PUBLIC REVIEW DRAFT

Town of Gill Hazard Mitigation Plan

Adopted by the Gill Select Board on xx, xx

Prepared by

Gill Hazard Mitigation Committee

and

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The Gill Select Board extends special thanks to the Gill Hazard Mitigation Planning Committee as follows:

Gene M. Beaubien, Gill Fire Chief & Emergency Management Director
Jason Bassett, Gill Police Department
Rick Couture, Northfield Mount Hermon School
Heath Cummings, Gill Montague School District
John Miner, Gill Highway Superintendent
Ray Purington, Gill Town Administrator
Chris Redmond, Gill Police Chief

The Gill Select Board 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 to staff for reviewing and commenting on the draft plan and to the Federal Emergency Management Agency (FEMA) for making the funds available and for the development of the Local Mitigation Planning Handbook, which provides a thorough overview of the Mitigation Planning process.

Franklin Regional Council of Governments

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1: PLANNING PROCESS

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 Town of Gill, 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.

HAZARD MITIGATION COMMITTEE

Updating the Town of Gill's Hazard Mitigation plan involved a committee comprised of the following members:

- Gene M. Beaubien, Gill Fire Chief & Emergency Management Director
- Jason Bassett, Gill Police Department
- Rick Couture, Northfield Mount Hermon School

- Heath Cummings, Gill Montague School District
- John Miner, Gill Highway Superintendent
- Ray Purington, Gill Town Administrator
- Chris Redmond, Gill Police Chief

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

- Reviewing and incorporating existing plans and other information including changes in development in the years since the Town'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 Hazard Mitigation Committee were held on the dates listed below. Agendas for these meetings are included in Appendix B. All meetings followed Massachusetts Open Meeting Law and were open to the public.

May 16, 2019
Planning kick-off meeting to review project goals and timeframe, and complete a hazard vulnerability assessment based on location, extent, probability, and severity of hazards in Gill. A stakeholder letter was sent to local and regional stakeholders inviting them to attend and participate in the meeting (see Appendix B for a copy of the letter).

June 27, 2019
Committee meeting to review the first draft of Section 2: Local Profile and Planning Context, and Section 3: Hazard Identification and Risk Assessment.

August 8, 2019
Committee meeting to review the second draft of Section 2: Local Profile and Planning Context and Section 3: Hazard Identification and Risk Assessment.

September 4, 2019
Meeting with the Gill Agricultural Commission to review hazard and climate change impacts to agriculture in Gill. A flyer was created for distribution to farmers at the Gill Fall Festival (see Appendix B for a copy of the flyer).

October 17, 2019
Committee meeting to review final revisions to Section 3, including agricultural impacts, and to review the first draft of Table 4-1: Existing Mitigation Strategies.

November 21, 2019
Committee meeting to review the second draft of Table 4-1: Existing Mitigation Strategies, and to review the first draft of Table 4-3: Gill Hazard Mitigation Prioritized Action Plan.

February 18, 2020
Public forum to review the final draft plan and prioritize the action items. The forum was followed by a two-week public review period. Comments and input from the forum and comment period were integrated into the final plan.

While not all members of the Hazard Mitigation Committee were able to attend each meeting, all members collaborated on the plan and were updated on progress by fellow Committee members after meetings occurred.

PARTICIPATION BY STAKEHOLDERS

A variety of stakeholders were provided with an opportunity to be involved in the update of the Gill 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

The Gill Town Administrator conducted outreach to local and regional agencies to invite them to meetings and the public forum, including:

- Franklin County Regional Housing and Redevelopment Authority
- FirstLight Power

- Kuzmeskus Bus
- Northfield Mount Hermon School
- Gill Montague Regional School District
- Eversource

FRCOG regularly engages with the Town of Gill as part of its regional planning efforts, which include the following:

- 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 Gill 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 Gill Planning Board is the primary Town agency responsible for regulating development in town. Feedback from the Planning Board was ensured through distribution of the draft plan to the Planning Board during the development phases of the plan and for the public comment period. In addition, the Franklin Regional Council of Governments, as a regional planning authority, works with all agencies that regulate development in Gill, 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 Gill 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 advertised on the Town website, in the Town newsletter, and were posted at the Town Hall and at other designated public notice buildings. A copy of the draft plan was available to the public at the Town Hall, at the Slate Memorial Library, and on the Town website at https://gillmass.org/. A public forum was held on February 18, 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 Town 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 Town website. The final public Comment Period was held from the date of the forum through March 2, 2020 (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:

- 2020 draft Gill Open Space and Recreation Plan
- 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan
- Resilient MA Climate Change Clearinghouse for the Commonwealth
- Additional data sources cited in footnotes throughout this Plan

2: LOCAL PROFILE AND PLANNING CONTEXT

COMMUNITY SETTING

The Town of Gill is a picturesque community with abundant natural features and a beautiful rural landscape with rolling hills, river valley vistas, and pastoral agricultural land. The Town is bordered by the Fall River to the west, the Towns of Bernardston and Northfield to the north, and the Connecticut River along the east and south. Parallel to the Connecticut River along the southern part of Town is Route 2, also known as the Mohawk Trail, a designated scenic byway.

Gill has a population of 1,500 people according to the 2010 U.S. Census. The predominant type of housing unit in Gill is single-family units, however, there are some multi-unit structures as well, including the Stoughton Place senior housing complex. According to the 2017 U.S. Census estimates, of the 626 housing units in Gill, 86% of them were single-family homes. As for the age of the housing stock in 2017, it was reported that 43% of the housing units were built after 1980. The overall demographics in Gill indicate higher household incomes and lower poverty rates in comparison to other towns in the region.

The major employer located in the town is the Northfield Mount Hermon School (NMH), a private co-ed secondary educational institution serving grades 9 through 12. The School generally enrolls over 600 students at its campus, the majority of whom are boarders (83% of students in 2018/2019). Twenty-three percent of students enrolled in 2018/2019 are international students. According to the school's website, NMH employs approximately 130 people in teaching and administrative faculty positions, and more than 210 in staff positions.[1] Other employers include the various farming operations throughout Town, the Kuzmeskus bus company on Main Road, and several relatively small retail stores along the western portion of Route 2.

According to 2005 land use data provided by MassGIS, the total land area of the Town of Gill is approximately 9,478 acres (14.8 square miles). Roughly 472 acres, or 5%, of the land area is residential (as of 2005). Most residential development in Gill has occurred along the scenic rural roads of Town, except, however, for the dense residential village area of Riverside, located between the Connecticut River and the western portion of Route 2. Approximately 60% or 5,730 acres of the land is classified as forest. Cropland, pastureland, orchards, and nurseries represent 18% of the total land area or 1,692 acres.

[1] Northfield Mount Hermon School website, accessed July 31, 2019: https://www.nmhschool.org/about

Population Characteristics

According to the 2010 U.S. Census, there are 1,500 residents in Gill (a 10% increase since 2000). As of 2017, Gill's total population is estimated to be 1,604 (a 7% increase since 2010).[2]

Environmental Justice Populations

The Commonwealth of Massachusetts identifies an environmental justice 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 Town of Gill does not currently have any environmental justice populations based on race, income, or language proficiency. Approximately 93% of the Town's population is White with the next largest racial group is Black at 4% of the total population. In terms of income, the annual median household income of Gill is estimated to be $69,226, which is well above 65% of the State's annual median household income. However, the Riverside neighborhood of Gill was qualified for a Community Development Block Grant, which demonstrates that at least 51% of the residents in the neighborhood are low-moderate income. According to the latest U.S. Census's American Community Survey, approximately 4% of the population speak English less than "very well."

Current Development Trends

Gill's land use patterns include: the Riverside neighborhood area located between Route 2 and the Connecticut River; Gill Center, the Town's primary village area and center of civic life; the campus of the Northfield Mount Hermon School in the northern section of Town; scattered single family homes along roads throughout Town; and working farm and forest lands that still blanket the mostly rural community.

The Connecticut River forms the eastern and southern border of Town. The Connecticut River floodplain continues to be utilized by farms for growing vegetables and dairy-related crops.

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

Commercial properties are located primarily along Route 2, and on Main Road close to where it intersects Route 2. This trend began in the early part of the 20th Century following the designation of Route 2 as the Mohawk Trail Scenic Auto Route. In 2006 the Town approved the creation of a new village district for this area, in order to encourage commercial development in the district over other locations in town, and to help preserve rural areas and the scenic character of the Mohawk Trail.

In the 1970s and 1980s, the population of Gill increased by 44 percent. In the late 1980s, Gill experienced a reduction in the number of dairy farms due to a federal buy-out program of dairy herds to control pricing. Over the last century, Gill saw a reduction in the number of dairy farms and an increase in the development of residential uses outside of the historic village centers.

Northfield Mount Hermon School is the largest landholder in town, owning approximately 640 acres, and the largest employer in the town. Originally with campuses in both Northfield and Gill, the school vacated most of its Northfield campus in 2005 to consolidate facilities onto the Gill campus. The facilities in Gill have been expanded to serve the increased population of students on the one campus. The school will likely continue to be a significant economic presence in the community.

In recent years, the primary development trend in Gill has been conversion of farm and forestland along existing roads for single-family home development. Since 2010, 22 permits were issued for new single-family homes in Gill.

National Flood Insurance Program Status

Gill is a participating member of the National Flood Insurance Program. Currently there are five flood insurance policies in effect in Gill, for a total insurance value of $1,450,000. No losses have been paid in Gill, and the town does not have any repetitive loss properties. Gill's floodplain map is from 1980.[3] In 2018, the Federal Emergency Management Agency (FEMA) initiated a 5-year process to update the floodplain maps for Franklin County towns.

Roads and Highways

Route 2 has been a primary transportation corridor through Gill since its days as a significant Native American trail and trading stop along the Connecticut River. Today, the average daily

[3] National Flood Insurance Program (NFIP) Statistics as of December 18, 2018.

traffic count on Route 2 is between 10,000 to over 14,000 vehicles.[4] As the most significant transportation feature in Gill, Route 2 is also the Commonwealth's primary northern tier east-west corridor that connects the northern Boston metropolitan area to the Berkshires and New York. Other major north-south transportation corridors in nearby communities include Interstate 91 in Greenfield, and Routes 10 and 63 in Northfield. Gill's connections to surrounding towns is reliant on bridges that cross the Connecticut River (Route 2, Route 10, and Main Road), and the Fall River (Route 2). Three of these bridges have undergone recent improvements or reconstruction – French King Bridge, Gill-Montague Bridge, and Factory Hollow Bridge.

Within Gill, there are some limitations of the transportation system due to the rural character of the road network. The road network in the Town of Gill is comprised of both paved and gravel surfaced roadways. As of 2017, the Town of Gill was responsible for maintenance of 38.4 miles of roadway, of which 10.4 miles (27%) were gravel. MassDOT is responsible for 4 miles of roadway in Gill, including Route 2, Route 10, and the Gill-Montague Bridge.[5]

The French King Bridge connecting Erving and Gill via Route 2 is a concern for the town. The Town estimates that the Police or Fire Department is called 3 times a week to monitor the bridge for suicide attempts, and on average, there are two suicides a year. The bridge is also occasionally the site of jumps from thrill seekers. This is a large strain on Town resources. The Gill Fire Department documented 16 search and rescue operations between June 2009 and June 2014 that were initiated in response to individuals jumping from the bridge.[6] Installing suicide barriers on the bridge is a priority for Erving and Gill. Design is underway by MassDOT, but construction funding has not yet been identified. The two towns and the Franklin Regional Council of Governments requested that the project be included in the State's 2020-2024 Capital Improvement Plan for construction.

Rail

There are no rail facilities located in Gill. However, freight rail lines do operate in the neighboring towns of Northfield, Erving, Montague, Greenfield and Bernardston. Amtrak passenger rail service is available in Greenfield, and travels through Bernardston.

[4] MassDOT Transportation Data Management System: https://mhd.ms2soft.com/tcds/tsearch.asp?loc=Mhd&mod=. Accessed June 17, 2019. Average daily traffic counts vary along Route 2 in Gill depending on the location of the count.
[5] Massachusetts Department of Transportation 2017 Road Inventory File.
[6] *Suicide Deterrent System Alternative Study: French King Bridge*. TranSystems, June 2016.

Aviation

There are no aviation facilities located in Gill. The closest airport, the Turners Falls Municipal Airport, is located in the neighboring town of Montague. The Committee notes that the flight path for the Turners Falls runway goes over the densely developed Riverside neighborhood in Gill.

Public Transportation

The Franklin Regional Transit Authority offers demand-response transportation services for the elderly and disabled residents within their jurisdiction, which includes the Town of Gill. As of 2019 there currently are no fixed bus routes serving Gill, but it is hoped that this service can be reestablished in the future. The closest bus stops are located in Turners Falls in Montague, and in Ervingside in Erving.

Public Drinking Water Supply and Sewer Service

There are six individual public water suppliers in the Town of Gill. They include the Gill Elementary School on Boyle Road, the Oak Ridge Golf Club on West Gill Road (now closed), the Gill Tavern on Main Road, Alans BBQ on Route 2 (now closed), FM Kuzmeskus on Main Road, and the Barton Cove Campground on Barton Cove Road. The Elementary School has a shallow well that has been vulnerable to contamination in the past. A water filtration system was installed in 2019 for the Elementary School water supply to address potential contamination.

There are two areas within Gill that have community water supply and sewer treatment systems. The Gill campus of the Northfield Mount Hermon School has both a water supply system and a sewage system. In addition, the Riverside neighborhood and western Route 2 area near Main Road is served by the Riverside Water District with water supplied from the Town of Greenfield. Sewage collection for the same area is provided by a Town-operated system that delivers to a pump station on Riverview Drive. The pump station sends the wastewater under the Connecticut River to the Town of Montague's system for treatment at the Montague Water Pollution Control Facility. The remaining households of Gill have individual private wells and septic systems.

Telecommunications

Telephone and other telecommunications services are provided to Gill through the central office switch in Turners Falls. The most widely accessible form of telecommunications broadband service for Gill residents is cable broadband through the cable television provider, Comcast. In 2018, Comcast completed broadband build-out in Gill through renewal of their 10-year license, which extended broadband service to at least 96% of residents. In addition, MBI's MassBroadband 123 middle mile fiber network, completed in 2014, travels through Gill. Five Town facilities (called Community Anchor Institutions) are connected to this network – Town Hall, Gill Elementary School, Slate Memorial Library, Public Safety Building, and the Four Winds School building.

Cellular telecommunications service is available in most areas of Gill, but is not available throughout all areas of Town. The Town of Gill has zoning bylaws to regulate the locating of wireless communication towers. Currently there is one cell tower in Gill. The area surrounding the public safety complex, which serves as the Town's Emergency Operations Center (EOC), is a well-known dead-zone for cell service. Phone service at the building is reliant on an internet connection. The Town is investigating back-up communication solutions for the building.

The Town uses Reverse 911, bullhorns/loudspeakers, Emergency Alert System (EAS), Radio and TV, and the siren on the Northfield Mount Hermon Campus, to notify residents of emergency conditions and to provide instructions. Additionally, the Town uses its website, social media, and email to alert residents. The Town took over maintenance of the Reverse 911 system after the closure of Vermont Yankee in 2014. Residents can register their phone number through a link on the Town website.

Critical Facilities

A community's critical facilities include important municipal structures (i.e., town hall), emergency service structures (i.e., municipal public safety complex, shelters, and medical centers), locations of populations that may need special assistance (i.e., nursing homes, day cares, schools, prisons) and major employers or other areas where there is a dense concentration of people. In Gill, the identified critical facilities include the Town Hall, Gill Public Safety Building (which houses the Police Department, Fire Department, and Highway Department), the sewer pump station in Riverside, Barton Cove Campground, Schuetzen Verein off of Route 2, the Gill Elementary School, the Giving Tree School, Northfield Mount Hermon School, and Stoughton Place senior housing.

Emergency Shelters

The Turners Falls High School, located in neighboring Montague, is the designated emergency shelter for Gill. The Turners Falls High School has a back-up generator, but is located across the

Connecticut River, a potential barrier to accessing the shelter during severe flooding or other hazard events that may impact the bridge. Gill has formal agreements through the Franklin County Regional Shelter Plan to use the Turners Falls High School or the Greenfield High School as an emergency shelter.

The Town is interested in designating another shelter within the Town to increase its sheltering capacity. The Northfield Mount Hermon School is one possibility. The school has a campus-wide generator that provides back-up power during an outage. Additionally, the campus has multiple buildings, and could have a separate building designated as a community shelter during an emergency. The Town should collaborate with NMH staff to determine the feasibility of designating the school as a shelter, and execute a Memorandum of Understanding with the school if it is deemed feasible.

Natural Resources

Gill is characterized as a rural farming community with rising hills and deep river valleys. The natural resources of Gill include abundant open space, and access to outdoor recreational opportunities offered by the Connecticut and Fall Rivers.

Gill's landscape character is one of rolling hills, river terraces, farmlands, and upland forests. The town's topography is a result of glacial deposition and river erosion. Gill's terrain varies greatly in slope from level floodplains to steep river valley terraces. Elevations in Gill range from 150 feet at the junction of the Fall and Connecticut Rivers to 816 feet at the top of Pisgah Mountain. Unsorted glacial deposits of soil and rocks, or drumlins, are present throughout Gill's landscape. A fault line, inactive for more than 140 million years, is located along the French King Gorge at the border of Gill and Erving. Other significant geologic features include the plunge pools at Barton Cove, the falls at the Turners Falls Dam, and glacial eskers at the Town Forest.

The Town of Gill is bordered by the Fall River to the west, and the Connecticut River to the south and east. The Connecticut River separates Gill from the towns of Montague, Erving and Northfield, while the Fall River separates Gill from the towns of Greenfield and Bernardston. Additional water resources in Gill include Ashuela Brook, Dry Brook, Otter Brook and other smaller streams and brooks. Other water bodies include Shadow Lake on the Northfield Mount Hermon Campus, and Otter Pond located between Dole Road and Hoeshop Road.

Large blocks of contiguous forestland such as those in Gill are important resources for several reasons. Large blocks of forest provide clean water, air, and healthy wildlife populations. They represent an area with a low degree of fragmentation that can support wildlife species that require a certain amount of deep forest cover separate from people's daily activities. Forests help mitigate flooding by slowing and absorbing stormwater, and are critical in mitigating future climate change through sequestering and storing carbon.

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 in recent years, 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.[7]

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.

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 Committee identified the Memorial Chapel, Old Riverside School, and Slate Memorial Library as historical buildings in Gill that would be difficult or impossible to replace if destroyed.

Table 2-1: Gill Cultural Resources

Resource Name	Location	Type
Memorial Chapel	19 Cottage Row, NMH Campus	Historical Building
Old Riverside School	54 French King Highway	Historical Building

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

Table 2-1: Gill Cultural Resources		
	(Route 2)	
Slate Memorial Library	332 Main Road	Historical Building; Library
Gill Town Hall	325 Main Road	Historical Building; Town Records
Center Cemetery		Cemetery

The Gill Town Hall and the Center Cemetery were also identified by the committee as cultural and historic resources that may be vulnerable to natural hazards. Groundwater seepage in the basement of the Town Hall places town records stored there at risk of being destroyed. The town has made efforts to store important records out of the basement. Records stored in the basement have been moved higher off the floor. The Center Cemetery is at risk of streambank erosion on Dry Brook along one slope, which could result in the loss of graves. The Conservation Commission is assessing the location for possible streambank stabilization measures.

IMPACTS OF CLIMATE CHANGE

Greater variation and extremes in temperature and weather due to climate change has already begun to impact Gill, 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 Gill: 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

Average global temperatures have risen steadily in the last 50 years, and scientists warn that the trend will continue unless greenhouse gas (GHG) 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).

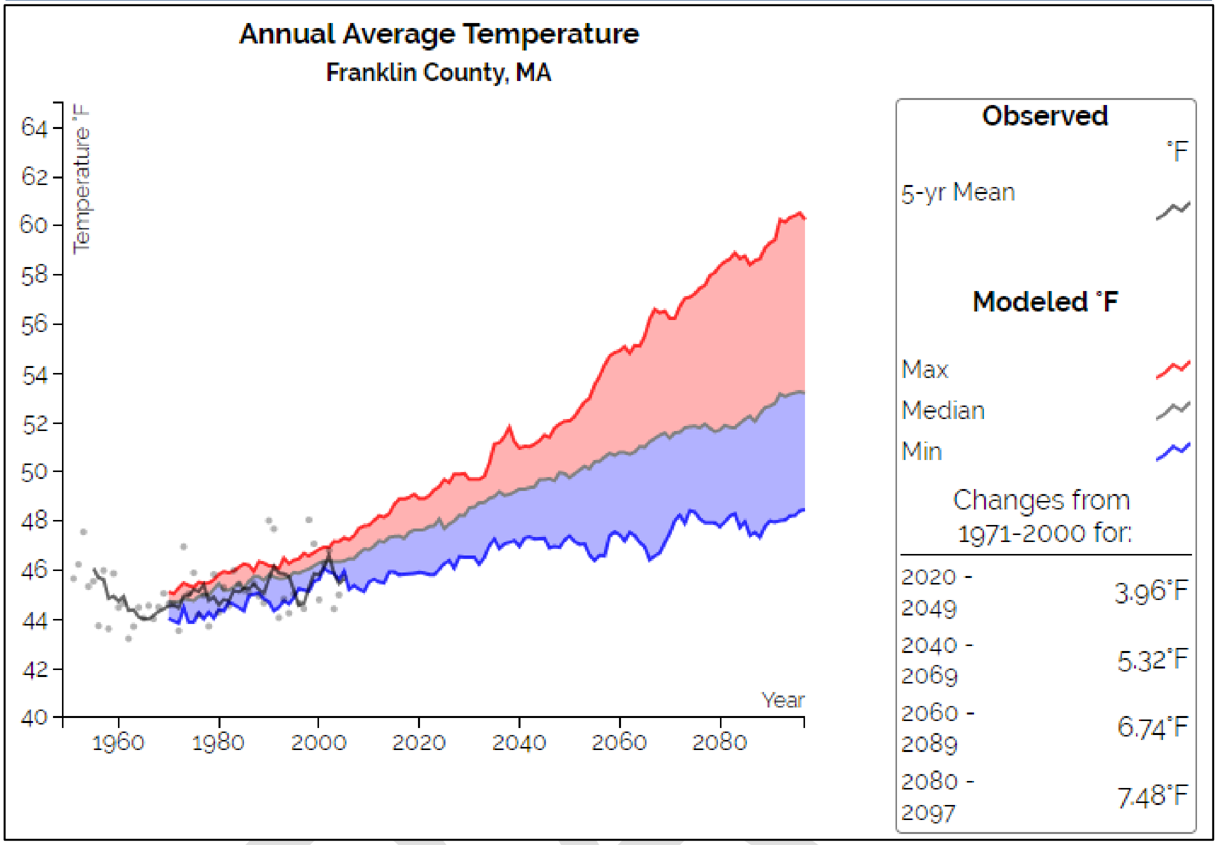
The average, maximum, and minimum temperatures in Franklin County are likely to increase significantly over the next century (Resilient MA, 2018). Figure 2-2 displays the projected increase in annual temperature by mid-century and the end of this century, compared to the observed annual average temperature 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

