plan coordinates its information and processes with the most current State Hazard Mitigation Plan.

• The plan includes Hazard Problem Statements at the end of hazard section, which provides a good informational synopsis for each.

***Opportunities for Improvement*:**

• Whenever possible, provide a longer timeframe when discussing previous occurrences. This can give a more accurate picture of future risks.
• As noted within the plan, the FEMA flood plain map for Greenfield is from 1980. At the time of the next plan update, newer flood maps should be available and any new information from those flood maps should be incorporated into the HMP, as appropriate.
• Although not required, the previous 2014 plan update included a Critical Facilities & Infrastructure map that the current plan update does not have. An option may be to add it back in. Maps can clearly show the planning area and risks / vulnerabilities.
• We encourage the community to work with MEMA to apply for FEMA Local High Hazard Potential Dams Risks' grant.

Element C: Mitigation Strategy

***Strengths*:**

• The plan highlight a near success story of one of the community's $9.2 million upgrade - floodproofing wastewater treatment plan in 2000. Good job.
• The plan update is comprehensive in mitigation strategies and includes nature-based solutions. The plan also identifies completed or obsolete mitigation actions.

• The plan update also identifies projects related to Hurricane Irene originally noted within the 2014 plan – and now shows those projects as predominantly completed.
• The plan includes existing mitigation capabilities within the community and how they could be improved to further reduce risk. E.g.: changing state law(s) to improve the dam safety program.
• This FROG HM plan update included on page 11 a little bit more information to support how the community is proactively standing in compliance with the NFIP C2 requirement of continued NFIP action.
Opportunities for Improvement:

• For future HM Plan updates, ensure that the C2 requirement is fully addressed. Include a narrative highlighting NFIP activities the community has accomplished since the last approval. See page 42 (4-4) of the FEMA Local Mitigation Handbook for help in addressing this requirement. https://www.fema.gov/media-library-data/20130726-1910-25045-9160/fema_local_mitigation_handbook.pdf.

• The previous (2014) plan update did not have clearly written mitigation goals that were easy to find within the plan. While the most recent plan update has written goals, two of the three goals on page 229 are related to response. Ensure that the focus of the mitigation strategy is on mitigation, rather than preparedness. A plan can be most effective with a range of 3-5 mitigation goals.

Element D: Plan Update, Evaluation, and Implementation (*Plan Updates Only*)

Strengths:
• Priorities in the plan recognize current conditions. They are reflective of the planning process, risk assessment and mitigation strategy.
• Progress on mitigation actions is clear and comprehensive.
• The plan describes the community's general development trends and projected / potential development.

Opportunities for Improvement:
• The City of Greenfield, MA is encouraged to consider for the next HM Plan update in 5 years the inclusion of an Executive Summary as an introduction to the whole Plan.
• Provide more details about how development trends have changed since the last plan update. Provide more information of what was constructed, proposed, and / or approved for development since the last plan was approved – and whether it has or has not impacted the community's risk and vulnerability. Consider mapping development with an overlay of .1 or .2% flood probability.
• Consider adding more connectivity to what occurred over the last planning period since the previous plan was approved. What changed, what worked or didn't go accordingly and why?
• Including a discussion of lessons learned about implementing mitigation actions would strengthen the plan, as would a short narrative on some "success stories" about their implementation.

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.