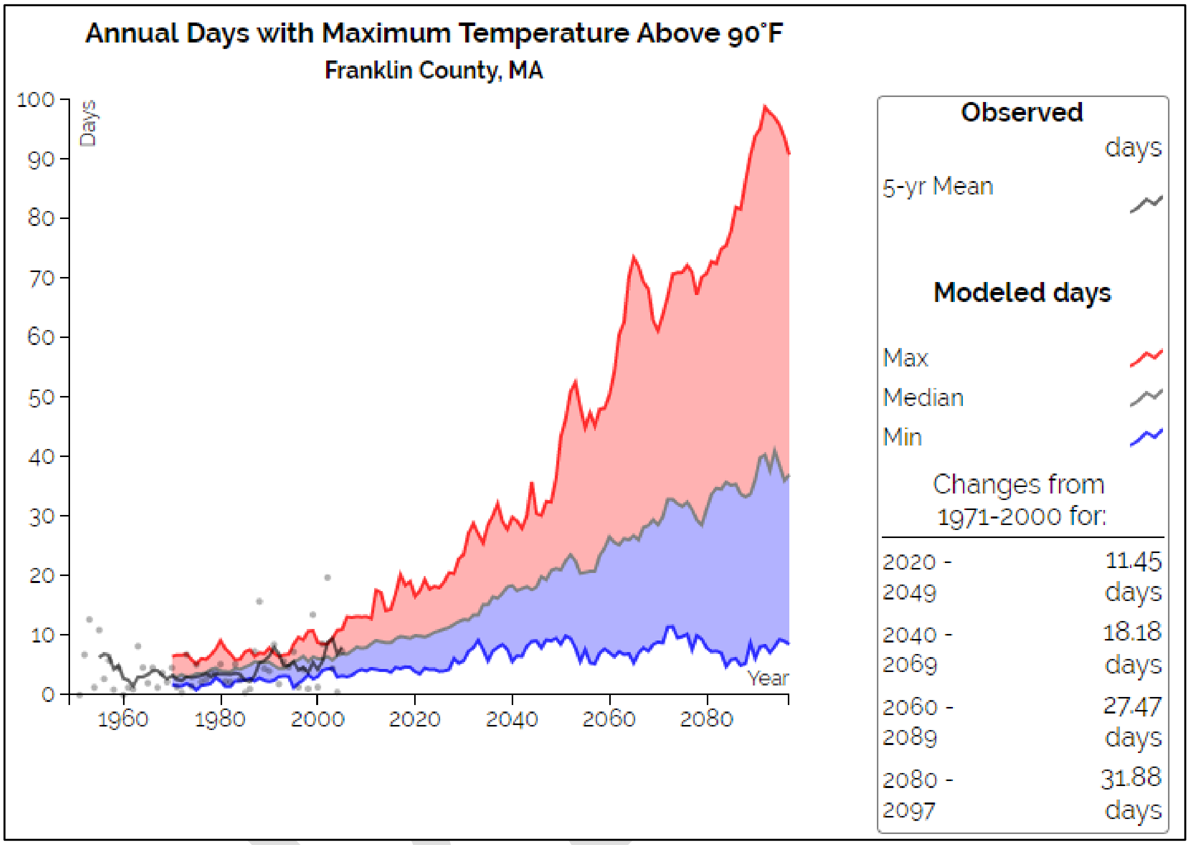


Source: Resilient MA, 2018

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



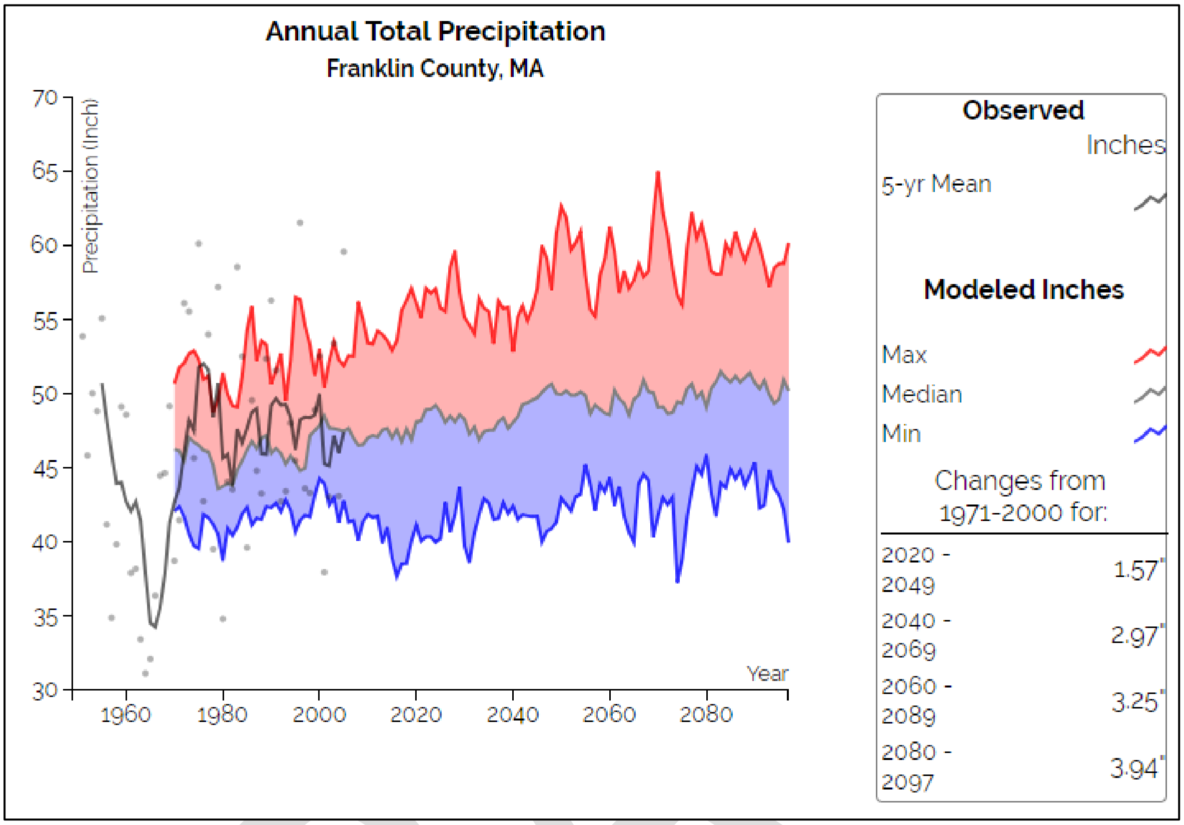
Source: Resilient MA, 2018

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.[8]

[8] 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.

3: HAZARD IDENTIFICATION AND RISK ASSESSMENT

The following section includes a summary of disasters that have affected or could affect Gill. 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 Gill. The table below illustrates a comparison between the relevant hazards in the State plan and in Gill's plan.

Table 3-1: Comparison of hazards in the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan and Gill Hazard Mitigation Plan*

Massachusetts State Hazard Mitigation and Climate Adaptation Plan (2018)	Town of Gill Relevance
	YES
	YES
	YES
	NO
	NO
	NO

Table 3-1: Comparison of hazards in the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan and Gill Hazard Mitigation Plan*	
Massachusetts State Hazard Mitigation and Climate Adaptation Plan (2018)	**Town of Gill Relevance**
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

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 Gill. 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 Gill are: severe winter storms, flooding, tornadoes, dam failure, hurricanes/tropical storms, severe thunderstorms/wind/microbursts, extreme temperatures, earthquakes, landslides, drought, wildfire and invasive species. Many of these hazards result in similar impacts to a community. For example, hurricanes, tornadoes 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 3-2: Location of Occurrence Rating Scale	
Classification	**Percentage of Town Impacted**
Large	More than 50% of the town affected
Medium	10 to 50% of the town affected
Isolated	Less than 10% of the town 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 3-3: 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 3-4: Impacts 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 3-5: 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	High
Extreme Temperatures	Large	Very High	Minor	High
Invasive Species	Medium	Very High	Critical	High
Hurricanes / Tropical Storms	Large	Moderate	Limited	Medium
Flash Flooding	Medium	Very High	Limited	Medium
Severe Thunderstorms / Wind / Microbursts	Medium	High	Limited	Medium
Earthquakes	Large	Very Low	Catastrophic	Medium
Drought	Large	Moderate	Minor	Medium
Wildfires	Isolated	Moderate	Limited	Medium
Flooding (100/500 year event)	Isolated	Moderate	Minor	Low
Tornadoes	Isolated	Very Low	Critical	Low
Dam Failure	Isolated	Very Low	Limited	Low
Landslides	Isolated	Very Low	Minor	Low

The Committee developed problem statements and/or a list of key issues for each hazard to summarize the vulnerability of Gill'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 Town's greatest vulnerabilities that will be addressed in the mitigation strategy (Section 4).

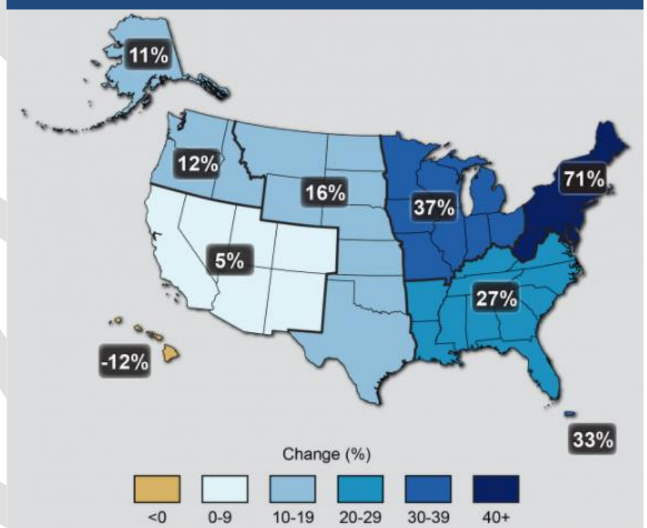
FLOODING

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.

Observed annual precipitation in Massachusetts for the last three decades 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. In the Connecticut River Watershed, annual precipitation has averaged around 45 inches in recent decades. By 2050, the annual average could remain relatively the same (but occur in more heavy, short intervals) or increase by up to 16 inches a year. In general precipitation projections are more uncertain than temperature projections.[9]

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.*

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

[9] http://resilientma.org/datagrapher/?c=Temp/basin/pcpn/ANN/Connecticut/ Accessed June 13, 2019.

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 some areas of Gill 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 in 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 Gill, fluvial erosion may cause more property damage than inundation. Furthermore, fluvial erosion can often occur in areas that are not part of the 100- or 500-year floodplain.

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.[10] Gill does not currently have any FEH zones mapped.

Urban Drainage Flooding

Urban drainage flooding entails floods caused by increased water runoff due to urban

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

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.

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 Gill’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.

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 towns in the 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.

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.

In Gill, there are approximately 583 acres within the 100-year floodplain. Key areas of flooding concern include the following:

<u>Connecticut River</u>
During the construction of the Northfield Mountain Pumped Storage Project, the dam at Turners Falls was raised to accommodate a power generating facility. A 2,500-acre lower reservoir, known as the Turners Falls Power Pool, was created behind the dam. The Turners Falls Power Pool is a 22-mile-long reach of the Connecticut River between the Turners Falls Dam located in Gill and Montague and the Vernon Dam in Vernon, Vermont.

The hydrodynamics of the Turners Falls Power Pool are primarily controlled by the three hydroelectric generating facilities: Turners Falls, Vernon, and the Northfield Mountain Pumped Storage Project. The joint operations of the Turners Falls facility and the Northfield Mountain Pumped Storage Project have resulted in larger and faster pool fluctuations, which have significantly changed the daily regime of this reach of the Connecticut River. Typical pool fluctuations average 3.5 feet per day at the dam. Much higher pool fluctuations, on the order of 9-10.5 feet at the dam, may occur over the course of the weekly pump/release cycle. The banks of non-cohesive, alluvial sand and silt, which dominate the Turners Falls Power Pool section of the Connecticut River, typically exceed twenty (20) feet in height. Erosive forces have destabilized many sections of bank resulting in slumping and mass wasting of large sections of bank and the loss of trees and other riparian vegetation on the top of the banks. Since 1996, a variety of bioengineering techniques have been used to stabilize over 10,000 feet of eroding river banks in the power pool, including locations in Gill. The multi-phase project is being implemented through a collaboration of FirstLight Power Resources, the Franklin Regional Council of Governments, the Massachusetts Department of Environmental Protection, and other local and regional stakeholders.

As part of the river bank stabilization project, a 2007 Fluvial Geomorphology Study of a reach of the river in the Gill area recommended the use of large woody debris (LWD) to protect eroding river bank along a 1,200 foot long stretch. The LWD would preserve existing beaches and promote the development of new beaches by trapping fine sediment. The beaches help to dissipate the erosive forces of water level fluctuations caused by the operation of the Northfield Mountain Project and boat wakes. The initial bank stabilization project was installed in 2009 and will continue to be monitored.

The Northfield Mountain Pumped Storage Project and Turners Falls Project are undergoing relicensing through the Federal Energy Regulatory Commission (FERC). A FERC license outlines the conditions under which the projects can operate and includes requirements to protect, mitigate, or enhance environmental resources impacted by the project. The FERC licenses will be valid for 30-50 years. The Connecticut River Streambank Erosion Committee (CRSEC), organized by the Franklin Regional Council of Governments (FRCOG), is actively involved in the relicensing process, reviewing reports and submitting comments to FERC.

According to the Gill Hazard Mitigation Committee, the closure of the Vermont Yankee nuclear power plant in Vernon, Vermont, in 2014 has resulted in colder water temperatures in the Connecticut River since the plant no longer uses the river for cooling. This has led to an increased risk in ice jams along the river, which historically had been more common prior to the operation of the power plant. Ice jams have the potential of flooding farmland along the banks of the river.

Center Road

Culverts along Center Road are undersized and caused flooding in fall 2018. Higher groundwater in this area is contributing to the flooding problems.

<u>Highland Road and Chappel Drive</u>

Runoff causes flooding along Highland Road, where a culvert needs to be continually unplugged. Chappel Drive was partially washed out recently from flooding in this area. If flooding in this area becomes more severe, it could impact Route 2.

<u>West Gill Road and Franklin Road</u>

Run off from West Gill Road and Franklin Road causes flooding in a nearby hayfield. Erosion is occurring along the streambanks of the brook that runs along the road. Flooding in this area of town has become exacerbated by an elevated water table and new development in recent years that has increased the amount of stormwater runoff.

<u>Dry Brook</u>

Streambank erosion is occurring along Dry Brook in the center of town, just south of Main Road. Erosion threatens the Center Cemetery.

<u>Water Main over the Fall River</u>

One area of potential concern is the water main laid on a~~n old~~ bridge that travels over the Fall River, which supplies the Riverside neighborhood and western area of Route 2 near Turners Falls with drinking water from Greenfield. If the bridge and main were damaged or destroyed due to flooding on the Fall River, the areas served would be without drinking water for an unknown amount of time. The bridge was recently reconstructed, reducing the risk that the water main would be impacted during flooding.

<u>River Road</u>

Failure of a catch basin on River Road has caused the road to be closed due to flooding several times in recent years.

<u>Bascom Hollow</u>

Riverbank erosion along the Fall River has resulted in the loss of farmland near Bascom Road. Debris from flash flooding becomes caught in the river, which then jumps its banks and floods nearby farm fields.

Other recent flood damage in town includes the Bascom Road bridge abutment, which was severely damaged from flooding during a major rain storm in 2007. The bridge was repaired and riverbank stabilization in this area has been partially effective at reducing erosion. This bridge is maintained by Greenfield.

Based on these locations, flash flooding is impacting 10% to 50% of the Town, or a “medium” area of occurrence.

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 Connecticut River in Montague City, as well as the highest flow event in the last 365 days at locations north and south of Gill.

The 100-Year Flood

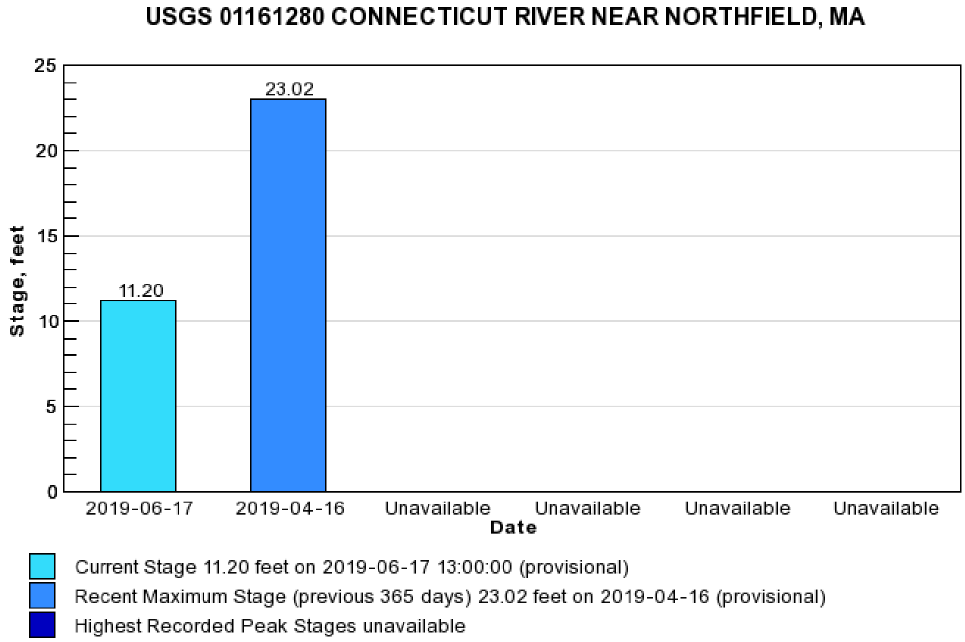
The 100-year flood is the flood that has a 1 percent chance of being equaled or exceeded each year. The 100-year flood is the standard used by most federal and state agencies. For example, it is used by the National Flood Insurance Program (NFIP) to guide floodplain management and determine the need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

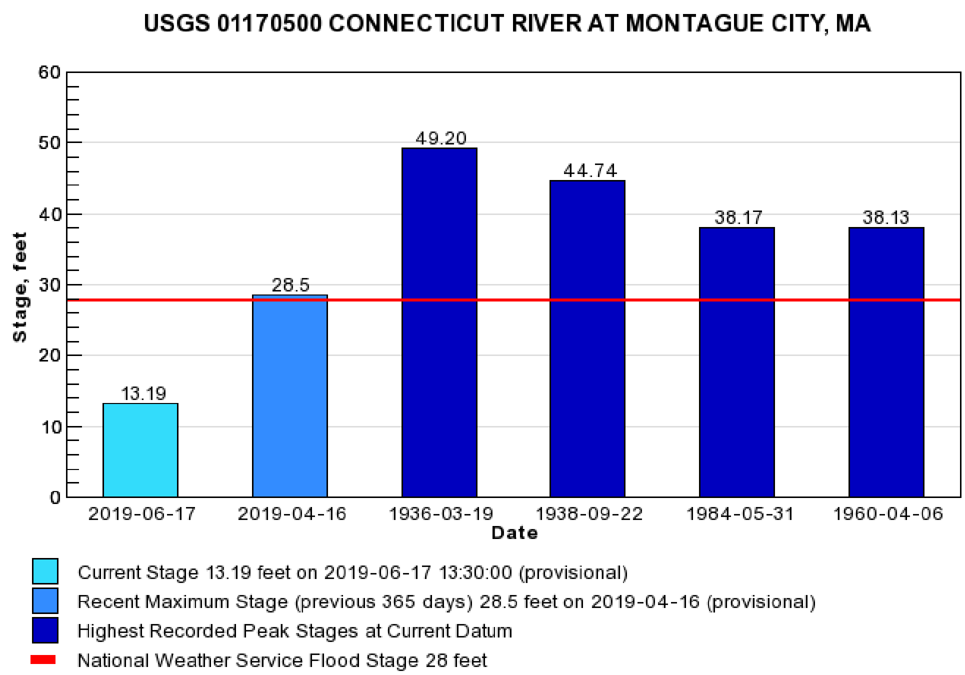
The extent of flooding associated with a 1 percent annual probability of occurrence (the base flood or 100-year flood) is called the 100-year floodplain, which is used as the regulatory boundary by many agencies. Also referred to as the Special Flood Hazard Area (SFHA), this boundary is a convenient 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.

Figure 3-3: Highest Recorded Flood Events on the Connecticut River





Source: USGS WaterWatch https://waterwatch.usgs.gov/index.php?id=wwchart_ftc&site_no=01170500

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

Between 1996 and 2017, 17 flash floods have been reported in Franklin County (Table 3-6), resulting in $3,245,000 in property damages. In Gill, on June 25, 2014, a house on Walnut Street was flooded with up to 8 inches of water in the basement. On August 13, 2014, several roads were closed in Gill and surrounding towns due to flooding.

Table 3-6: Previous Occurrences of Flash Floods in Franklin County

Year	# of Flash Flood Events	Annual Property Damage	Annual Crop Damage
1996	4	$1,800,000	$0
1998	1	$75,000	$0
2000	1	$0	$0
2003	1	$10,000	$0
2004	1	$10,000	$0
2005	3	$1,235,000	$0
2013	3	$65,000	$0
2014	2	$50,000	$0
2017	1	$0	$0
Total	**17**	**$3,245,000**	**$0**

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 3-7). The bulk of these damages ($22,275,000) were from Tropical Storm Irene in August, 2011. Gill did not suffer major flooding from Tropical Storm Irene. An increase in debris in rivers was the major impact of the storm in Gill. In particular, there were a number of propane tanks in the river after Irene. The tanks and debris from the storm piled up at the Turners Falls Dam, where First Light Power removed most of the debris. A rescue boat was deployed to help with the river clean up. The most severe impacts from Irene, however, were experienced in the western portion of Franklin County.

Table 3-7: Previous Occurrences of Floods in Franklin County			
Year	**# of Flood Events**	**Annual Property Damage**	**Annual Crop Damage**
1996	7	$0	$0
1998	3	$0	$0
2001	1	$0	$0
2004	1	$0	$0
2005	2	$2,600,000	$0
2007	1	$250,000	$0
2008	3	$38,000	$0
2010	1	$150,000	$0
2011	8	$22,375,000	$0
2012	2	$0	$0
2015	10	$31,000	$0
2017	1	$1,000	$0
2018	4	$137,000	$0
Total	**44**	**$25,582,000**	**$0**

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

Probability of Future Events

Based on previous occurrences, the frequency of occurrence of flooding events in Gill is "moderate," with a 2 to 25 percent probability in any given year. Flooding frequencies for the various floodplains in Gill 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 Gill.[11]

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 flood events in Gill is typically "minor," with only minor property damage, minimal disruption of quality of life, and temporary shutdown of facilities (roads, bridges,

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

critical facilities).

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.

Of Gill's total acreage, 583 acres lie within the 100-year floodplain. According to 2005 MassGIS Land Use data there are seven dwelling units located in the floodplain (Table 3-8). Using this number and Gill's estimated average household size, it is estimated that 16 people, or 1% of Gill's total population, reside in the floodplain.

Table 3-8: Estimated Gill 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
1,604	7	2.31	16	1.0%

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

<u>Vulnerable Populations</u>

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 3-9 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a flood event.

Table 3-9: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population (1,604)**
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households (583)**
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

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. There are several Hazardous Facilities in Gill where hazardous chemicals are stored (See Table 3-41 in Manmade Hazards Section). The sewer pump station on Riverview Drive in the Riverside neighborhood of Gill, and the wastewater treatment plant for the Northfield Mount Hermon School, are located within the Connecticut River floodplain. In addition to these facilities, 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.

Hazardous materials are routinely transported through town on common routes, including Route 2 and Route 10. There are locations where these vehicular transportation routes either cross over and/or travel along the rivers in town, placing the populations living within close proximity to the road at higher risk to a hazardous material spill in conjunction with riverine flooding.

Health Impacts

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 Gill. 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).

<u>Economic Impacts</u>

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 Gill 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 Town-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 3-10 shows the amount of commercial, industrial, and public/institutional land uses located in town and within the floodplain. There is almost no commercial or industrial land that lies within the floodplain. There is only 1.4 acres of public or institutional land uses located within the floodplain in Gill, accounting for less than 1% of the acreage in Town devoted to these uses.

Table 3-10: Acres of Commercial, Industrial, and Public/Institutional Land Use Within the Flood Hazard Area in Gill

Land Use	Total acres in Town	Acres in Flood Hazard Area	% of total acres in Flood Hazard Area
Commercial	38.8	0.05	>1%
Industrial	0	0	0%
Public/Institutional	148.2	1.4	>1%

Source: 2005 MassGIS Land Use data.

2019 insurance values were used for the sewer pump station in Riverside and the Northfield Mount Hermon wastewater treatment plant, significant structures located in the floodplain in Gill (Table 3-11), as estimates for the cost to replace these structures if completely damaged by flooding. The Committee feels that if the sewer pump building and the equipment inside were completely damaged by flooding, the cost to rebuild the pump station would be closer to $750,000, as a conservative estimate.

Table 3-11: Total Building Value in Flood Hazard Area

Structure	Building Structure Value	Other Value	Total Building Value
Sewer Pump Station	$331,000	$0	$331,000
Northfield Mount Hermon Wastewater Treatment Plant	$0	$500,000	$500,000
Total	**$331,000**	**$500,000**	**$831,000**

Source: 2019 insurance data.

NFIP data are useful for determining the location of areas vulnerable to flood and severe storm hazards. Table 3-12 summarizes the NFIP policies, claims, repetitive loss (RL) properties, and severe repetitive loss (SRL) properties in Gill associated with all flood events as of December 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). Gill currently has five policies in force; no losses have been paid and there are no repetitive loss properties in town.

Table 3-12: NFIP Policies, Claims, and Repetitive Loss Statistics for Gill						
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
626	5	0.8%	$1,450,000	0	$0	0

* Student dormitories are not included in the total housing unit count.
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. The hydroelectric facilities on the Connecticut River are in active use and are inspected on a regular basis.

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 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, Gill has a "Low" vulnerability to flooding. The following problem statements summarize Gill's areas of greatest concern regarding the flood hazard.

Flood Hazard Problem Statements
• Continue to cut brush immediately around bridge abutments and culverts to reduce the opportunity for snags.
• Develop and maintain a list of specific addresses within the 50- and 100-year floodplains for use by the EOC.
• According to the Agricultural Commission, a fair amount of farmland in town consists of soils that do not drain well; these areas can become difficult or impossible to farm during periods of heavy precipitation.
• Investigate whether the water main crossing the Fall River could be placed underground. Develop agreements with surrounding towns to supply back-up drinking water in the event the water main is damaged by flooding.
• Culverts on Center Road and Highland Road are not large enough to handle an increase in runoff and drainage. Culverts in town should be assessed and prioritized for replacement.
• Streambank erosion is an issue along Dry Brook and West Gill Road and Franklin Road. Streambank stabilization measures should be explored in these areas.
• The potential for ice jams on the Connecticut River is greater now that Vermont Yankee is closed. Farmland along the banks of the river could be impacted by flooding from an ice jam.
• Farmland has been lost due to erosion along the Fall River in the Bascom Hollow section of town.
• A catch basin on River Road has failed in recent years, resulting in flooding that blocks the road.

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 show 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 town of Gill is susceptible to severe snowstorms and ice storms. Because these storms occur regionally, they impact the entire town. 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 3-13. 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 3-13: 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 3-14.

Table 3-14: Northeast Snowfall Impact Scale Categories		
Category	**NESIS Value**	**Description**
1	1—2.499	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

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 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 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.

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. Gill was not severely impacted by the 2008 ice storm. Expenses for the town, which included routine emergency procedures and some debris clearing, amounted to $13,548.

On October 29, 2011, an early snow storm brought over a foot of snow in some areas of the county. In lower elevations, the snow was heavier and caused many tree limbs, most of which still held their leaves, to break and fall. Power outages were widespread across New England, and lasted over a week in a few places in the Connecticut River valley. In Gill, 100% of the town lost electricity. As of the morning of November 3, 2011, there were still an estimated 1 – 10% of electric customers without power in town, according to the Western Massachusetts Electric Company. According to an article in The Recorder on November 1, 2011, Boyle Road, Ben Hale Road, and Hoe Shop Road remained closed on the Monday after the storm, with various other roads remaining blocked due to downed tree limbs and wires, including: Main Road, closed at the town common due to a downed wire; River Road at the intersection with Barney Hale Road; Pisgah Mountain Road at the intersection with Route 2; and South Cross Road at the intersection with Green Hill Road. In addition the traffic light at the intersection of Route 2 and Main Road was without power. A regional shelter was opened at the Turners Falls High School in Montague. Gill residents who could not drive themselves to the shelter could contact the Franklin Regional Transit Authority for a free ride to the shelter. Due to the widespread and prolonged power outages in town and the region, access to fuel for generators became scarce following the storm. Costs incurred by the Town for the storm are currently being determined, but are estimated to approach $50,000.

On November 26, 2014, six to ten inches of wet, heavy snow fell in the region, causing downed tree limbs and wires across the county. In Gill, numerous trees and wires were downed, roads were blocked, and residents lost power. The Town declared a State of Emergency, which was lifted on November 30.

On January 26-27, 2015, eastern Franklin County, including Gill, received roughly 5 to 10 inches of snow. This storm had a much larger impact on eastern and central Massachusetts, and is rated as a “Major” storm according to the RSI High-Impact snowstorm classification. On February 14, 2015, Gill received between 4 to 9 inches of snow from a storm that again affected eastern Massachusetts to a much greater degree than the western part of the State. According to the National Oceanic and Atmospheric Administration (NOAA), this was the latest in a series of snowstorms that piled nearly 60 inches of snow on the city of Boston in barely three weeks. This amount of snow in such a short amount of time wreaked havoc on much of eastern Massachusetts. The MBTA commuter rail and subway lines were plagued with delays and cancellations that lasted until the end of March. The large amount of snow, combined with wintry, frigid temperatures resulted in snow piling up on roofs and numerous (250) roof collapses were reported to emergency management and to the National Weather Service in the days after this snowstorm. Fortunately, no injuries to humans were reported. In barn collapses in Stoughton and Andover, a total of 40 horses were trapped and rescued. In another barn collapse in Westford, two horses died. A falling icicle ruptured a gas line causing an explosion at the Duxbury House, an Alzheimer's care facility in Duxbury. No one was injured. There were several indirect fatalities related to the snow. These include: a 57 year old man who died shoveling snow, a 57 year old woman hit by a snow plow, and a 60 year old man hit by a snow plow.

In late October 2016, an early snow storm caused tree limbs to come down in eastern Franklin County towns resulting in power outages. In Gill, multiple trees and wires were reported downed on Pisgah Mountain Road.

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 3-15, in order of their RSI severity.

Table 3-15: 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
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
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

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 snowstorm will hit Gill 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 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 Erving is exposed to severe winter weather events.

Vulnerable Populations

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 3-16 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a severe winter storm event.

Table 3-16: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583
Note: Individuals and households may be counted under multiple categories.
Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

<u>Health Impacts</u>

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.

[12] Fink, 2012

Economic Impacts

The entire building stock inventory in Gill 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 Gill 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 event. Disruptions to key public services such as electricity, transportation, schools, and health care may become more common.[13] Table 3-17 identifies the assessed value of all residential, open space, commercial, industrial, and tax exempt and municipal land uses in Town, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a severe winter storm.

[13] Resilient MA 2018

Table 3-17: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

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 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.

<u>Water Infrastructure</u>

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, Gill faces a "High" vulnerability from severe snow storms and ice storms. Severe Winter Storms / Ice Storms occur frequently in Gill. However, the severity of impact is typically limited. The following problem statements summarize Gill's areas of greatest concern regarding severe winter storms.

Severe Winter Storm Hazard Problem Statements
• Many Gill residents rely on private wells for water, and need power to operate their heating systems, placing them at risk during prolonged power outages.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies. The Town lacks staff capacity to operate a shelter within its borders.
• The Gill Elementary School should be wired with a transfer switch for a portable generator.
• Continue program of tree maintenance & trimming along roads. Make efforts to have the State do a similar program along its highways in Gill (Route 2 and Route 10).
• The low-income senior housing at Stoughton Place does not have a back-up generator.
• Gill's reliance on Route 2 as the major transportation route, especially for large commercial vehicles that do not have a viable alternative, places residents and emergency responders at risk if the road becomes blocked from downed wires or trees. Some alternative routes, like Pisgah Mountain Road, are not passable in the winter months.
• The Town does not have gasoline storage for Town-vehicles, placing departments that utilize gasoline vehicles, such as the Gill Police, at risk of running out of fuel during a prolonged power outage. The gas station in Town is not equipped with a back-up generator. A regional plan is needed to insure reliable access to fuel during extended power outages.

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.

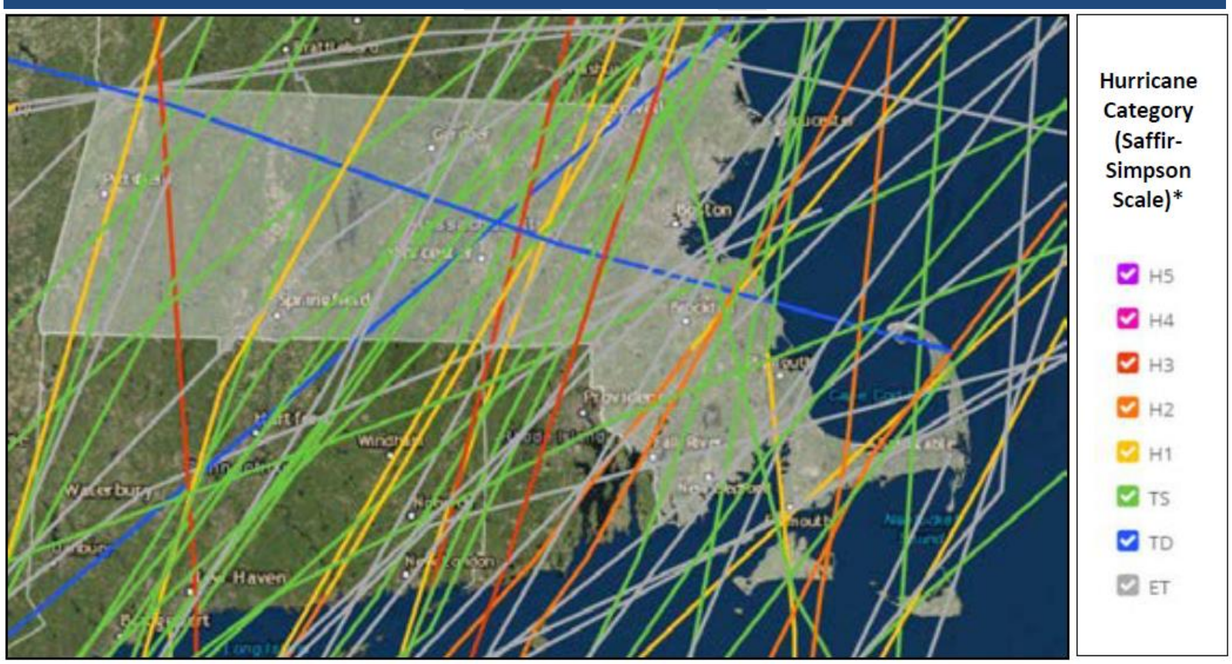
The term "tropical" refers both to the geographical origin of these systems, which usually form in tropical regions of the globe, and to their formation in maritime tropical air masses. The term "cyclone" refers to such storms' cyclonic nature, with counterclockwise wind flow in the Northern Hemisphere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

Location

Because of the hazard's regional nature, all of Gill 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.

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.

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



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

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 3-19 gives an overview of the wind speeds and range of damage caused by different hurricane categories.

Table 3-19: 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 Town of Gill.

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. In 2011, Tropical Storm Irene caused over $26 million in property damage in Franklin County, mostly from flooding impacts. Wind gusts did cause power outages in parts of the county. Power outages in Gill affected less than 5% of the town, and lasted less than two hours for most. One exception was the Northfield Mount Hermon campus, which lost power for 4-5 hours, a significant amount of time for the school to be without power.

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]

Gill's location in western Massachusetts reduces the risk of extremely high winds that are associated with hurricanes, although it can experience some high wind events. Based upon past occurrences, Gill has a moderate probability, or a 2% to 25% chance, of experiencing a hurricane or tropical storm event in a given year.

Impact

A hurricane or tropical storm would likely have a limited impact on Gill, with a potential of more than 10% of property damaged or destroyed and complete shutdown of facilities for more than one day.

Vulnerability

The entire town 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 town's communication and energy infrastructure.

Society

<u>Vulnerable Populations</u>
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. There are several Hazardous Facilities in Gill where hazardous chemicals are stored (See Table 3-41 in Manmade Hazards Section). The sewer pump station on Riverview Drive in the Riverside neighborhood of Gill, and the wastewater treatment plant for the Northfield Mount Hermon School, are located within

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

the Connecticut River floodplain. In addition to these facilities, 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.

Hazardous materials are routinely transported through town on common routes, including Route 2 and Route 10. There are locations where these vehicular transportation routes either cross over and/or travel along the rivers in town, placing the populations living within close proximity to the road at higher risk to a hazardous material spill in conjunction with riverine flooding.

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. 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 3-20 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a hurricane or tropical storm event.

Table 3-20: Estimated Vulnerable Populations in Gill

Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583

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

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

The Committee noted that Stoughton Place, a low-income senior housing complex on Main Road, lacks a back-up power generator. Residents who rely on electricity for medical devices are at risk. If power is lost during a period of high heat and humidity, residents may also be susceptible to heat-related illnesses due to lack of air-conditioning.

<u>Health Impacts</u>

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.

<u>Economic Impacts</u>

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 affect the Town with a potential of more than 10% 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 3-21 identifies the assessed value of all residential, open space, commercial, industrial, tax exempt and municipal land uses in Town, 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 3-21: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

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

<u>Energy</u>

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.

<u>Public Health</u>

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

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

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 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-

[16] Resilient MA 2018.

term population impacts on species in the area.

Vulnerability Summary

Based on the above analysis, Gill faces a medium vulnerability from hurricanes and tropical storms. The following problem statements summarize Gill's greatest areas of concern regarding hurricanes and tropical storms.

Hurricane / Tropical Storm Hazard Problem Statements
• Many Gill residents rely on private wells for water, placing them at risk during prolonged power outages. Residents who rely on sump pumps to remove water from basements would also be affected.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies. The Town lacks staff capacity to operate a shelter within its borders.
• The Gill Elementary School should be wired with a transfer switch for a portable generator.
• The public safety complex, which serves as the Town's Emergency Operations Center (EOC) relies on internet phone service. In the event the internet is down, there is no back-up phone system for the EOC. The Police department in particular relies on the internet for accessing police records. The MBI fiber cable is aboveground and could be susceptible to damage. It is unknown how quickly the State would be able to repair the system if damaged.
• The Stoughton Place low-income senior housing complex lacks a back-up generator.
• Hazardous debris in the Connecticut River is a concern, especially when it accumulates at the Turners Falls dam.
• Gill's reliance on Route 2 as the major transportation route, especially for large commercial vehicles that do not have a viable alternative, places residents and emergency responders at risk if the road becomes blocked from downed wires or trees.
• Continue program of tree maintenance & trimming along roads. Make efforts to have the State do a similar program along its highways in Gill (Route 2 and Route 10).
• The Town does not have gasoline storage for Town-vehicles, placing departments that utilize gasoline vehicles, such as the Gill Police, at risk of running out of fuel during a prolonged power outage. The gas station in town is not equipped with a back-up generator. A regional plan is needed to insure reliable access to fuel during extended power outages.

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 3-6: 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

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

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 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 town of Gill is at risk for severe thunderstorms, wind and microbursts. The location of occurrence is generally “Medium,” impacting 10% to 50% of the Town.

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.

Gill 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 3-7).

Figure 3-7: 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

Previous Occurrences

Since 1996, a total of 13 high wind events occurred in Franklin County (Table 3-21), 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 3-21: High Wind Events in Franklin County

Year	# of High Wind Events	Annual Property Damage	Annual Crop Damage
1996	2	$0	$0
1999	1	$0	$0
2003	2	$130,000	$0
2004	1	$30,000	$0
2005	1	$10,000	$0
2006	3	$68,000	$0
2011	1	$15,000	$0
2013	2	$35,000	$0
Total	**13**	**$288,000**	**$0**

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. Gill has experienced seven (7) thunderstorm wind events since 1994 (Table 3-22). These storms resulted in downed trees and wires and caused an estimated $78,000 in property damage. In one instance a tree landed on a mobile home. On May 26, 2010, strong thunderstorm winds caused damages throughout the Connecticut River Valley with numerous trees and wires down and widespread power outages. The storm resulted in a total of $20,000 in damages in Gill, and caused power outages at the Northfield Mount Hermon School that resulted in the loss of the public drinking water well fields and well pumps for three days. Luckily, the outage occurred shortly after school year ended and no students were living on campus. Since then, Northfield Mount Hermon School has installed a back-up generator at the pump station for the drinking water wells.

Table 3-22: Thunderstorm Wind Events in Gill				
Year	**# of Thunderstorm Wind Events**	**Annual Property Damage**	**Annual Crop Damage**	**Event Description**
2006	1	$15,000	$0	Telephone poles and wires were downed on West Gill Road.
2008	2	$13,000	$0	Trees and wires were downed by thunderstorm winds. One of these trees landed on a trailer home.
2010	1	$20,000	$0	Trees and wires were downed by thunderstorm winds resulting in power outages.
2013	1	$10,000	$0	Trees and wires on West Gill Road and Center Road were downed by thunderstorm winds.
2015	1	$5,000	$0	Trees and wires on River Road were downed by thunderstorm winds near Grist Mill Road.
2016	1	$15,000	$0	Trees were downed on Ben Hale Road in Gill.
Total	**7**	**$78,000**	**$0**	

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 3-23). In August 2018, lightning caused a house fire on Barney Hale Road in Gill, with $6,000 in damages reported.

Table 3-23: Lightning Events in Franklin County			
Year	**# of Lightning Events**	**Annual Property Damage**	**Annual Crop Damage**
1997	1	$3,000	$0
2001	1	$20,000	$0
2002	1	$15,000	$0
2004	1	$35,000	$0
2005	1	$50,000	$0
2008	1	$10,000	$0
2010	2	$25,000	$0
2012	1	$500,000	$0
2013	4	$49,000	$0
2014	3	$93,000	$0
2018	6	$35,500	$0
Total	**22**	**$835,500**	**$0**

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 3-24). 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. There were no hail events reported in Gill during this time period.

Table 3-24: Hail Events in Franklin County

Year	# of Hail Events	Annual Property Damage	Annual Crop Damage
1998	4	$0	$0
2000	1	$0	$0
2001	1	$0	$0
2003	1	$0	$0
2004	2	$0	$0
2005	3	$5,000	$0
2007	5	$0	$0
2008	7	$0	$50,000
2009	2	$0	$0
2010	4	$0	$0
2011	4	$0	$0
2012	1	$0	$0
2013	3	$0	$0
2017	3	$0	$0
2018	1	$0	$0
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 "high" probability (25% - 50% chance) of a severe thunderstorm or winds affecting the town in a given year. Climate change is expected to increase the frequency and intensity of thunderstorms and other severe weather.

Impact

The entire town of Gill 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 town of Gill can experience the effect and impact from severe thunderstorms, microbursts, and hail. The magnitude of impact of a severe thunderstorm event is likely "Limited," with more than 10% of property in the affected area damaged or destroyed.

Vulnerability

Society

The entire population of Gill 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.

Vulnerable Populations

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 3-25 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a severe weather event.

Table 3-25: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583
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

[18] (Andrews, 2012).

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 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. Erving 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

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

Massachusetts) for appropriate reference wind pressures, wind forces on roofs, and similar data.

All elements of the built environment are exposed to severe weather events such as high winds and thunderstorms. Table 3-26 identifies the assessed value of all residential, open space, commercial, industrial, tax exempt and municipal land uses in Town, 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 3-26: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section; FY2019 Gill Assessor data.

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, Gill has a “Medium” vulnerability to severe thunderstorms and wind events. Thunderstorms are common in New England, and can impact property, crops, utilities and the population of Gill. 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 Gill's areas of greatest concern regarding severe thunderstorms and wind events.

Severe Thunderstorm / Wind Hazard Problem Statements
• Many Gill residents rely on private wells for water, placing them at risk during prolonged power outages. Residents who rely on sump pumps to remove water from basements would also be affected.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies. The Town lacks staff capacity to operate a shelter within its borders.
• The public safety complex, which serves as the Town's Emergency Operations Center (EOC) relies on internet phone service. In the event the internet is down, there is no back-up phone system for the EOC. The Police department in particular relies on the internet for accessing police records. The MBI fiber cable is aboveground and could be susceptible to damage. It is unknown how quickly the State would be able to repair the system if damaged.
• Gill's reliance on Route 2 as the major transportation route in town, especially for large commercial vehicles that do not have a viable alternative, places residents and emergency responders at risk if the road becomes blocked from downed wires or trees.
• The Gill Elementary School should be wired with a transfer switch for a portable generator. • The Stoughton Place low-income senior housing complex lacks a back-up generator.
• Continue program of tree maintenance & trimming along roads. Make efforts to have the State do a similar program along its highways in Gill (Route 2 and Route 10).
• The Town does not have gasoline storage for Town-vehicles, placing departments that utilize gasoline vehicles, such as the Gill Police, at risk of running out of fuel during a prolonged power outage. The gas station in town is not equipped with a back-up generator. A regional plan is needed to insure reliable access to fuel during extended power outages.

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 3-6: 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.

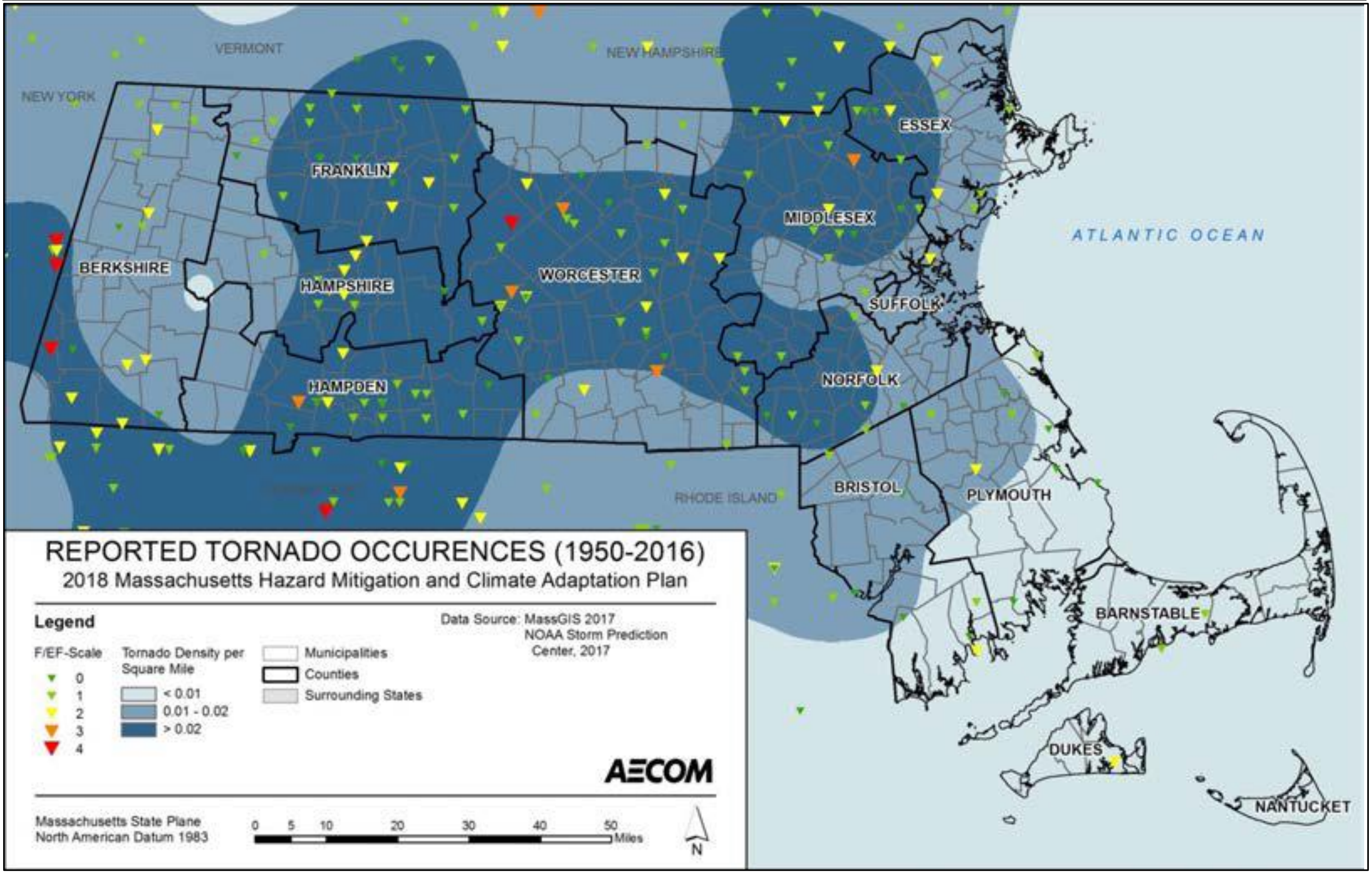
Location

Figure 3-7 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 Gill and much of Franklin County. Tornadoes are rated as having an Area of Occurrence of “Isolated.” If a tornado were to occur in Gill, it would likely impact less than 10% of the town.

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 3-8 provides guidance from NOAA about the impacts of a storm with each rating.

Figure 3-7: 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 3-8: 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

High wind speeds, hail, and debris generated by tornadoes can result in loss of life, downed trees and power lines, and damage to structures and other personal property (cars, etc.). 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 towns of Heath, Charlemont, Wendell, New Salem, and Conway (Table 3-27). 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. There have been no occurrences of a tornado in Gill in recent years.

Table 3-27: 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 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

Table 3-27: Tornado Events in Franklin County				
Date	**Severity**	**Property Damage**	**Crop Damage**	**Event Narrative**
				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 Deerfield 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 town 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 Gill, 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. The severity of impact of a tornado event could be "Critical," with multiple injuries possible, more than 25% of property damaged and complete shutdown of facilities for more than a week.

Vulnerability

Society

The entire town of Gill 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.

Vulnerable Populations

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 266 housing units in Gill, or 42% of all housing units in town, were built prior to the 1970s when the first building code went into effect in Massachusetts. An estimated 9 mobile homes are located in Gill, accounting for 1% of the total housing stock.[20] Table 3-28 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a tornado event.

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

Table 3-28: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583
Note: Individuals and households may be counted under multiple categories.
Source: U.S. Census American Community Survey 2013-2017 Five-Year Estimates.

In addition, residents, workers, and visitors to Gill who are outside during a tornado are vulnerable. People doing construction, farming, or other outdoor work may not have time to seek adequate shelter. Residents and visitors partaking in Gill's outdoor recreation activities are also vulnerable. Areas such as Barton Cove where many people may congregate for outdoor picnics, camping, and boating, are potentially vulnerable.

Many of the buildings on the Northfield Mount Hermon campus, including student dormitories, were constructed prior to the State Building Code going into effect in the 1970s and may be susceptible to wind damage from a tornado.

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, 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 Gill are exposed to tornado events. Table 3-29 identifies the assessed value of all residential, open space, commercial, industrial, tax exempt and municipal land uses in Town, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a tornado.

Table 3-29: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section; FY2019 Gill Assessor data.

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, Gill has a “Low” vulnerability to tornadoes. Tornadoes are not common occurrences in Gill, but could 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, housing built prior to State building codes and 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 Gill’s areas of greatest concern regarding tornadoes.

Tornado Hazard Problem Statements
• An estimated 42% of Gill's housing stock, as well as much of the student housing on the Northfield Mount Hermon campus, was built prior to building codes that require structures to withstand high winds; 1% of Gill's housing stock are mobile homes.
• Residents, workers, and visitors working or recreating outdoors are susceptible to impacts from a tornado.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies. The Town lacks staff capacity to operate a shelter within its borders.
• Gill's reliance on Route 2 as the major transportation route in town, especially for large commercial vehicles that do not have a viable alternative, places residents and emergency responders at risk if the road becomes blocked due to damage from a tornado.
• The Stoughton Place low-income senior housing complex lacks a back-up generator.
• The public safety complex, which serves as the Town's Emergency Operations Center (EOC) relies on internet phone service. In the event the internet is down, there is no back-up phone system or internet for the EOC. The Police department in particular relies on the internet for accessing police records. The MBI fiber cable is aboveground and could be susceptible to damage. It is unknown how quickly the State would be able to repair the system if damaged.
• The Gill Elementary School should be wired with a transfer switch for a portable generator.
• Continue program of tree maintenance & trimming along roads. Make efforts to have the State do a similar program along its highways in Gill (Route 2 and Route 10).
• The Town does not have gasoline storage for Town-vehicles, placing departments that utilize gasoline vehicles, such as the Gill Police, at risk of running out of fuel during a prolonged power outage. The gas station in town is not equipped with a back-up generator. A regional plan is needed to insure reliable access to fuel during extended power outages.

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 3-9: 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 by natural events, human activity, or prescribed fire. Wildfires often begin unnoticed but spread

[21] Abatzoglou and Williams, 2016
[22] Romps et al., 2014

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 Town 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 towns. 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

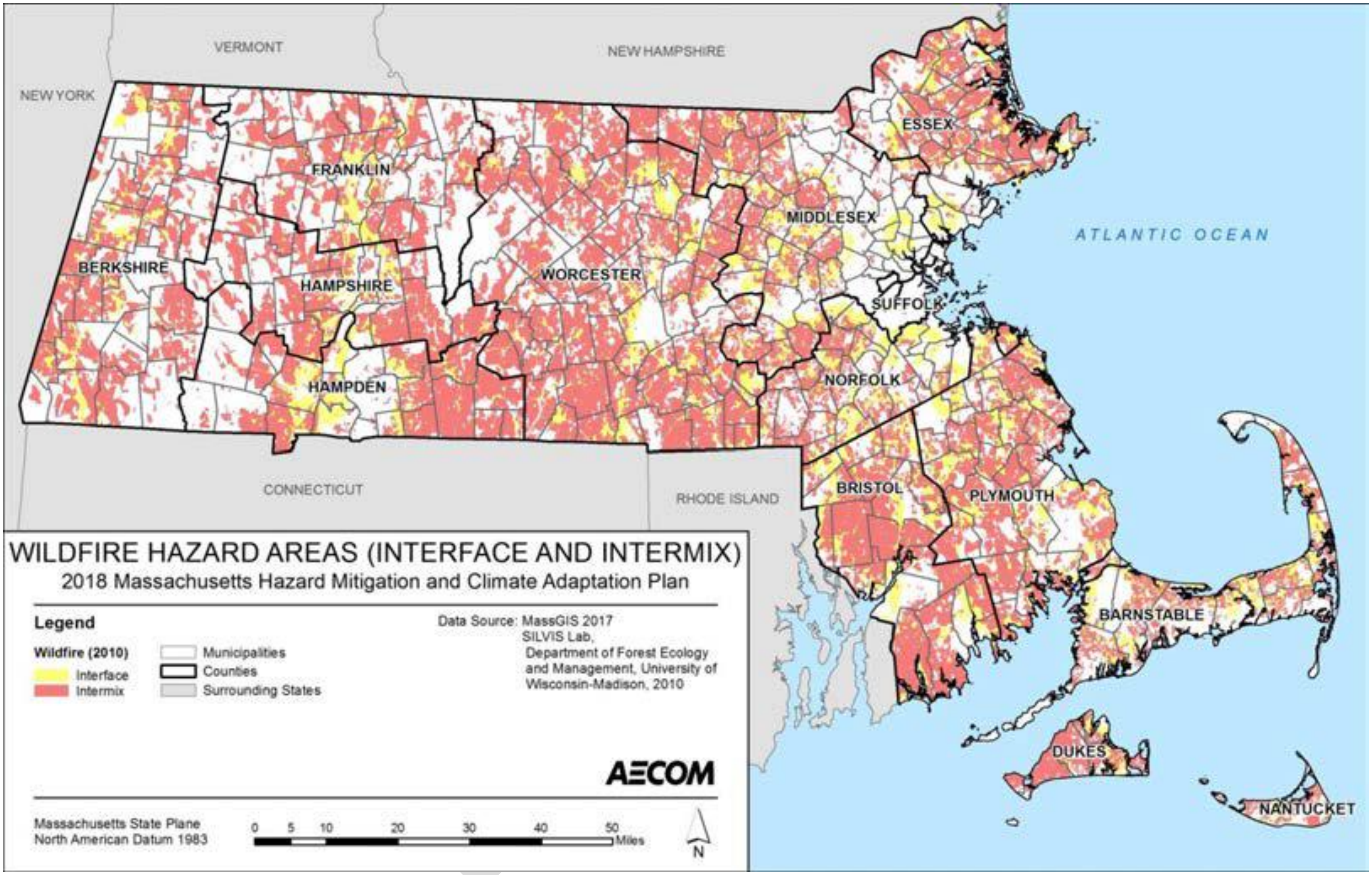
The ecosystems that are most susceptible to the wildfire hazard are pitch pine, scrub oak, and oak forests, as these areas contain the most flammable vegetative fuels. Other portions of the Commonwealth are also susceptible to wildfire, particularly at the urban-wildland interface. The SILVIS Lab at 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 3-10. Inventoried assets (population, building stock, and critical facilities) were overlaid with these data to determine potential exposure and impacts related to this hazard. Gill has many areas of "intermix" zones within town.

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 3-11 illustrates the areas identified for the Commonwealth. Gill falls partly within the "High" wildfire risk area. The entire town of Gill, which is approximately 60% forested, is at risk for wildfire. In particular, the Hazard

Mitigation Planning Committee identified the heavily forested area in the southeast section of town around Darby Hill and Pisgah Mountain as an area with a higher potential for wildfire. The center of town lacks an adequate water supply for firefighting, and is therefore also at risk.

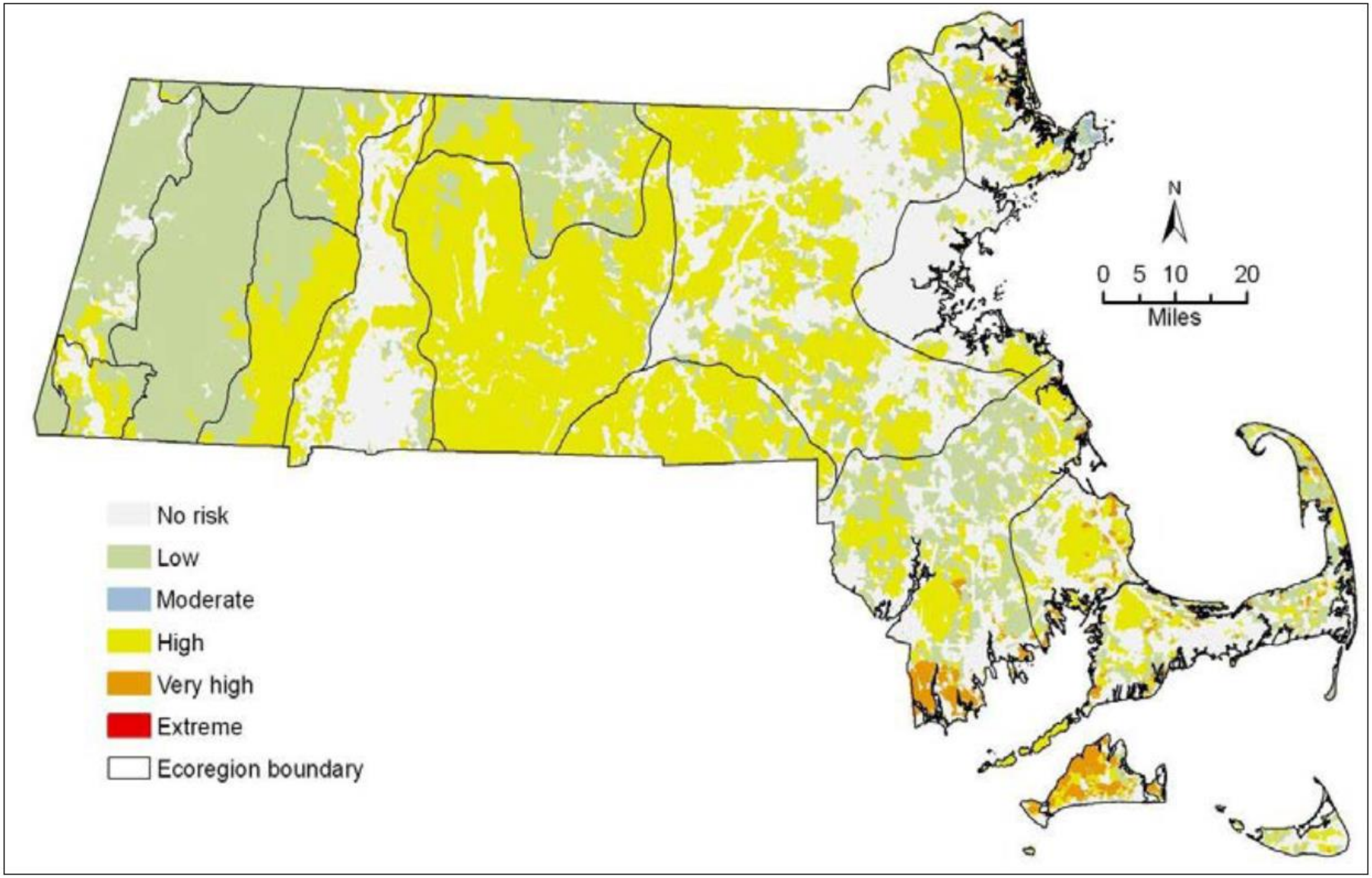
Early detection of wildfires is a key part of the Bureau’s overall effort. Early detection is achieved by trained Bureau observers who staff the statewide network of 42 operating fire towers. During periods of high fire danger, the Bureau conducts county-based fire patrols in forested areas. These patrols assist cities and towns in prevention efforts and allow for the quick deployment of mobile equipment for suppression of fires during their initial stage. Figure 3-12 displays the Bureau’s fire control districts and fire towers in Massachusetts.

Figure 3-10: Wildland-Urban Interface and Intermix for the Commonwealth of Massachusetts



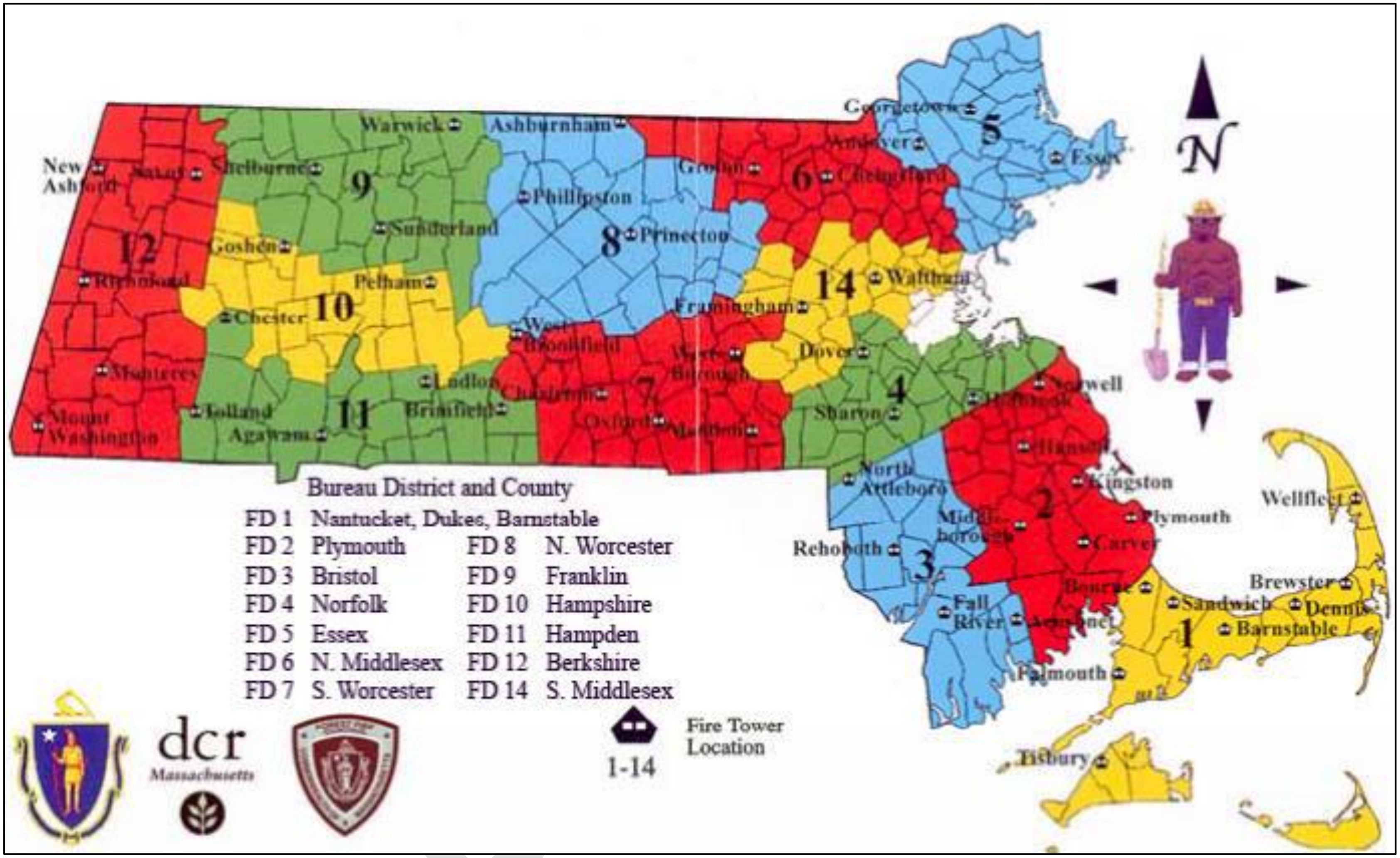
Source: Massachusetts State Hazard Mitigation and Climate Adaptation Plan. September 2018

Figure 3-11: 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 3-12: 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.

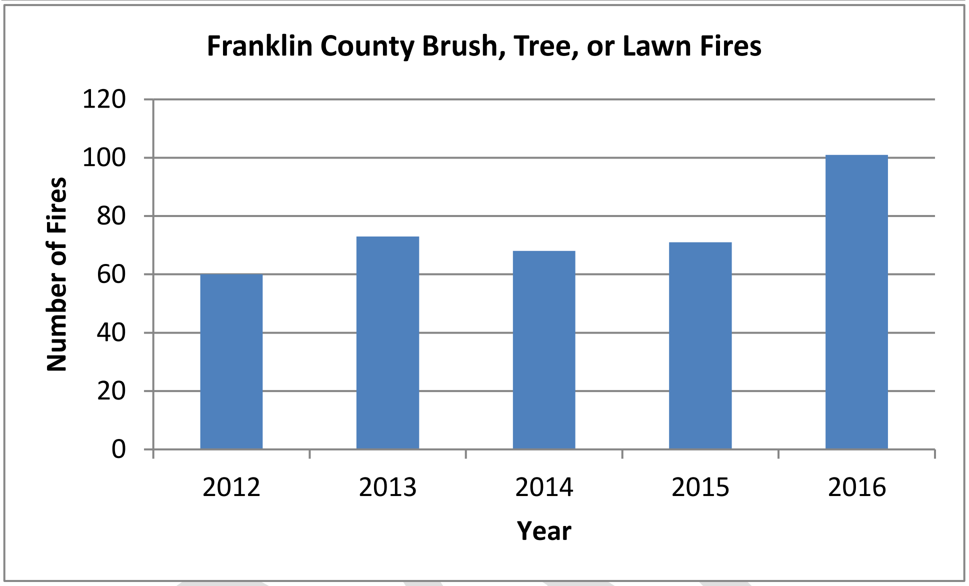
Previous Occurrences

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 3-13). These fires may

[24] (NPS, n.d.).

be started on residential lots to clear grass, leaves, brush and other woody debris and become a problem when the homeowner can no longer control them. Other types of fires may be started by campground visitors, or others. During 2016, Franklin County and Massachusetts experienced one of the worst droughts in the last 50 years.

Figure 3-13: Outdoor Vegetation Fires in Franklin County 2012 - 2016



Source: Massachusetts Fire Incident Reporting System County Profiles.

Gill is approximately 60% forested and therefore vulnerable to wildfires. In March 2019, a brush fire on North Cross Road in Gill burned down a barn. The Turners Falls, Bernardston, Greenfield, Deerfield, Northfield, Erving, and Shelburne fire departments assisted the Gill Fire Department with putting out the fire. No other significant brush fires or wildfires have impacted the Town in recent years.

Areas of concern, or critical facilities, such as schools and senior housing complexes are important to identify because these populations may need special assistance in times of an emergency. In Gill, these areas include the Stoughton Place senior housing complex, the Gill Elementary School, the Giving Tree School, Four Winds School, and the Mountain Road School (daycare). In addition, the Northfield Mount Hermon School and Barton Cove campground may also be areas considered critical facilities because of the potential need for community assistance in time of emergency and/or special communication efforts. Currently the campground has an existing radio communication system with the Northfield Mountain recreation facility for notification in times of emergency, though only when staffed by a seasonal ranger.

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, Gill 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 Gill 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 Gill from a wildfire is to the natural environment. Otherwise, the impact of a wildfire in Gill would likely be “Limited,” 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.

<u>Vulnerable Populations</u>

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 3-30 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during a wildfire event.

Table 3-30: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583

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 ($CO2$), 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 3-31 identifies the assessed value of all residential, open space, commercial, industrial, tax exempt and municipal land uses in Town, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of a wildfire.

Table 3-31: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section; FY2019 Gill Assessor data.

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.

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.

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, Gill faces a “Medium” vulnerability from wildfire and brushfires. While wildfires have caused minimal damage, injury and loss of life to date in Gill, 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 Gill 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 Gill regarding wildfires.

Wildfire Hazard Problem Statements
• Many residents in Gill live within or adjacent to heavily forested areas.
• The Fire Department should continue to maintain access to existing water sources. The center of town lacks an adequate water supply for firefighting.
• A copy of all forest cutting plans submitted to the Conservation Commission should be distributed to the Fire Department. The plans include the location of wood roads and access trails that could be used in the event of a wildfire.
• The Gill Fire Department is interested in seeing a pond on the Northfield Mount Hermon campus dredged and a dry hydrant installed for firefighting purposes at the school.
• Continue offering fire education in the Town newsletter and on the Town website.

EARTHQUAKES

Potential Impacts of Climate Change

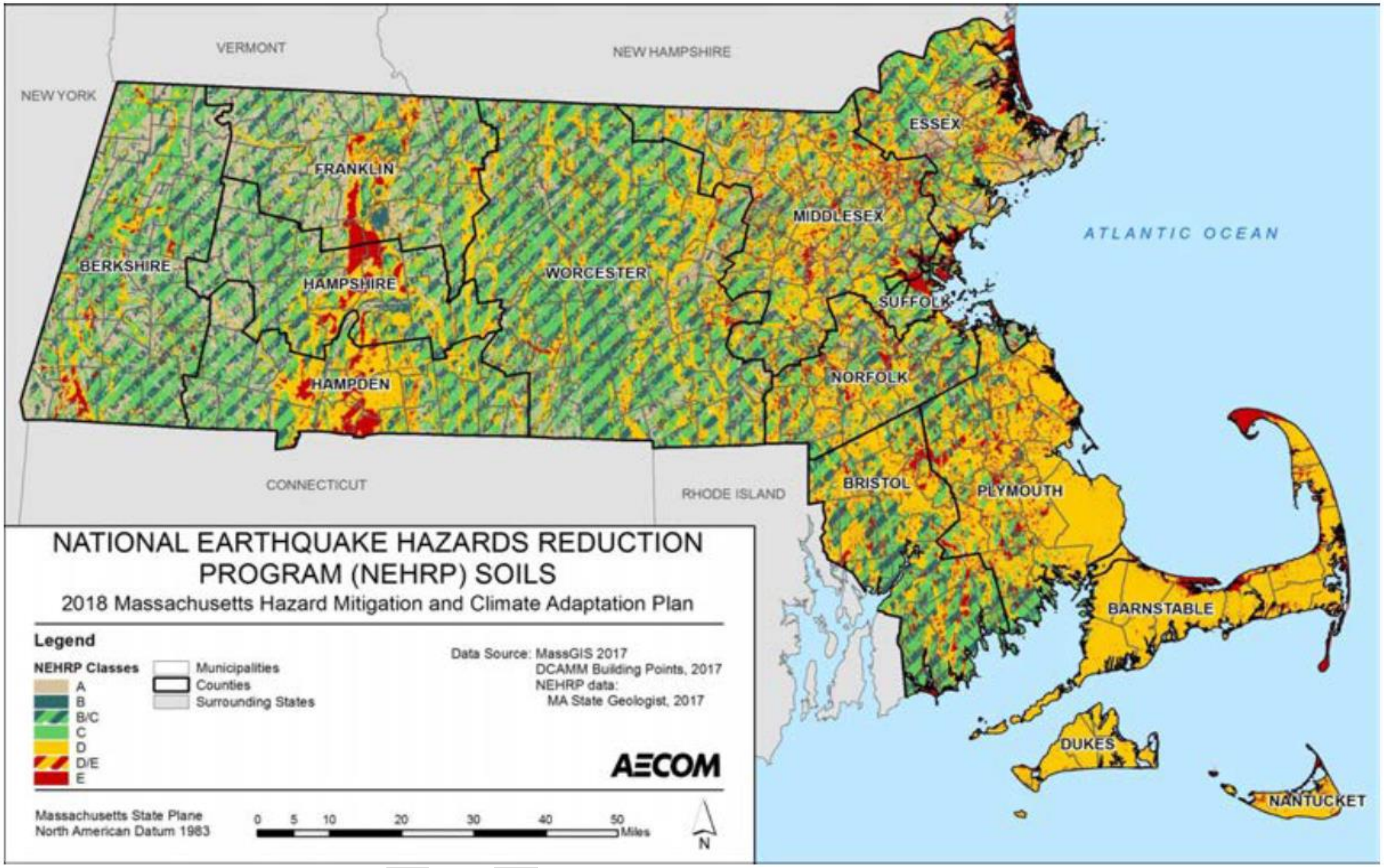
The State Hazard Mitigation and Climate Adaptation Plan does not identify any effects of climate change on the earthquake hazard in Massachusetts.

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 3-14.

Figure 3-14: 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]

According to the United States Geological Survey, a fault line extends north-south along the Connecticut River Valley, passing just east of Gill. The fault was originally responsible for the creation of the Connecticut River. Because of the regional nature of the hazard, the entire town is susceptible to earthquakes, and the location of occurrence would be "large," with over 50% of the town 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

[25] (USGS, 2012).

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 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 3-32 and 3-33 summarize the Richter scale magnitudes, Modified Mercalli Intensity scale, and associated damage.

Table 3-32: Richter 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

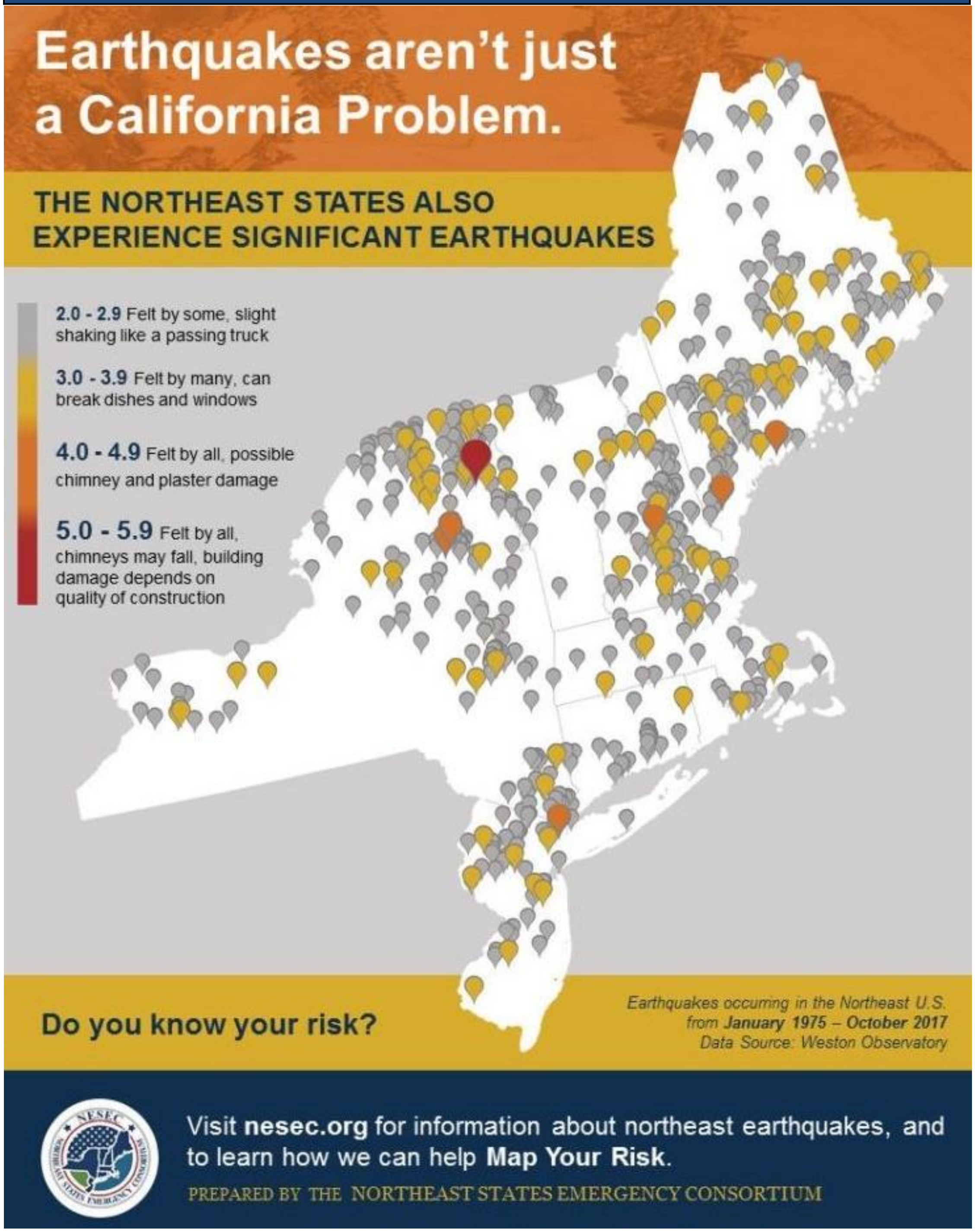
Table 3-33: Modified Mercalli Intensity Scale for and Effects			
Scale	**Intensity**	**Description of Effects**	**Corresponding Richter Scale Magnitude**
I	Instrumental	Detected only on seismographs.	
II	Feeble	Some people feel it.	< 4.2
III	Slight	Felt by people resting; like a truck rumbling by.	
IV	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 3-15). Damaging earthquakes have taken place historically in New England (Table 3-34). 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 Town of Gill are shown in Figure 3-15. There is no record of any damage to the Town of Gill as a result of these earthquakes.

Figure 3-15: Earthquakes Occurring in the Northeast from 1975 - 2017



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

Table 3-34: 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, Gill 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.

Gill faces potentially “Catastrophic” impacts from earthquakes, with more than 50% of property damaged in the affected area.

Vulnerability

Society

The entire population of Gill 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.

<u>Vulnerable Populations</u>

The populations most vulnerable to an earthquake event include people over the age of 65 (17% of Gill’s population) and those living below the poverty level (5.8% of Gill’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 266 housing units in Gill, or 42% of all housing units in town, were built prior to the 1970s. An estimated 9 mobile homes are located in Gill, accounting for 1% of the total housing stock.[26] Additionally, much of the student housing on the Northfield Mount Hermon campus was built prior to 1970.

Earthen dams and levees are highly susceptible to seismic events, and the impacts of their eventual failures can be considered secondary risks for earthquakes. Dam failure at Firstlight’s Northfield Mountain Pumped Storage Hydroelectric Facility in Gill, or any of the high hazard dams on the Connecticut River upstream of Gill could affect the town and are discussed in more

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

detail in the Dam Failure section.

Health Impacts

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.

Economic Impacts

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 Gill are exposed to the earthquake hazard. Table 3-35 identifies the assessed value of all residential, open space, commercial, industrial, tax exempt and municipal land uses in Town, and the losses that would result from 1%, 5%, and 10% damage to this inventory as a result of an earthquake.

Table 3-35: 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	$121,345,570	$1,213,456	$6,067,279	$12,134,557
Open Space	$0	$0	$0	$0
Commercial	$11,725,306	$117,253	$586,265	$1,172,531
Industrial	$16,542,800	$165,428	$827,140	$1,654,280
Tax Exempt & Municipal	$74,596,300	$745,963	$3,729,815	$7,459,630
Total	**$224,209,976**	**$2,242,100**	**$11,210,499**	**$22,420,998**

Source: Massachusetts Department of Revenue - Division of Local Services, Municipal Databank/Local Aid Section; FY2019 Gill Assessor data.

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. Evacuation and transportation to emergency shelters and hospitals from Gill relies heavily on bridges.

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, Gill has a "Medium" vulnerability to earthquakes. The following problem statements summarize Gill's areas of greatest concern regarding earthquakes.

Earthquake Hazard Problem Statements
• Approximately 266 housing units in Gill, or 42% of all housing units in town, as well as much of the student housing on the Northfield Mount Hermon campus, were built prior to the 1970s when building codes first went into effect in Massachusetts.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies, however, these shelters may be inaccessible after an earthquake if bridges are damaged. The Town lacks staff capacity to operate a shelter within its borders.
• Gill's reliance on Route 2 as the major transportation route in town places residents and emergency responders at risk if the road is damaged by an earthquake. The Town's reliance on bridges to access neighboring communities also places it at risk in the event of an earthquake.
• The public safety complex, which serves as the Town's Emergency Operations Center (EOC) relies on internet phone service. In the event the internet is down, there is no back-up phone or internet system for the EOC.

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.

Location

The Turners Falls Dam is located both in Gill and Montague, southwest of the Gill-Montague

Bridge over the Connecticut River. The Connecticut River serves as the boundary that separates the towns of Gill and Montague. The Turners Falls Dam is classified as a High Hazard Potential dam by the MA DCR Office of Dam Safety. The Owner and Caretaker of the dam is FirstLight Power Resources. Town officials have on file the Emergency Action Plan for the Turners Falls Dam. According to the inundation maps of the Emergency Action Plan, there are no areas of Gill that would be impacted by the failure of this dam**.**

The fire pond on the Northfield Mount Hermon campus has a dam with a low hazard rating, according to school officials. This dam has been registered with the DCR Office of Dam Safety, but has not been inspected. The School is planning on completing some work on the dam, including installing a new outlet structure, in conjunction with putting in a new water line. The Gill Fire Department is interested in seeing the pond dredged and a dry hydrant installed to allow for water supply in the event of a fire on campus.

Northfield Mountain Pumped Storage Project located east of Gill in Erving is owned and maintained by FirstLight Power Resources. The Emergency Action Plan for this facility was produced by FirstLight Power Resources and includes inundation maps for the Northfield Main Dam and the Northwest Dike of the Northfield Mountain Reservoir in Erving. Both the Dam and the Dike are classified as Significant Hazard Potential dams by the DCR Office of Dam Safety. According to inundation maps included in the Emergency Action Plan, if the Dike were to fail, floodplain areas in Gill along the Connecticut River south of Four Mile Brook in Northfield would be impacted. No additional areas, outside of the floodplain were identified as being significantly impacted.

Upon failure of the dike, residents would have approximately 36 minutes to 1 hour and 24 minutes before flooding. However, according to these maps, if the Dam failed, the floodplain and additional areas in Gill along the Connecticut River south of the Millers River would be impacted. In particular residences and businesses located in the Riverside residential neighborhood would be greatly impacted. Upon failure, residents would have approximately 39 to 48 minutes before flooding. There is currently no flood warning siren in the Riverside neighborhood. FirstLight has implemented a reverse call system for residences within the inundation area of the dam or dike, which would send a message to registered phone numbers within minutes of a failure.

The Harriman Dam located in Whitingham, VT stores waters from Lake Whitingham, the head source of the Deerfield River. According to the Emergency Action Plan for the dam, the Town of Gill is included on the inundation maps. However, according to these maps, the only area of Gill identified to be impacted by flooding if dam failure were to occur is the Fall River outlet area. No residential or commercial structures are found in this area.

Of additional concern is the Moore Dam, owned by TransCanada and located on the Connecticut River in the towns of Littleton, New Hampshire, and Waterford, Vermont, approximately 158 miles upstream from Gill. According to the Emergency Action Plan, flooding caused by a failure of the dam would reach Gill within 23 hours. Under Probable Maximum Flood conditions, flood waters would inundate a section of Munns Ferry Road and the area surrounding the intersection of River Road and Pisgah Mountain Road.

Additional dams found upstream on the Connecticut River in neighboring states may pose a hazard to the Town of Gill. Some publicly owned reservoirs and dams that are located upstream of Gill include the Vernon Dam, Townshend Lake and North Springfield Lake in Vermont, and Surry Mountain Lake and Otter Brook Lake in New Hampshire .

On the Northfield Mount Hermon campus, beavers have dammed up the Dry Brook, causing two main problems: contamination of the school's water supply, and flooding of a field used for agriculture, thereby damaging crops and removing topsoil. The school has spent approximately $2,000 so far on beaver removal in the area. In addition, the utility department at the school monitors the area on a monthly basis. In August 2011, flooding from Tropical Storm Irene damaged a beaver deceiver in the area. The school is working with the U.S. Department of Agriculture with the hopes of receiving funding to replace the device. Overall the beaver problem in this area will require ongoing maintenance, monitoring, and the removal of beavers. The school anticipates spending roughly $1,000 a year in these efforts.

Beaver activity has caused property damage in a number of places throughout town (identified on the Critical Facilities and Infrastructure map). The largest problem caused by beavers is flooding of farmland. The Town has explored the option of trapping and removing beavers from certain areas, but found the process to be too cumbersome. Residents can make specific requests to have beavers removed from their land.

A dam failure in Gill would impact an "isolated" location, affecting less than 10% of the town.

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.

Previous Occurrences

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

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.

According to FirstLight staff at Northfield Mountain, the next Emergency Action Plan (EAP) and dam inundation maps for the facility will include an extreme weather scenario.

Impact

A dam failure in Gill is likely to have a limited impact, with more than 10% of property damaged or destroyed in the affected area. The majority of the land within the dam inundation areas in Gill are not developed, but do include farmland and bridges that may be impacted.

Vulnerability

Dam failures, while rare, can destroy roads, structures, facilities, utilities, and impact the population of Gill. Existing and future mitigation efforts should continue to be developed and employed that will enable Gill 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

<u>Vulnerable Populations</u>
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. In Gill, the Riverside neighborhood could be impacted by dam failure at the Northfield Mountain Pumped Storage Facility. This neighborhood recently qualified for Community Development Block Grant funding, demonstrating that a majority of residents in the neighborhood are low income.

<u>Economic Impacts</u>

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 Gill are vulnerable to a dam failure. Buildings located within the floodplain are also vulnerable to dam failure in Gill. Table 3-11 in the Flooding section provides the 2019 assessed building values for significant structures partially or completely located in the floodplain in Gill. Together these buildings are valued at $831,000.

Environment

Examples of environmental impacts from a dam failure include:

- 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

[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

- Degradation to wetlands
- Loss of topsoil or vegetative cover
- Loss of indigenous plants or animals[28]

Vulnerability Summary

Based on the risk assessment the Town has a "Low" vulnerability from dam or levee failure.

Dam Failure Hazard Problem Statements
• New residents in the Riverside neighborhood may not be aware of the reverse call system or how to register for notification of a dam failure. Investigate with FirstLight Power Resources the potential for installing a flood warning siren in the Riverside neighborhood.
• Gill has agreements with Montague and Greenfield to use regional shelters in those towns during emergencies. The Town lacks staff capacity to operate a shelter within its borders. If bridges are impacted by a dam failure, the regional shelters would be inaccessible.
• Gill's reliance on Route 2 as the major transportation route in town places residents and emergency responders at risk if the road were flooded, blocked, or damaged by a dam failure. The Town's reliance on bridges to access neighboring communities also places it at risk in the event of a dam failure.
• Develop a beaver management plan that identifies locations of existing and potential beaver activity, the extent of flooding caused at each location, and possible solutions. The plan should prioritize projects in the locations that require intervention.

[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

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 3-15: 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.

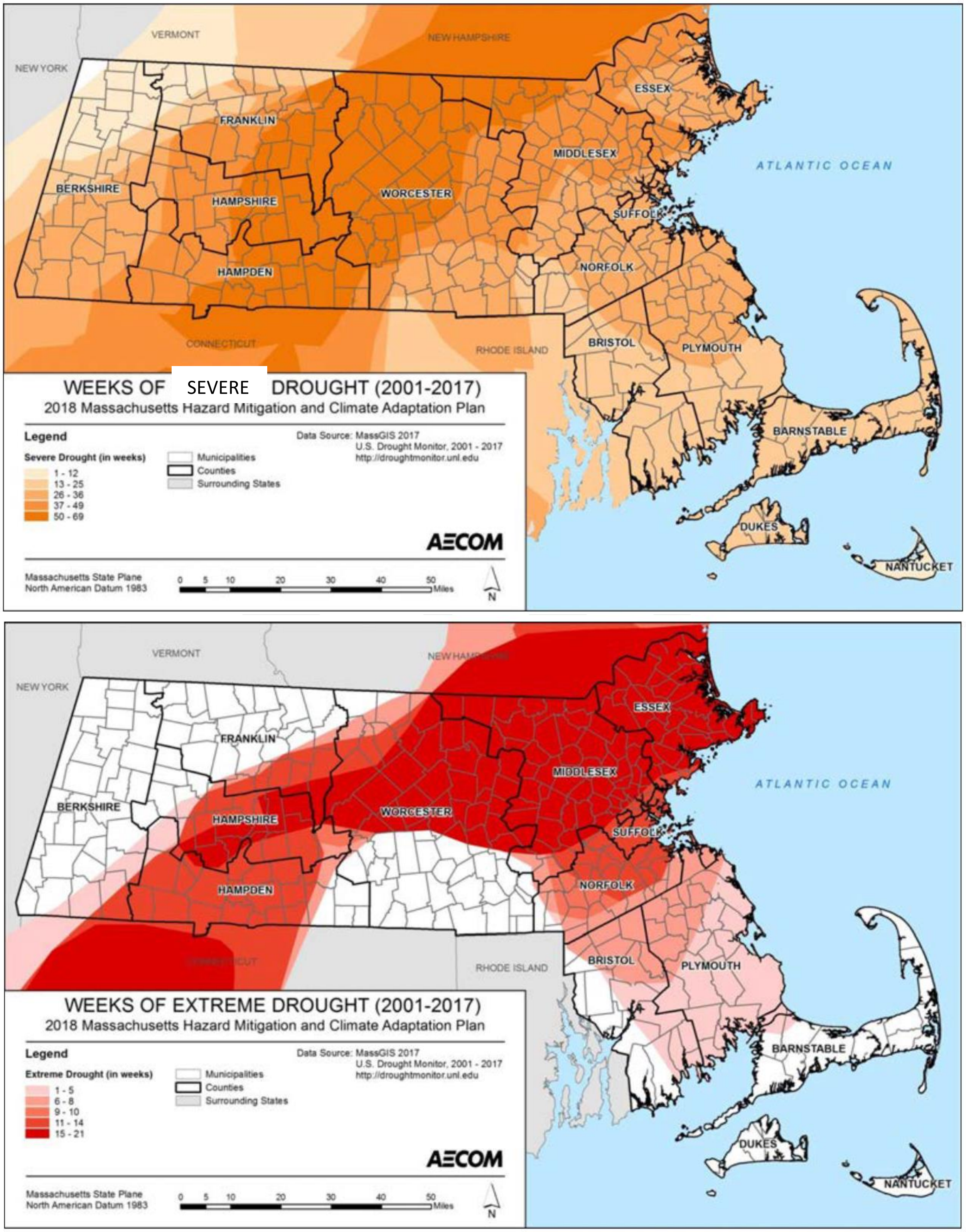
Highly urbanized areas with traditional stormwater drainage systems tend to result in higher peak flood levels during rainfall events and rapid decline of groundwater levels during periods of low precipitation. Thus, the hydrology in these areas becomes more extreme during floods and droughts.[29] The 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

Gill 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 3-17). Because of this hazard's regional nature, a drought would impact the entire town, resulting in a "large" location of occurrence, or more than 50 percent of total land area affected.

[29] ERG and Horsley Witten Group, 2017

Figure 3-17: 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 town residents depending on whether the residents' water supply is derived from a private well or the public water system. The Gill campus of the Northfield Mount Hermon School has a water supply system that serves the campus. In addition, the Riverside neighborhood and western Route 2 area near Turners Falls and Greenfield is served by the Riverside Water District that has water supplied from the Town of Greenfield. 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 3-36: 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

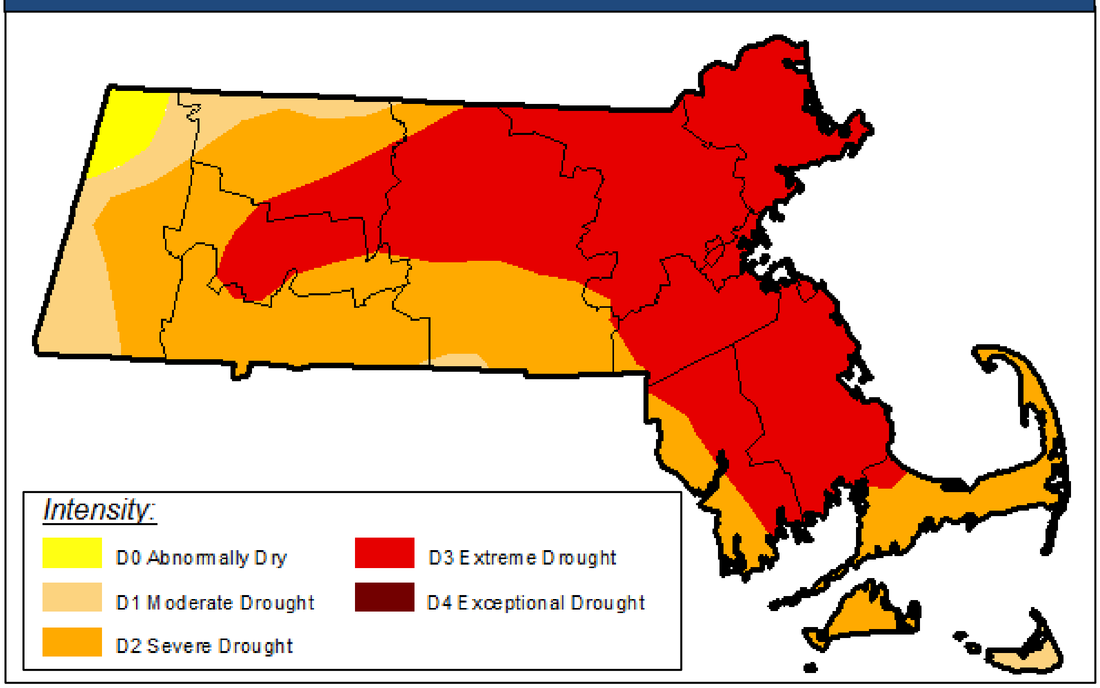
In Massachusetts, six major droughts have occurred statewide since 1930. They range in severity and length, from three to eight years. In many of these droughts, water-supply systems were found to be inadequate.

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 3-18).[30] By May 2017, the entire Commonwealth had returned to "normal" due to wetter-than-normal conditions in the spring of 2017.

Figure 3-18: Drought Conditions in Massachusetts on September 20, 2016



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

According to Gill Board of Health records, applications were received for two private residential wells to be drilled in late 2016 to replace shallow wells. It is not certain that the drought caused the need for these new wells, but it is likely the case considering the timing of the applications.

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

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 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. In Gill, drought has a "moderate" probability of future occurrence, or between a 2% and 25% chance of occurring in any given year.

Impact

Due to the water richness of western Massachusetts, Gill 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. Firefighting capabilities could be compromised in a drought if aquifers, fire ponds, or rivers used for pumping water are low. In general, the impact of a drought would be “minor” 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 Gill 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. The Riverside Water District serves residents and businesses in the Riverside area of Town. Drinking water is supplied by the Greenfield Water Department. Back-up supply would either come from Greenfield (via the Leyden Glen Reservoir), or residents would need to use bottled water in the event that Greenfield could not provide water to the district. The Northfield Mount Hermon campus water system does not have a back-up water supply source. Other parts of Gill 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.

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
- 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 Gill's environment as well as economic damage

[31] Clark et al., 2016

related to the loss of valuable natural resources.

Vulnerability Summary

Based on the above assessment, Gill 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 Gill's areas of greatest concern regarding droughts.

Drought Hazard Problem Statements
• Northfield Mount Hermon School is working on drilling a new well and pump head, which will increase its stores of drinking water, and address the need for a back-up water supply.
• The Riverside Water District does not have a back-up water supply if Greenfield cannot supply water to the district.
• A drought would increase in the risk of wildfire in Gill, and could make the forests in town more susceptible to damage from storms, pests and invasive species.
• A drought could compromise firefighting efforts, particularly in areas of town where the Fire Department relies on surface water bodies to fight a fire. Specifically the center of town does not have easy access to a water supply.

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 3-19: 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.

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.[33]

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:

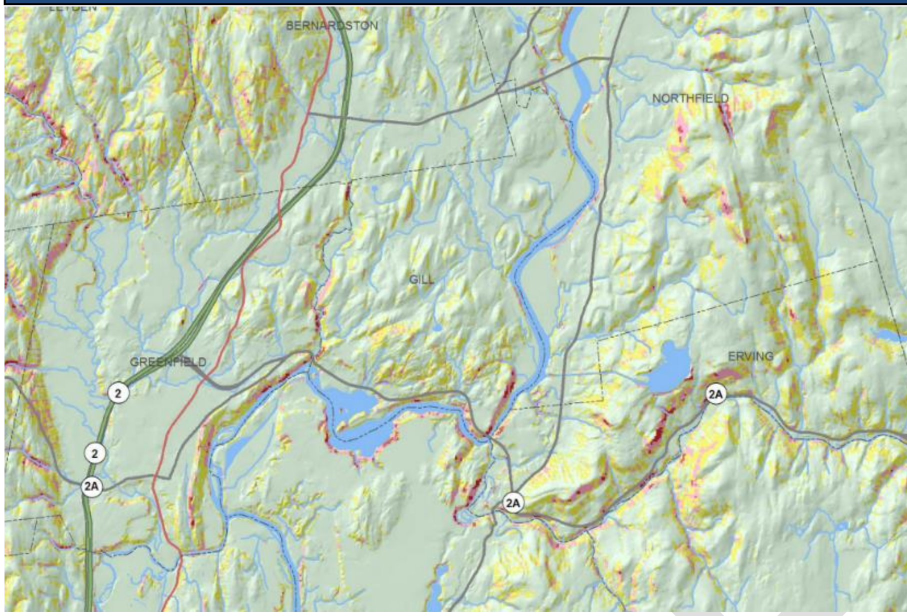
- vibrations from machinery or traffic;
- blasting;
- earthwork which alters the shape of a slope, or which imposes new loads on an existing slope;
- in shallow soils, the removal of deep-rooted vegetation that binds colluvium to bedrock; and
- construction, agricultural or forestry activities (logging)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

[32] Mabee and Duncan, 2013
[33] Mabee, 2010

Figure 3-20: Slope Stability Map for Gill and Surrounding Towns



Map Legend

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

Source: Massachusetts Geologic Survey and UMass Amherst, 2013. https://mgs.geo.umass.edu/biblio/slope-stability-map-massachusetts

Gill has areas in town with high and moderate landslide rankings. These areas are shown in Figure 3-20 and are mostly located along the banks of the Connecticut River in the southeast section of town and along the banks of the Fall River on the western border of town. A specific area of concern is the Factory Hollow section of Route 2, where large boulders could be susceptible to a landslide that would block Route 2. In addition, farmland has been lost to erosion along the Fall River in the Bascom Hollow section of town.

The location of occurrence for landslides is rated as "Isolated," affecting less than 10% of the town.

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 timeframe when a landslide might occur. The distribution of susceptibility in Gill 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

In Gill, the banks along the Connecticut River are susceptible to slumping and mass wasting as a result of erosion and bank destabilization. The Center Cemetery adjacent to Dry Brook is at risk from streambank erosion. More detail is provided in the Flooding section. No other areas of Gill have experienced a landslide in recent history.

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 Gill. There is a "very low" probability, or less than 1% 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 Gill would be "minor" with only minor property damage in the affected area. Route 2, the Town's major roadway, could be impacted by a landslide due to its location below some of the unstable slope areas identified in the Slope Stability Map.

Vulnerability

Society

<u>Vulnerable Populations</u>
Populations who rely on potentially impacted roads for vital transportation needs are considered to be particularly vulnerable to this hazard. In Gill, some residents may be vulnerable to landslides when homes are built on property below steep slopes.

<u>Health Impacts</u>
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 Town 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, Gill has a hazard index rating of “Low” for landslides. The following problem statements summarize Gill’s areas of greatest concern regarding landslides.

Landslide Hazard Problem Statements
• The banks along the Connecticut River are susceptible to slumping and mass wasting as a result of erosion and bank destabilization.
• Gill's dependence on Route 2 as a primary transportation route places residents and emergency responders at risk if the road were impacted by a landslide. Specifically, the area near Factory Hollow on Route 2 is susceptible to a landslide.
• The Center Cemetery is vulnerable to streambank erosion along Dry Brook.
• Farmland has been lost due to erosion along the Fall River in the Bascom Hollow section of town and along the banks of the Connecticut River

EXTREME TEMPERATURES

Potential Impacts of Climate Change

Beyond the overall warming trend associated with global warming and climate change, Gill 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 3-21: 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

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

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 3-37.

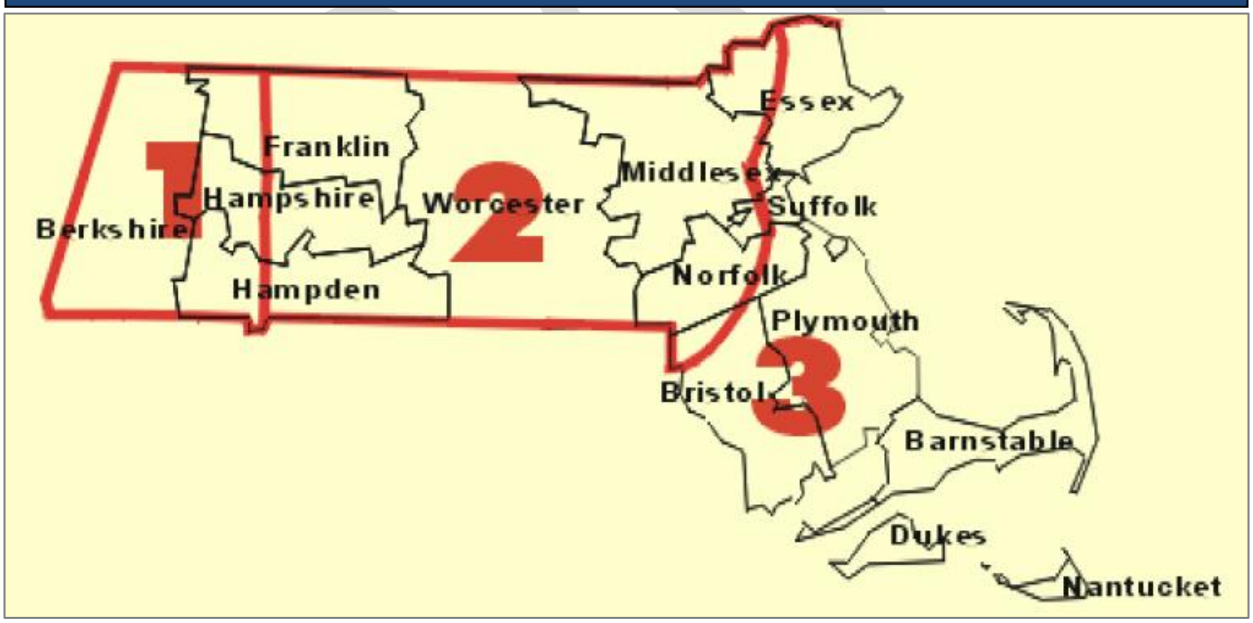
Table 3-37: Annual Average High and Low Temperatures (Greenfield)		
	July (Hottest Month)	**January (Coldest Month)**
Average High (°F)	81°	33°
Average Low (°F)	57°	12°

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 3-22. 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). Gill falls within the Central climate division.

Figure 3-22: 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 3-23 shows the Wind Chill Temperature

Figure 3-23: 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

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

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

Effective 11/01/01

Index.

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 3-24. 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

Figure 3-24: 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

with very hot, dry air, can increase the risk of heat-related impacts.

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 Gill 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 Gill 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 Gill 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.

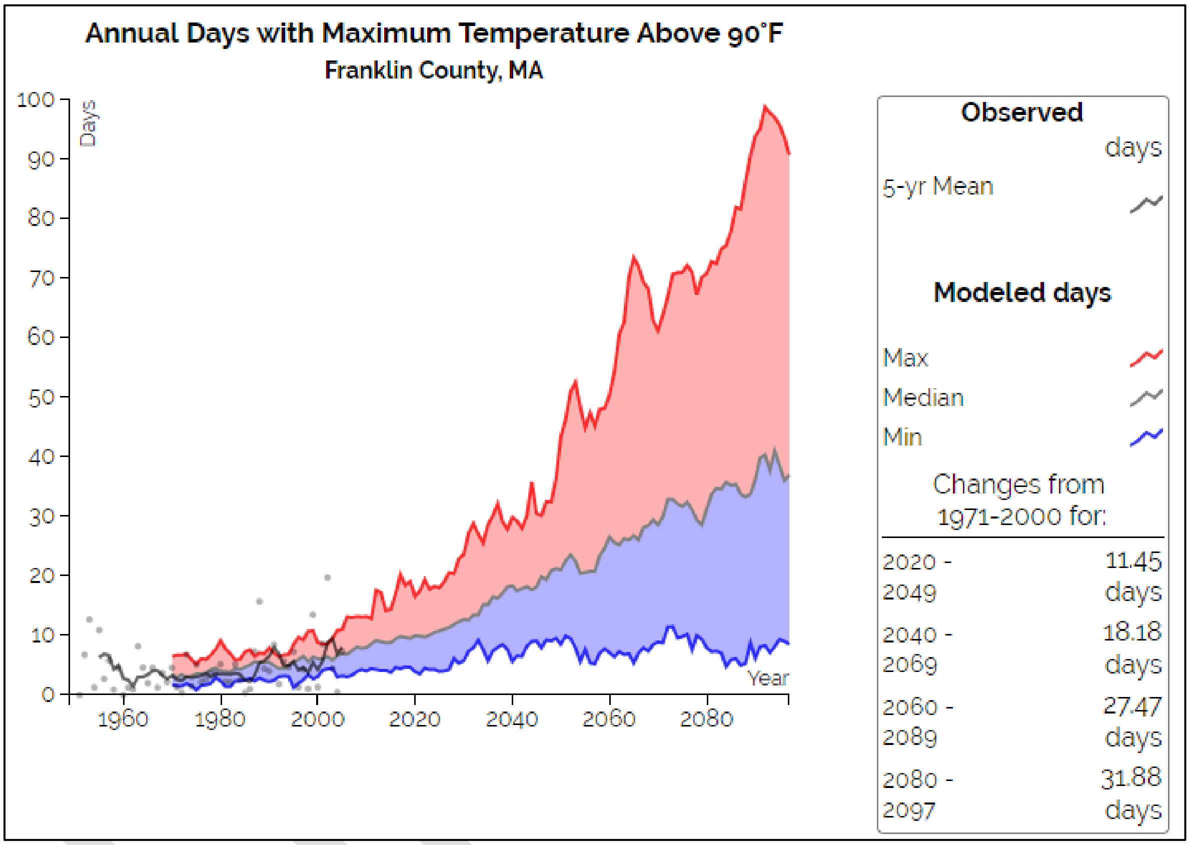
Probability of Future Events

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 3-25 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 3-25: 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 town of Gill is vulnerable to extreme temperatures.

Society

<u>Vulnerable Populations</u>

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 during extreme cold in January 2019 in Greenfield.

Table 3-38 estimates the number of vulnerable populations and households in Gill. Individuals and households may fall into multiple categories, so the numbers should not be added. Rather, the table provides Town officials and emergency response personnel with information to help plan for responding to the needs of Gill residents during an extreme temperature event.

Table 3-38: Estimated Vulnerable Populations in Gill		
Vulnerable Population Category	**Number**	**Percent of Total Population***
Population Age 65 Years and Over	267	17%
Population with a Disability	158	10%
Population who Speak English Less than "Very Well"	64	4%
Vulnerable Household Category	**Number**	**Percent of Total Households***
Low Income Households (annual income less than $35,000)	107	18%
Householder Age 65 Years and Over Living Alone	75	13%
Households Without Access to a Vehicle	18	3%

*Total population = 1,604; Total households = 583
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

[35] Hattis et al., 2011)
[36] Madrigano et al., 2013
[37] (Shi et al., 2015).

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 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 3-26. 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 3-27, 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 3-28), 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.

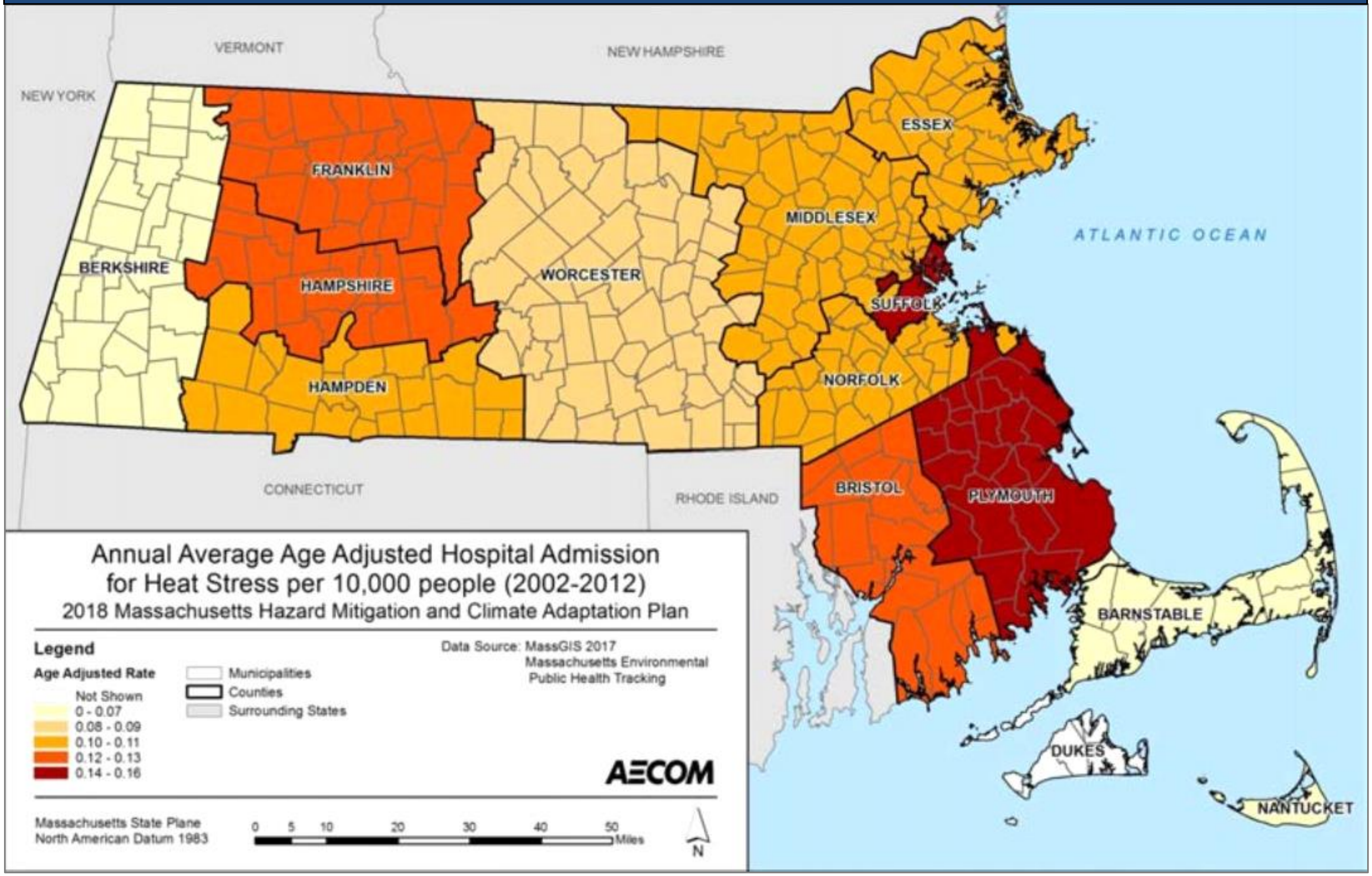
Economic Impacts

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.

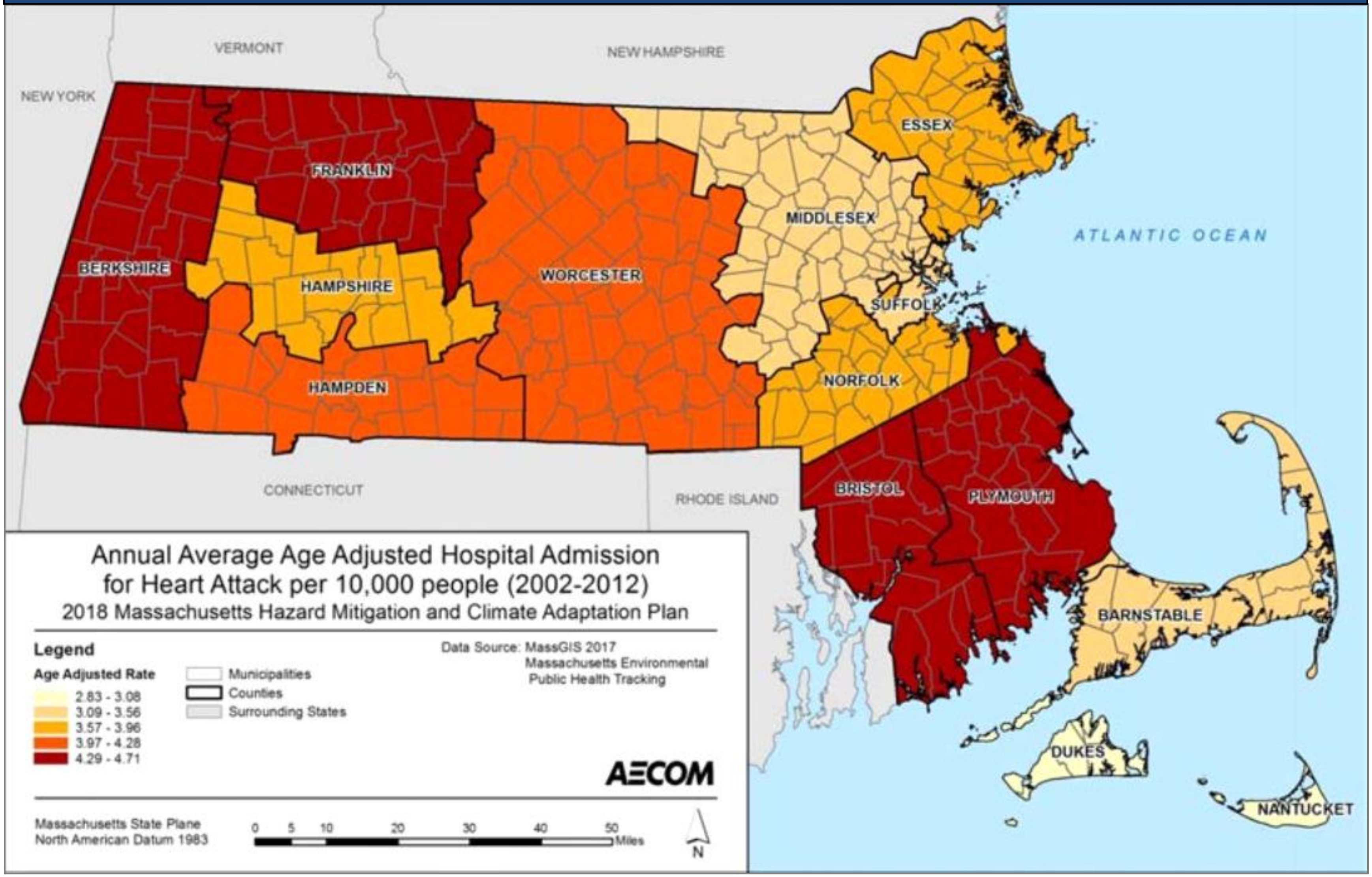
Livestock are also impacted, as heat stress can make animals more vulnerable to disease, reduce their fertility, and decrease the rate of milk production. Additionally, scientists believe the use of parasiticides and other animal treatments may increase as the threat of invasive species and pests grows.

Figure 3-26: Rates of Heat Stress-Related Hospitalization by County



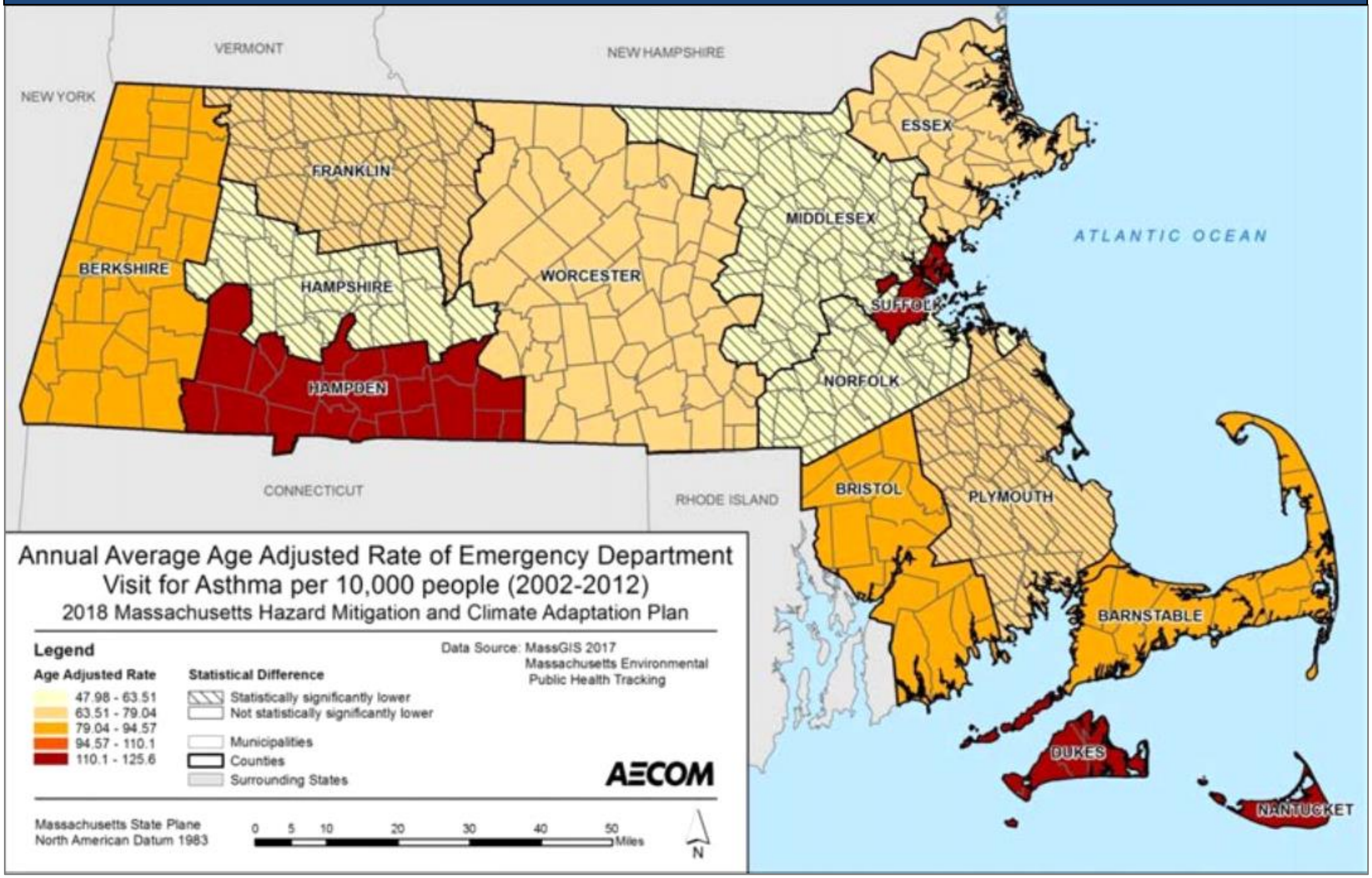
Source: Massachusetts Hazard Mitigation and Climate Adaptation Plan, September 2018.

Figure 3-27: Rates of Hospital Admissions for Heart Attacks by County



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

Figure 3-28: Rates of Emergency Department Visits Due to Asthma by County



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

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.

<u>Agriculture</u>

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]

<u>Energy</u>

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.

<u>Transportation</u>

[38] Resilient MA: http://resilientma.org/sectors/agriculture. Accessed March 4, 2019.
[39] EOEEA, 2011

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 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

[40] MassDOT, 2017
[41] Resilient MA: http://resilientma.org/sectors/transportation. Accessed March 4, 2019.
[42] MassDOT, 2017
[43] Resilient MA: http://resilientma.org/sectors/water-resources. Accessed March 4, 2019.

stations. Warmer temperatures can also lead to corrosion, water main breaks, and inflow and infiltration into water supplies.[44] 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. 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.[45] 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.[46] 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

[44] (Jha and Pathak, 2016).
[45] (MCCS and DFW, 2010).
[46] (NPS, 2016).

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 1964 and 2004.[47] 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.[48] As temperature increases, the length of the growing season will also increase.

Vulnerability Summary

Based on the above assessment, Gill has a "High" vulnerability to extreme temperatures. The following problem statements summarize Gill's areas of greatest concern regarding extreme temperatures.

[47] USGRP, 2014
[48] MCCS and DFW, 2010)

Extreme Temperature Hazard Problem Statements
• Gill's capacity to open and staff cooling and warming centers is limited. There are no formal plans in place for cooling and warming centers.
• Stoughton Place senior housing does not have back-up power. This places the residents at risk to extreme temperatures in the event of a power outage.
• Elderly residents lacking proper heating or cooling in their homes are vulnerable to extreme temperatures.
• The pipes at the elementary school could be at risk if a prolonged power outage occurs during a cold spell.

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.[49]

Figure 3-29: 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

[49] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 4, 2019.

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 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.[50]

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

[50] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 4, 2019.

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 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.[51]

Location

The damage rendered by invasive species is significant. The massive scope of this hazard means that the entire Town of Gill 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.

[51] https://masswoods.org/outsmart. Accessed March 5, 2019.

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).

Immediate threats to Gill include Bittersweet and Japanese Knotweed. Bittersweet is found climbing on large trees, eventually killing them. This has resulted in changes to portions of Gill's forests and is creating more fuel load in the forests. Japanese Knotweed has been identified along river and stream banks in town. It is known for being less effective at erosion control along banks than the native plants that it crowds out. Hogweed has been spreading along roadways in town. The State marked and removed it in the past, but it continues to spread and needs to be mowed before going to seed. It can burn skin and eyes if touched.

Invasive and aggressive plants and pests are a major concern for farmers in Gill. According to the Gill Agricultural Commission, hay and pasture crops are impacted by new grasses and weeds that are unfamiliar. New insects are getting into vegetable crops that have not been seen before. There are more instances of mold, blight, and rot among crops. Some farms in the region are moving towards more greenhouse growing to have better control over invasives and other impacts from climate change; however, this may be too expensive for smaller farms, which are more typical in Gill. Trees are declining because of invasive species and other climate change affects, including pine, ash, and sugar maples. Programs are available through the USDA Natural Resource Conservation Service to address invasive species, but these programs may not be easily accessible to all farmers.

Areas of multi-flora rose were observed in the Gill Town Forest property, located in the northwest corner of town, during a baseline inventory report in 2017. The 2014 Forest Stewardship Plan for the Town Forest notes that the forest is in generally good health, but does have some minor infestations of hemlock elongated scale, hemlock wooly adelgid, beech-bark disease, and bacterial cankers on the immature cherry. Knotweed is also present.

Overall, the location of occurrence of invasive species in Gill is "Medium," with 10% to 50% of the town impacted.

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 3-39. 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-seven of the invasive species on the list have been observed in Gill since 2010.

Table 3-39: Invasive Plants Occurring in Western Massachusetts		
Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Gill**
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 occuring 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 occuring 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 occuring in all regions of the state in aquatic habitats. Common in the aquarium trade; chokes waterways.	Y
Celastrus orbiculatus Thunb. (**Oriental bittersweet; Asian or Asiatic bittersweet**)	A perennial vine occuring 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 Monarch butterflies.	Y

Species (Common Name)	**Notes on Occurrence and Impact**	**Observed in Gill**
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
Euphorbia esula L. (**Leafy spurge; wolf's milk**)	A perennial herb occurring in all regions of the state in grasslands and coastal habitats. Grows in full sun. An aggressive herbaceous perennial and a notable problem in western USA.	ND
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.	N
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 escaping from cultivation via bird dispersal.	Y
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

Species (Common Name)	Notes on Occurrence and Impact	Observed in Gill
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
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.	N
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

Species (Common Name)	Notes on Occurrence and Impact	Observed in Gill
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.	N
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
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.	Y

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 Erving (Table 3-40). One invasive species, the Zebra mussel, was first documented in Massachusetts in Laurel Lake in Berkshire County 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 3-40: 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 towns 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.
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.

Species (Common Name)	Notes on Occurrence and Impact
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. Based on the presence of invasive species in Gill, the probability of future occurrence is “Very High.”

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.[52]

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 Gill, the entire town 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.

Vulnerable Populations

[52] This section excerpted from the MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 5, 2019.

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.[53]

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 Erving for their economic success. This includes all individuals working in forestry and agriculture-related fields, as well as those whose livelihoods depend on outdoor recreation activities such as hunting, hiking, or aquatic sports. Businesses catering to visitors who come to a town for outdoor recreation opportunities can

[53] MassWildlife Climate Action Tool: http://climateactiontool.org/content/invasive-plants-and-animals. Accessed March 5, 2019.

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 town of Gill 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

Gill is 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.[54]

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

[54] 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

Gill has a "High" vulnerability rating for invasive species. Following are problem statements highlighting the areas of greatest concern for Gill regarding invasive species.

Invasive Species Hazard Problem Statements
• Invasive species and pests are affecting Gill's forests and adding to the fuel load in the forest, increasing the risk for wildfire.
• Japanese knotweed has been identified along streams and rivers in town, and is less effective at erosion control than native species. This could lead to greater erosion, property loss and infrastructure damage, and reduced water quality due to flooding.
• Hay fields and pastures across Gill are being impacted by a variety of invasive weeds.
• Agriculture and forestry in Gill 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 farmers and foresters can afford or manage on their own.
• An inventory and assessment of priority invasive species in Gill is needed to help prioritize mitigation efforts and choose the most effective strategies for controlling specific pests, plants or pathogens, in specific locations.
• While tillage agriculture inherently controls many invasive plants in farm fields, many species, including multiflora rose, oriental bittersweet, and Japanese knotweed, become established along the edges of fields and forests.
• Education and outreach is needed to increase local awareness around invasive species and equip residents with appropriate control measures.
• Hog Weed has been found in town along road ways and is dangerous to human health. Hog Weed requires special precautions to remove.
• Gill residents are more at risk to mosquito and tick borne diseases due to climate change. Additional public health outreach is needed to educate residents about safety pre-cautions.

MANMADE HAZARDS

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, infrastructure failure, industrial and transportation accidents. Accidental events can arise from human activities such as the manufacture, transportation, storage, and use of hazardous materials.

This plan does not address all manmade hazards that could affect Franklin County. A complete hazards vulnerability analysis was not within the scope of this update. For the purposes of this plan, non-natural hazards that are of an accidental nature were evaluated. They include industrial transportation accidents and industrial accidents in a fixed facility.

Hazard Description

Hazardous materials in various forms can cause death, serious injury, long-lasting health effects, and damage to buildings, homes, and other property. Many products containing hazardous chemicals are used and stored in homes routinely. These products are also 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.

A release may occur at a fixed facility or in transit. Communities with a large industrial base may be more inclined to experience a hazardous materials release due to the number of facilities that use 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.

Location and Extent

<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. Other active truck routes in the region include Routes 5/10, Route 47, Route 116, Route 63, and Route 112. According to the Franklin County Hazardous Material Emergency Plan (HMEP), an estimated 12 or more trucks per hour travel through the region containing hazardous materials. Most of these trucks are on Interstate 91. However, approximately two vehicles per hour travel along Route 2, and up to one vehicle per hour travel along Route 10, both routes passing through Gill. In addition, the HMEP notes that all roads in the county likely have vehicles carrying hazardous materials at varying intervals. In Gill, Main Road is locally identified as a hazardous transportation route.

The HMEP also identifies the hazardous materials being carried on highways. On Route 2, which runs through Gill, the hazardous materials regularly carried on trucks carrying these materials include:

- Gasoline
- Fuel oil
- Kerosene
- LPG
- Propane
- Sodium aluminate
- Sulfuric acid
- NOS Liquids 3082

Safe and efficient transportation routes for trucks traveling 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.

Franklin County has two primary rail lines that carry hazardous materials to and through the county. No rail lines pass through the Town of Gill. The hazardous chemicals carried by rail through the county in 2013 were:

- Petroleum crude
- Liquefied petroleum
- Petroleum gases
- Sodium chlorate
- Sodium hydroxide
- Carbon dioxide
- Phenol molten
- Hydrochloric acid
- Acetone
- Methanol
- Air bag inflation
- chemicals
- Methyl methacrylate
- Alkylphenols
- Batteries, wet
- Adhesives
- Caustic alkali
- Helium, compressed
- Fire extinguisher
- chemicals
- Sulfuric acid
- Paint
- Gasoline
- Toluene
- Hydrogen peroxide

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 Environmental Protection Agency's Toxics Release Inventory (TRI) contains information about more than 650 toxic chemicals that are being used, manufactured, treated, transported, or released into the environment.

Northfield Mount Hermon is listed on the Toxic Release Inventory. In addition, the Hazard Mitigation Planning Committee identifies the following facilities in Town containing hazardous materials (Table 3-11).

Table 3-11: Hazardous Facilities in Gill

Hazardous Facility	Location	Description of Hazard
F. M. Kuzmeskus	52 Main Road	Diesel Fuel, Gasoline
NMH Water Treatment Plant	28 Mt. Hermon Road	Chlorine
NMH McCollum Arena	11 Mt. Hermon Road	Ammonia
NMH Campus Generator	21A Mt. Hermon Road	Diesel Fuel
Gill DPW	196C Main Road	Diesel Fuel
Gill Mobil Station	23 French King Highway	Gasoline, Diesel Fuel
Renaissance Excavating	390 Main Road	Diesel Fuel

Source: Gill Hazard Mitigation Planning Committee, 2019.

In addition to the above facilities, 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, farmers do use and store pesticides, herbicides and fertilizers on their property. 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 Town could take to help prepare for a hazardous materials spill on a farm would be to become familiar with the types and quantities of chemicals stored on site at the larger farms. This 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 town boundaries can also be of concern to Gill. The Vermont Yankee nuclear power plant is located on the Connecticut River in Vernon, Vermont, near the Vermont/Massachusetts border, approximately 9.5 miles from Gill center. 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.

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.[55]

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. While Vermont Yankee is no longer in operation, the storage of spent fuel at the site still presents a potential risk. Gill officials should continue to stay

[55] Vermont Department of Public Service: https://publicservice.vermont.gov/content/nuclear_decommissioning_citizens_advisory_panel_ndcap/history. Accessed July 6, 2019.

abreast of proper evacuation procedures in the event of an accident at the Vermont Yankee nuclear power plant.

Because parts of Gill falls within a ten mile radius of Vermont Yankee, the Town's emergency personnel previously participated in regular trainings that evaluated shelters, evacuation procedures, traffic control, and what equipment and materials would be needed in the event of an accident at the plant. Now that the plant is no longer in operation, these trainings are not provided. In addition, the Town had a nuclear planning document that was updated regularly. The plan still exists and could be used as a reference, but Vermont Yankee not longer provides support for updating the plan. These trainings helped the Town to be better prepared for a nuclear event, and also served as a basis for dealing with other emergencies.

Cyber Threats

A failure of networked computer systems could result in the interruption or disruption of town services (including public safety and other critical services), the disruption or interruption of the functioning of town departments, and the potential for loss or theft of important data (including financial information of the town 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 town.

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. 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. [56] These threats are not only external; many acts of cyber-crime happened from current or former employees who were given network access legitimately.

For Gill, the most likely cyber-threat effecting the town and town departments come from malware and social engineering. These crimes pray on the vulnerable and unprepared and every individual and organization that connects a device to the internet is a potential mark.

Social Engineering:

Social engineering involves obtaining confidential information from individuals through deceptive means by mail, email, over the phone, and increasingly through text messages.[57] These techniques are referred to as 'Phishing'.

Malware:

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 activity without their permission. The most common way for malware to infect a town'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

[56] NYC Hazard Mitigation, Cyber Threats, https://nychazardmitigation.com/hazard-specific/cyber-threats/what-is-the-hazard/

[57] Cybersecurity Precautions, MA Executive Office of Technology Services & Security, 2017

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.

In Gill, phishing attempts to the Treasurer and the Fire Department have been identified. In addition, the Committee estimates that close to $50,000 in cyber theft has been reported to the Police Department by residents. The Franklin County Regional Housing and Redevelopment Authority reports that landlord names are being used by cyber criminals to request rents be sent to over-sea accounts.

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)[58] 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.

[58] https://www.mass.gov/cybersecurity

Manmade Hazard Problem Statements
• Approximately two vehicles per hour travel along Route 2, and up to one vehicle per hour travel along Route 10, carrying hazardous materials. However, there are likely many more vehicles travelling through Gill than officially reported, especially carrying heating oil or propane.
• A spill from fixed facilities that store hazardous materials can affect nearby populations and contaminate critical or sensitive environmental areas and groundwater resources.
• Facilities located outside of Gill can affect the town – an example is hazardous materials carried downstream during flooding events. The spent nuclear fuel stored at the former Vermont Yankee Nuclear Power plant continues to be a concern for the region.
• Cyber-attacks on local government is a growing threat. Keeping up with current best practices in cyber security can be challenging for a small community like Gill. The Town and residents have experienced cyber security threats and attacks.

OTHER HAZARDS

In addition to the hazards identified above, the Hazard Mitigation Team reviewed the full list of hazards listed in the Massachusetts Hazard Mitigation and Climate Adaptation Plan. Due to the location and context of the Town, coastal erosion, coastal flooding, and tsunamis were determined not to be a threat.

4: MITIGATION CAPABILITIES & STRATEGIES

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 town, 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 Municipal Vulnerability Program (MVP) 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 Gill Multi-Hazard Mitigation Plan incorporates Nature-Based Solutions into mitigation strategies where feasible.

EXISTING AUTHORITIES POLICIES, PROGRAMS, & RESOURCES

One of the steps of this Hazard Mitigation Plan update process is to evaluate all of the Town's existing policies and practices related to natural hazards and identify potential gaps in protection.

Gill 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. Gill has appropriate staff dedicated to hazard mitigation-related work for a community its size, including a Town Administrator, Emergency Management Director, a Highway Department, and a Tree Warden. Gill is a member of the Franklin County Inspection Service, which provides Building, Plumbing, and Electrical permitting and inspections in town. In addition to Town staff, Gill has an experienced Planning Board and Zoning Board of Appeals that review all proposed developments and assures that buildings are built to the current zoning requirements.

Gill has some recommended plans in place, including a Community Development Plan and an Open Space and Recreation Plan. Both plans need to be updated and supplemented by a Capitol Improvements Plan. The Town also has very committed and dedicated volunteers who serve on Boards and Committees and in Volunteer positions. The Town collaborates closely with surrounding communities and is party to Mutual Aid agreements through MEMA. Gill 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 upland forested areas) and wetlands. As more land is developed, more flood storage is demanded of the town's water bodies and waterways. The Town of Gill has no flood control structures within its corporate boundaries. However, along the southwestern border of Gill is the Turners Falls Dam, which is technically located in the Town of Montague.

Located on the Connecticut River, southwest of the Gill-Montague Bridge, the Turners Falls Dam is owned and maintained by FirstLight Power Resources. Generally, 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 Town of Gill has adopted several land use regulations that serve to limit or regulate development in floodplains, to reduce and manage stormwater runoff from new development, 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.

Severe Snowstorms / Ice Storms

Winter storms can be especially challenging for emergency management personnel even though the duration and amount of expected 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 Town 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, affecting infrastructure such as public water supply wells and water treatment plants. These effects can be mitigated by installing back-up power to ensure adequate service. Most of Gill's critical facilities have back-up power generators or are wired for a portable generator. Exceptions include the Elementary School and Stoughton Place low-income senior housing.

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. The Town of Gill is a member of the Franklin County Cooperative Building Inspection Program, which provides building inspection services. Restrictions on development that are wind-related are the provisions in the zoning bylaw related to wireless communications facilities.

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.

Wildfire

In Gill, roughly 60% of the town is forested, so wildfires and brushfires could impact a significant portion of Gill. Annually there are between 2 – 10 brushfires in town, typically consuming less than an acre of land.

Burn permits for the Town of Gill are issued by the Fire Chief. During this process, the applicant is read the State Law, which includes guidelines for when and where the burn may be conducted as well as fire safety tips provided by the control center. 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.

The Gill Fire Department reviews subdivision plans to ensure that their trucks will have adequate access and that the water supply is adequate for firefighting purposes. The Fire Department has an ongoing fire safety educational program in the Elementary School and preschools in Gill.

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. The first edition of the Massachusetts State Building Code went into effect on January 1, 1975 and included specific earthquake resistant design standards. These seismic requirements for new construction have been revised and updated over the years. According to the U.S. Census American Community Survey, an estimated 42% of Gill's housing stock, as well as much of the student housing on the Northfield Mount Hermon campus, was built prior to building codes.

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 Town's recovery from an earthquake.

Dam Failure

Dam failure is a highly 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.

There are no dams identified by DCR as being in Gill. The dams that would cause the most damage to people and property in Gill, if they failed, are located in neighboring communities or states. The Turners Falls Dam in Gill and Montague is rated a High Hazard dam which is to be inspected every two years. The Northfield Main Dam and Northwest Dike of the Northfield Mountain Pump Storage Facility in Erving are both rated Significant Hazard dams which are to be inspected every five years.

Landslides

Regulating land use and development to avoid construction on steep slopes and ensuring that construction does not reduce slope stability is one way to mitigate the hazard potential of landslides. Existing mitigation measures are detailed in Table 4-1.

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.[59] Regulations that limit impervious surfaces, reduce stormwater runoff, and increase infiltration and recharge of groundwater resources are some ways to mitigate the impacts of drought. Gill currently regulates development on steep slopes and requires controls for erosion and stormwater management.

The drinking water supply for the Riverside Water District comes from Greenfield; there is no back-up supply if Greenfield cannot supply water to the district during a drought.

Forest landowners in town 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.[60]

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. Gill does not currently have formal plans for setting up a warming or cooling center.

Reducing the amount of paving in new development, and planting and maintaining shade trees in villages and developed areas of towns, 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

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[59] MassWildlife Climate Action Tool: https://climateactiontool.org/content/drought. Accessed March 8, 2019.
[60] 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

lower the temperature in a neighborhood, making it easier to be outside and reducing cooling costs for homeowners. Gill encourages open space protection in new subdivision development, and minimizing removal of existing vegetation through site plan review.

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.[61]

In addition, Gill can require only native, non-invasive species be used in new development and redevelopment.

All Hazards

Gill has formal agreements through the Franklin County Regional Shelter Plan to use the Turners Falls High School or the Greenfield High School as an emergency shelter. Establishing a regional shelter plan, agreements, and putting the plan into practice is a major accomplishment since the last Multi-Hazard Mitigation Plan update. However, these shelter locations may be inaccessible from Gill if roads or bridges are blocked or damaged from hazard events. Gill does not have the capacity to staff and operate a shelter in town.

Most of Gill's critical facilities have back-up power generators or are wired for a portable generator. The Gill Elementary School does not have a generator or transfer switches to use a portable generator. The Stoughton Place low-income senior housing complex does not have a back-up generator.

The Town uses various methods to notify residents of emergency conditions and to provide instruction. The public safety complex, which serves as the Town's Emergency Operations

[61] MassWildlife Climate Action Tool: https://climateactiontool.org/content/maintain-or-restore-soil-quality-limit-recreational-impacts. Accessed March 8, 2019.

Center (EOC) relies on internet phone service, and is a cell phone dead-spot. In the event the internet is down, there is no back-up phone system for the EOC.

Primary and secondary evacuation routes are shown on the Critical Infrastructure map for Gill. Route 2 is a heavily traveled state highway, and accidents on the road can cut off the Town from nearby hospitals and other communities.

A regional disaster debris management plan was created for Franklin County in 2015; however, establishing agreements for regional debris sites was not feasible. Towns need to identify a site in their own town to store local storm debris. The Western Region Homeland Security Advisory Council has a template for municipalities to use to create a disaster debris management plan on their website.[62]

Existing Mitigation Capabilities

The Town of Gill has numerous policies, plans, practices, programs and regulations in place, prior to the creation of this plan, that are serving to mitigate the impact of natural hazards in the Town of Gill. 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 District	Regulation - Zoning Bylaw	Overlay district to control development in the 100-year floodplain	Flooding	Partially Effective. Gill's floodplain maps are from 1980; an update is in process – revisit the floodplain regulations once new floodplain maps are available.
Special Permit Guidelines	Regulation – Zoning Bylaw	Require protection of the natural environment and the potential impacts on surface and ground water as considerations when determining the issuance of a special permit.	Flooding Landslides Drought	Partially Effective. Add impact on flooding as a consideration
Site Plan Review	Regulation – Zoning Bylaw	Standards include provision for adequate drainage and stormwater management to prevent flooding and to protect	Flooding Landslides Drought	Effective at mitigating impacts of development.

[62] WRHSAC disaster debris management page: https://wrhsac.org/projects-and-initiatives/disaster-debris-management/

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		surface and ground water from pollutants; minimizing soil erosion during and after construction; minimizing removal of existing vegetation		
Logging Operations	Regulation – Zoning Bylaw	Regulates logging operations to remove slash from within 50 feet of highway or waterway; and beyond 50 feet slash may not exceed 3 feet in height.	Flooding Wildfire	Partially Effective. Require logging operations to follow the MA Forestry Best Management Practices to protect soil and water quality
Earth Removal Operations	Regulation – Zoning Bylaw	Regulates the removal of soil, loam, sand & gravel through the Special Permit process.	Flooding Landslides	Not effective for controlling localized flooding / Require mitigation of potential impacts from removal of soil on stormwater runoff and flooding.
Conservation Development	Regulation - Zoning Bylaw	Requires areas subject to flooding and high and significant hazard dam inundation areas identified on plans; Requires a minimum 35% open space	All Hazards	Partially Effective. Consider increasing open space requirement and update using MA Smart Growth Toolkit model bylaw[63]
Solar Electric Installations	Regulation – Zoning Bylaw	Regulates the siting, installation, operation, and decommissioning of large scale ground-mounted solar installations	Flooding Landslides Drought	Partially Effective. Add stormwater management requirements; prohibit installations on steep slopes; limit the number of acres allowed to be cleared for an installation
Wireless Communications Facilities	Regulation – Zoning Bylaw	Regulates siting of wireless communications towers including setback distance form surrounding properties and limiting removal of vegetation	Flooding Landslides Wind-related Hazards	Effective.
Mobile Homes	Regulation – Zoning Bylaw	New mobile homes are allowed only in the rural zoning districts in Gill by Special Permit	Severe Winter Storms Wind-related Hazards	Partially Effective / Ensure new mobile homes are tied down. Provide existing mobile homeowners with information on resources to rehabilitate or replace their home.
Subdivision Rules & Regulations	Regulation	Dictates street, utility, and drainage design and construction; Requires erosion control plan & stormwater	All Hazards	Partially Effective. Consider allowing for narrower paved widths for small subdivisions; encourage or require Low

[63] https://www.mass.gov/files/documents/2017/11/03/Open%20Space%20Design%20%28OSD%29-Natural%20Resource%20Protection%20Zoning%20%28NRPZ%29_0.pdf

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		management plan; an environmental assessment is required for developments of 10 or more lots		Impact Development (LID) stormwater management design
Curb Cut Regulations	Regulation	There is no formal design standard regulation for new driveway openings or curb cuts.	Flooding Landslides Severe Winter Storms	Not Effective / Develop formal regulations for new driveway openings or curb cuts that include grade and design standards
Participation in the National Flood Insurance Program	Program	As of 2018 there were five (5) flood insurance policies in effect in Gill	Flooding	Effective for properties with flood insurance through the program. Conduct public outreach and education when new floodplain maps are completed.
Gill Open Space and Recreation Plan	Plan	Inventories natural resources and identifies land protection priorities in the Town	All Hazards	Effective / The plan was last completed in 2011; an update is underway
State Building Code	Regulation	The Town of Gill has adopted the Massachusetts State Building Code	All Hazards	Effective for new construction & significant rehabilitation
Emergency Shelters	Practice	Gill has formal agreements through the Franklin County Regional Shelter Plan to use the Turners Falls High School or the Greenfield High School as an emergency shelter.	All Hazards	Effective / The regional shelters may be inaccessible during some hazards. However, the Town does not have the capacity to staff and run its own shelter.
Culvert Assessment / Replacement	Practice	The Highway Department maintains culverts in town	Flooding	Partially Effective / Culverts should be assessed and prioritized for replacement; designs for new culverts should take into account increases in precipitation from climate change
Tree Maintenance	Practice	The Highway Department and electric company trim tree branches near overhead power lines	Severe Winter Storms Wind-related Hazards Invasive Species	Partially Effective / Encourage the State to trim tree branches along State routes in town.
Burn Permits	Regulation	The Fire Chief oversees the issuance of burn permits. State guidelines are followed.	Wildfire	Partially Effective / The burning season does not align well with the months when burning is least likely to create a fire hazard.

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
Fire Safety Education	Practice	The Fire Department has an ongoing fire safety educational program in the elementary school and preschools in Gill	Wildfire	Effective
Fire Towers	Practice	Pisgah Mountain is visible from the regional fire tower network	Wildfire	Effective
Firefighting Water Supplies	Practice	The center of town lacks an adequate water supply for firefighting; a pond on the NMH campus needs dredging and a dry hydrant for use as a firefighting source	Wildfire	Not Effective / Identify a water supply source for the center of town; encourage NMH to dredge and install a dry hydrant at the pond on campus.
Permits for Dam Construction	Regulation	State law requires a permit for the construction of any dam.	Dam Failure	Effective
High / Significant Hazard Dam Emergency Action Plans	Regulation	Owners of high hazard and certain significant hazard dams are responsible for preparing Emergency Action Plans	Dam Failure	Effective / FERC-licensed dams have up-to-date EAPs; Plans are adequate and tested annually by EMD.
Back-Up Drinking Water Supply	Policy	The drinking water supply for the Riverside Water District comes from Greenfield; there is no back-up supply if Greenfield cannot supply water to the district	All Hazards	Not Effective / Identify potential back-up water supplies for the Riverside Water District
Back-Up Power	Practice	Most of Gill's critical facilities have back-up power generators or are wired for a portable generator. The Gill Elementary School does not have a generator or transfer switches to use a portable generator. The Stoughton Place low-income senior housing complex does not have a back-up generator	All Hazards	Partially Effective / Install an emergency back-up generator at the Gill Elementary School or complete electrical work for portable generator use at the building; work with the regional housing authority to install a generator at Stoughton Place
Warming / Cooling Centers	Practice	Gill does not have formal plans for setting up a warming or cooling center	Extreme Temperatures	Not Effective. Identify formal warming and cooling centers and develop a plan for operating them during times of extreme temperature
Emergency Communications	Practice	The Town uses various methods to notify residents of emergency conditions and to provide instruction; The public	All Hazards	Partially Effective / The town has explored and exhausted all available back up options for the EOC at this time.

Table 4-1: Existing Mitigation Capabilities				
Strategy	**Capability Type**	**Description**	**Hazards Mitigated**	**Effectiveness / Improvements**
		safety complex, which serves as the Town's Emergency Operations Center (EOC) mainly relies on internet phone service. Recently a Verizon mini-tower was installed to extend cell-phone coverage to the EOC.		
Sheltering Plan	Plan	A regional sheltering plan has been completed; Shelter Management Teams need to be created and cost sharing agreements between towns established	All Hazards	Partially Effective / Participate in the REPC's planning process to operationalize the regional shelter plan
Evacuation Plan	Plan	Primary and secondary evacuation routes are identified. Gill's reliance on bridges, Route 2, and lack of viable alternatives places it at risk. The Town lacks the man-power necessary to establish detours when Route 2 is blocked.	All Hazards	Not Effective / Work with the REPC and surrounding towns to identify resources for assisting the Town with establishing detours for Route 2
Debris Management	Plan	Gill does not have a site identified for local storm debris.	All Hazards	Not Effective / Gill does not currently have a plan in place. WRHSAC has a template on its website that the town may use.
Local and Regional Emergency Response Capacity	Practice	Gill utilizes mutual aid to help respond to emergencies; however, regional resources can be taxed during larger events.	All Hazards	Partially Effective. Franklin County towns have good working relationships but the number of volunteers and funding for emergency and disaster recovery have dwindled.

HAZARD MITIGATION GOAL STATEMENTS AND ACTION PLAN

As part of the multi-hazard mitigation planning process undertaken by the Gill Multi-Hazard Mitigation Planning 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, Town 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 Town of Gill has limited capabilities and resources (especially staffing) to be able to expand and improve upon existing policies and programs when the town identifies a need for improvement.

Hazard Mitigation Goals

Based on the findings of the Risk Assessment, public outreach, and a review of previous town plans and reports, Gill 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 town based on probability of occurrence, severity of impacts, area of occurrence and preparedness. Those hazards receiving the highest Overall Hazard Vulnerability Rating were assigned the highest priority, as shown in Table 4-2.

Table 4-2: Hazard Priority Level Rating		
Natural Hazard	**Overall Hazard Vulnerability Rating**	**Priority Level**
Severe Winter Storms	10	High
Invasive Species	10	High
Extreme Temperatures	9	High
Flash Flooding	9	High
Hurricanes / Tropical Storms	8	Medium
Severe Thunderstorms / Wind / Microbursts	8	Medium
Earthquakes	8	Medium
Drought	7	Medium
Wildfires	6	Medium
Flooding (100/500 year event)	5	Low
Tornadoes	5	Low
Dam Failure	4	Low
Landslides	3	Low

Prioritization of Action Items

The Hazard Mitigation Committee identified several strategies that are currently being pursued, and other strategies that will require additional resources to implement. Strategies are based on previous experience, as well as the hazard identification and risk assessment in this plan.

Prioritization Methodology

The Gill Hazard Mitigation Planning 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:

- Town 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 town)
- Town 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 Gill is a small town 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 Town staff and volunteers, result in a large benefit to the community for a relatively small cost.

For larger construction projects, the town has limited funds to hire consultants and engineers to assist them with implementation. For these projects, the Town 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 Gill 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 Town 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 town's "general fund."

Table 4-3: 2020 Gill 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)**	**2014 Priority / 2019 Priority**	**Current Status**
MULTI-HAZARD ACTION ITEMS									
Local Plans & Regulations	Develop and implement a record management plan to digitize and/ or duplicate important records housed in the Town Hall and other town facilities to mitigate the potential loss of information from a hazard event.	Multi-Hazard	Select Board, Town Administrator, Emergency Management Director, Historical Commission, Library Director, Town Clerk	Medium	Town,	Ongoing	S	High / High	Mostly complete. All new town records are digitized and backed up on a hard-drive and on the cloud. Steady progress has been made digitizing older records. Most of the critical town documents and records have been backed up since 2014. The town will continue to digitize the remaining past records.
Critical Facilities & Infrastructure	To reduce the risk to property and infrastructure during severe storm events, identify priority areas for tree maintenance near utility lines in town and submit the list to Eversource for inclusion in its five-year action plan, which includes regular tree maintenance to reduce the number of limbs near overhead power lines. Meet bi-annually with the utility to ensure priority areas are included in the plan.	Multi-Hazard	Highway Department, Eversource	Low	Town, Eversource	Ongoing	S, I	High / High	Carried over from 2014 Plan; partially complete. Eversource has been effectively tree trimming near power lines in town. Initiating regular meetings with the utility will ensure this work continues and can address new problem areas as they emerge.
Critical Facilities & Infrastructure	To reduce the risk to property and infrastructure during severe storm events, ensure adequate funding and staffing to continue the program of tree maintenance and trimming along Town roads by the Highway Department.	Multi-Hazard	Highway Department	Low	Town	Ongoing	S, I	High / High	Ongoing from 2014 Plan.
Critical Facilities & Infrastructure	To reduce the risk to property and infrastructure during severe winter storm events, coordinate with the State to implement a tree maintenance and trimming program along State-owned Route 2 and Route 10 in Gill. Establish bi-annual meetings with MassDOT to review and revise the program as necessary.	Multi-Hazard	Select Board, Highway Department, MassDOT	Low	Town, MassDOT	Year 2	S, I	High / High	Carried over from 2014 Plan. In the past the State was not effective at maintaining trees along State Route 2 and Route 10 in Gill, resulting in power outages and road blockages. Recently the State has been more effective at implementing clear cutting around Route 2.
Critical Facilities & Infrastructure; Education & Awareness	Utilize Community Development Block Grant (CDBG) funding for home rehabilitation work for low to moderate income households to bring existing homes up to code and better withstand high wind events. Publicize weatherization and energy efficiency programs offered through the utilities. Work with the HRA and the Energy Commission to develop and distribute a brochure to publicize available programs at the Town Hall, public events, and through the Town newsletter and website.	Multi-Hazard	Select Board, Energy Commission, Franklin County Regional Housing and Redevelopment Authority, Community Action	Low	CDBG, Mass Save, Town, HRA	Year 2	S, I, E	High / High	Modified from 2014 Plan. The Town has an agreement with the Franklin County Regional Housing and Redevelopment Authority (HRA) to run the home rehabilitation program on a yearly basis when funding is available. The current funding cycle is coming to an end. The Town will reapply for funding in FY2021.

Table 4-3: 2020 Gill 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)**	**2014 Priority / 2019 Priority**	**Current Status**
Local Plan and Regulations	Work with MassDOT, neighboring communities, and other relevant agencies to have a detour plan established for Route 2 and I-91 closures.	Multi-Hazard	Police Department, Fire Department, Planning Board, Emergency Management Director, REPC	Low	Town, REPC, FRCOG Local Technical Assistance	Year 2	S, I	N/A / High	New action item.
Education & Awareness	Plan a meeting and regular collaboration between public safety and Gill Neighbors group regarding emergency preparedness for seniors	Multi-Hazard	Police Department, Fire Department, Emergency Management Director	Low	Town	Year 1 and ongoing	S, I	N/A / High	New action item. Gill Neighbors is a community group that helps coordinate services for seniors.
Critical Facilities & Infrastructure	Equip the Gill Elementary School and Stoughton Place senior housing with an auxiliary power supply, or equip with transfer switches for portable generators.	Multi-Hazard	Emergency Management Director, Building Inspector, HRA, Gill-Montague School District	Medium	Town HRA	Year 3	S	Low / High	Modified from 2014 Plan. The library, town offices, and public safety complex have been equipped with transfer switches and/or back-up power.
Local Plans & Regulations	Formalize regional shelter agreements between the Town of Montague and City of Greenfield for use of their shelters. Participate in the REPC's project to operational the regional shelters.	Multi-Hazard	Emergency Management Director, Select Board, Franklin County Regional Emergency Planning Committee (REPC)	Low	Town, WRHSAC	Year 1	S	Low / High	Modified from 2014 Plan.
Local Plans & Regulations	Formalize regional shelter agreements between the Town of Montague and City of Greenfield for use of their shelters. Participate in the REPC's project to operational the regional shelters.	Multi-Hazard	Emergency Management Director, Select Board, Franklin County Regional Emergency Planning Committee (REPC)	Low	Town, WRHSAC	Year 1	S	Low / High	Modified from 2014 Plan.
Local Plans & Regulations	Coordinate with state and regional agencies to identify a location(s) for the temporary storage of contaminated/ hazardous flood debris within Gill.	Multi-Hazard	Emergency Management Director, Highway Department, Franklin County Regional Emergency Planning Committee (REPC)	Low	Town	Year 2	S, I, E	Low / High	Carried over from 2014 Plan. There are no formal disaster debris sites within Gill or Franklin County. The WRHSAC has a disaster debris management template for use by municipalities on its website.[64]
Local Plans & Regulations	Develop a regional plan to insure reliable access to fuel for generators during extended power outages; advocate for changes in the State Building Code to require fuel filling stations to have backup power generation.	Multi-Hazard	Emergency Management Director, Franklin County REPC, FRCOG	Low	Town, FEMA	Year 5	I	Low / Medium	Modified from 2014 Plan.

[64] https://wrhsac.org/projects-and-initiatives/disaster-debris-management/.

Table 4-3: 2020 Gill 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)**	**2014 Priority / 2019 Priority**	**Current Status**
Education & Awareness	Add home preparedness links to Town website: FEMA and Ready.Gov, MEMA and Mass211.org, and other links pertinent to Gill residents.	Multi-Hazard	Police Department, Fire Department, Highway Department, Town Administrator	Low	Town	Year 1 and ongoing	S	High / Medium	Incomplete and modified from 2014.
Local Plans & Regulations / Nature-Based Solutions	Conduct a community discussion about adopting the Community Preservation Act (CPA) to provide funding for local and regional, watershed-wide open space protection efforts, particularly in floodplain areas.	Multi-Hazard	Planning Board, Select Board, Open Space Planning Committee, Board of Assessors, Tax Collector	Low	Town, Volunteers, CPA	Year 4	E	Medium / Medium	Carried over from 2014 Plan. Partially Complete. An update to the Town of Gill Open Space and Recreation Plan is underway. Protection of land is dependent upon funding and is an ongoing process. The CPA could provide a steady source of funding for open space protection projects.
Education & Awareness / Nature-Based Solutions	Utilize existing outreach materials to introduce residents to best practices in forest stewardship that produce resilient, stable, and successional forested landscapes. These practices mitigate the risk of fire, landslides, flooding, drought, invasive species, and severe storm hazards.	Multi-Hazard	Conservation Commission, Fire Department, Town Forest Committee, UMass Extension	Low	Town, MA DCR Forest Stewardship Program, Rural Fire Assistance, National Fire Plan, UMass Extension	Year 1 and ongoing	S, I, E	Medium / Medium	Modified from 2014 Plan. The Town completed a Forest Stewardship Plan in 2014 for the 162-acre Town Forest, and was awarded a Forest Stewardship Implementation Grant in 2017. UMass Extension (MassWoods) provides outreach materials for private forest landowners that can be utilized for resident education.
Local Plans & Regulations	Develop a regional plan to insure reliable access to fuel for generators during extended power outages; advocate for changes in the State Building Code to require fuel filling stations to have backup power generation.	Multi-Hazard	Emergency Management Director, Franklin County REPC, FRCOG	Low	Town, FEMA	Year 5	I	Low / Medium	Modified from 2014 Plan.
Education & Awareness	Include an annual insert in the Town newsletter with important emergency phone numbers, radio stations, and websites.	Multi-Hazard	Emergency Management Director, Police Department, Fire Department, Highway Department, Town Administrator	Low	Town	Year 1 and ongoing	S	Low / Medium	Carried over from 2014 Plan.
Education & Awareness	Encourage Gill residents to join the Medical Reserve Corps (MRC) and include information in the Town website and newsletter.	Multi-Hazard	Emergency Management Director, Fire Department, Police Department, Board of Health	Low	Town, Volunteers, MEMA, Massachusetts Department of Public Health (DPH), FRCOG	Year 1 and ongoing	S, I, E	Low / Low	Carried over from 2014 Plan.

Table 4-3: 2020 Gill 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)	2014 Priority / 2019 Priority	Current Status
Local Plans & Regulations	Develop formal agreements with the Northfield Mount Hermon school to use a facility on their campus as a shelter during an emergency.	Multi-Hazard	Emergency Management Director, Building Inspector, Board of Health, Northfield Mount Hermon School	Low	Town	Year 3	S	Low / Low	Carried over from 2014 Plan. In order for this agreement to work, the shelter would require NMH employees to staff the shelter as the Town lacks the capacity to staff its own shelter.
Local Plans & Regulations / Critical Facilities & Infrastructure	Investigate options and develop agreements with surrounding towns to supply back-up drinking water to the Riverside water district in the event the connection to Greenfield's water supply is damaged.	Multi-Hazard	Riverside Water District Commission, Board of Health	Medium	Riverside Water District, USDA, CDBG	Year 3	S	N/A / Low	New Action Item.
HAZARD-SPECIFIC ACTION ITEMS									
Critical Facilities & Infrastructure / Local Plans & Regulations	Seek technical assistance to develop a culvert and bridge maintenance plan that identifies infrastructure susceptible to flooding, and document replacement or rehabilitation needs. Ensure projects are designed to take into account increased precipitation from climate change.	Flooding	Highway Department, Conservation Commission	Low	FRCOG Local Technical Assistance, Town	Year 2	S, I, E	High / High	Partially complete. The Town currently monitors culverts and bridges and replaces or rehabilitates as needed. A plan is needed to prioritize long term maintenance and replacement of infrastructure. The Town will seek assistance from the FRCOG.
Critical Facilities & Infrastructure	Prioritize the replacement of the two culverts on Center Road and Highland Road, taking into account increased precipitation from climate change.	Flooding	Highway Department, Conservation Commission	High	MEMA, MassWorks, MA DER	Year 4	S, I, E	N/A / High	New Action Item.
Critical Facilities & Infrastructure / Nature-Based Solutions	Hire a consultant to conduct a geomorphic engineering assessment and fluvial erosion mapping of the Dry Brook and the Fall River to determine possible bank stabilization measures to mitigate damages to farmland, the environment and nearby infrastructure. Seek funding to implement recommended measures.	Flooding, Landslides	Highway Department, Conservation Commission, Selectboard	High	MA DEP, MEMA	Year 2	S, I, E	N/A / High	New Action Item.
Critical Facilities & Infrastructure	To reduce the risk of flooding and damage to infrastructure, cut brush immediately surrounding bridge abutments and culverts to ensure an unobstructed flow of water.	Flooding	Highway Department	Low	Town	Ongoing	I, E	High / High	Complete and Ongoing.
Local Plans & Regulations	To reduce the risk of flooding and damage to the built environment, revisit and update the Floodplain Regulations once new maps are available from FEMA. Special consideration should be given to further restricting or eliminating new development within the 100-year floodplain.	Flooding	Planning Board	Low	Town, Volunteers, FRCOG Local Technical Assistance	Year 3	S, I, E	Medium / Medium	Modified from 2014 Plan. Gill's floodplain maps are from 1980; FEMA is currently updating the floodplain maps for Gill.

Table 4-3: 2020 Gill 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)	2014 Priority / 2019 Priority	Current Status
Local Plans & Regulations	To reduce the risk of flooding and damage to infrastructure from uncontrolled stormwater runoff, include impacts of runoff and flooding as considerations for a Special Permit, and require mitigation of runoff and flooding for Earth Removal Operations.	Flooding	Planning Board	Low	Town, Volunteers, FRCOG Local Technical Assistance	Year 3	S, I, E	Medium / Medium	Modified from 2014 Plan. The Town will seek technical assistance from the FRCOG to complete this action.
Local Plans & Regulations / Nature-Based Solutions	To reduce the risk of flooding and damage to infrastructure from uncontrolled stormwater runoff, allow for narrower paved roadway widths and encourage or require Low Impact Development (LID) stormwater design in new subdivisions	Flooding	Planning Board	Low	Town, Volunteers, FRCOG Local Technical Assistance	Year 3	S, I, E	Medium / Medium	Modified from 2014 Plan. The Town will seek technical assistance from the FRCOG to complete this action.
Local Plans & Regulations	Once new floodplain maps are available, develop and maintain a list of addresses within the 100 year floodplain for use by the Emergency Operating Center (EOC).	Flooding	Emergency Management Director, Franklin Regional Council of Governments	Low	Town	Year 4	S	Low / Medium	Modified from 2014 Plan. FEMA is currently updating Gill's floodplain map and the committee will update their list of addresses in the floodplain once the new data is released.
Education & Awareness	Set up a system to provide new residents in the Riverside neighborhood with information on Northfield Mountain's emergency alert system and how to register.	Flooding, Dam Failure	Select Board, Town Administrator, Northfield Mountain / FirstLight	Low	Town, FirstLight	Year 1 and Ongoing	S	Medium / Medium	Modified from 2014 Plan. FirstLight Power Resources utilizes a reverse call system to notify residents and businesses within dam inundation zones of the need to evacuate. The list of phone numbers needs to be kept up-to-date to be effective.
Local Plans & Regulations	Develop a beaver management plan that identifies locations of existing and potential beaver activity, the extent of flooding caused at each location, and solutions to mitigate impacts. Prioritize projects in the locations that require intervention, and seek funding to implement.	Dam Failure	Select Board, Board of Health, Town Administrator, Highway Department, Conservation Commission, Board of Health	Low	Town, MassDEP	Year 3	E, I	Medium / Medium	Carried over from 2014 Plan. Gill currently uses an informal system to track and mitigate against hazardous beaver activity.
Local Plans & Regulations; Education & Awareness	Revise the Special Permit requirements to include tying trailers and mobile homes down to reduce damage impacts from high winds. Publicize resources for mobile homeowners to rehabilitate or replace aging mobile homes.	Hurricanes and Tropical Storms, High Wind Events	Planning Board	Low	Town, FRCOG Local Technical Assistance	Year 4	S	Medium / Medium	Modified from 2014 Plan. Not yet started. It is estimated there are 10 existing mobile homes in Gill.

Table 4-3: 2020 Gill 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)**	**2014 Priority / 2019 Priority**	**Current Status**
Education & Awareness	Review, update, and distribute educational materials for homeowners on safe open burning practice and reducing the risk from wildfires. Distribute this information via the Town website, newsletter, and when issuing burn permits. Advocate for changing the burning season to better align with the months when burning is less of a risk for wildfire.	Wildfire	Fire Department, Shelburne Control	Low	Town, Rural Fire Assistance	Year 1 and ongoing	S, I, E	High / High	Ongoing from 2014 Plan. The Town offers fire education in the Town newsletter and on the Town website. Shelburne Control provides guidance on fire safety when issuing burn permits.
Critical Facilities & Infrastructure	Reestablish access to the water supply on the Old Boyle Road Bridge to provide a needed water supply to the center of town for firefighting.	Wildfire	Fire Department, Conservation Commission	Low	Town	Year 3	S, I, E	N/A / High	New action item.
Critical Facilities & Infrastructure	Dredge the fire pond on the Northfield Mount Hermon Campus and install a dry hydrant to provide access to the pond for firefighting.	Wildfire	Highway Department, Fire Department, Emergency Management Director, Northfield Mount Hermon School Officials	Medium	Pre-Disaster Mitigation Program, Town, Northfield Mount Hermon School	Year 2	S, I, E	Low / High	Modified from 2014 Plan. The Northfield Mount Hermon School plans to replace the dry hydrant in 2020 along with installing a new potable water supply system.
Local Plans & Regulations	Initiate the practice of submitting all forest cutting plans to both the Fire Department and the Conservation Commission. The Fire Department should document the location of any logging roads or access trails identified on the plans that could be used for wildfire fighting or for other emergencies.	Wildfire	Conservation Commission, Fire Department	Low	Town	Year 1	S, I, E	Medium / Medium	Carried over from 2014 Plan. Cutting plans are submitted to the Conservation Commission but not to the Fire Department.
Critical Facilities & Infrastructure	Maintain Fire Department vehicle access to existing water sources to mitigate the risk wildfire risk to the natural and built environment. Map water resources used for fire suppression and identify areas in need of maintenance. Review annually.	Wildfire	Fire Department	Low	Town	Year 1 and ongoing	S, I, E	Medium / Medium	Ongoing from 2014 Plan.
Critical Facilities & Infrastructure	Identify and document locations along rivers and streams in town where ice jams have the potential to form, and monitor annually.	Ice Jams, Flood	Emergency Management Director, Highway Department	Low	Town	Year 1 and ongoing	I, E	Low / Low	Carried over from 2014 Plan. Gill has not experienced an ice jam in the last 20 years. However, cooler water temperatures in the CT River reported since the closure of VT Yankee Nuclear Power Plant may increase the risk of ice jams.
Critical Facilities & Infrastructure	Through participation in the Connecticut River Streambank Erosion Committee, seek funding to continue to implement bank stabilization measures along the Connecticut River to reduce damages to farmland and the natural and built environment from landslides associated with flooding events.	Landslides	Select Board, Conservation Commission, FirstLight	High	Town, Volunteers, MA DEP Section 319 grant	Year 1 and ongoing	S, I, E	Medium / Medium	Ongoing from 2014 Plan. Since 1996, bioengineering techniques have been used in areas along the Connecticut River in Gill to stabilize eroding banks. Funding is still needed for additional projects.

Table 4-3: 2020 Gill 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)	2014 Priority / 2019 Priority	Current Status
Local Plans & Regulations	Hire a consultant to conduct river corridor mapping along major rivers and streams in Gill; seek technical assistance to revise land use regulations to limit development in mapped river corridor areas.	Landslides, Flooding	Planning Board, Conservation Commission	Medium	Town, MA DEP, FRCOG Local Technical Assistance	Year 5	S, I, E	Low / Low	New Action Item. FRCOG developed a model river corridor bylaw for use by towns with mapped river corridor areas.
Critical Facilities & Infrastructure	Continue to participate in the Regional Emergency Planning Committee (REPC) hazardous materials response planning and training.	Manmade Hazards	Emergency Management Director, Franklin County REPC	Low	FEMA, Town	Ongoing	S, I, E	Medium / Medium	Complete and ongoing.
Local Plans & Regulations	Continue to participate in annual meetings with high hazard dam owners to update and test Emergency Action Plans. Update evacuation and communication procedures for inundation areas from dam failures for the flood prone areas in town (identified on the map). Particular attention should be paid to residents that may be in need of special assistance.	Flood, Dam Failure	Fire Department, Police Department, Emergency Management Director, Planning Board	Low	Town	Year 1 and ongoing	S	Low / Medium	Modified from 2014 Plan.
Local Plan and Regulations	Review the recently updated Emergency Action Plan for the Great River Hydro dams upstream of Gill on the Connecticut River. Revise evacuation plans according to any changes in expected inundation areas in Gill.	Dam Failure	Select Board, Emergency Management Director, Police Department, Fire Department, Planning Board	Low	Town	Year 2	S, I, E	Low / High	Carried over from 2014 Plan. Great River Hydro, released updated plans in 2018.
Local Plans & Regulations	Begin planning for how to open and operate a warming and/or cooling center in Gill. Reach out to private businesses and non-Town organizations to gauge willingness to serve as informal warming or cooling centers. Develop a list of locations and contact information.	Extreme Temperatures	Board of Health, Selectboard, Emergency Management Director	Low	Town Volunteers	Year 2	S	N/A / Medium	New Action Item.
Local Plan and Regulations	Consider participating in the Pioneer Valley Mosquito Control District. Joining the PVMCD would allow Gill to receive weekly monitoring of vector species and the presence of West Nile Virus and EEE via trapping, sorting, lab testing, and reporting. Such surveillance is the first line of defense against mosquito-borne illness.	Invasive Species	Board of Health, Selectboard	Low	Town	Year 1 and ongoing	S	N/A / High	New action item.
Local Plans & Regulations	Inventory Town land and right of ways for invasive species. Prioritize locations and species to focus on. Develop a management plan for controlling and mitigating the spread of invasive species on Town property.	Invasive Species	Highway Department, Conservation Commission	Low	Town, Volunteer Time	Year 2	S, I, E	N/A / High	New Action Item.

Table 4-3: 2020 Gill 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)**	**2014 Priority / 2019 Priority**	**Current Status**
Education & Outreach	Provide landowner education about invasive species, and assist landowners with accessing funding for invasive plant/pest control. Promote forestry Best Management Practices during timber harvests or other forest management activities (trail building/maintenance, wildlife management etc.) to prevent the establishment of opportunistic invaders.	Invasive Species	Conservation Commission, land trusts, UMass Extension (MassWoods)	Low	Town, Volunteer Time, NRCS, UMass	Year 2 and ongoing	S, E	N/A / Medium	New Action Item.
Education & Outreach	Install boot brushes and educational signage about invasive species at the Town Forest trailheads.	Invasive Species	Town Forest Committee, Conservation Commission	Low	Town, MassTrails Grant, DCR	Year 3	S, E	N/A / Medium	New Action Item.

Table 4-4: Gill Completed or Obsolete 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**
Education & Awareness	Utilize existing emergency preparedness outreach materials to disseminate information through the Town newsletter, the Town website, and at the Town Hall, Library, and local events on what to include in a 'home survival kit,' how to prepare homes and other structures to withstand flooding and high winds, the proper evacuation procedures to follow during a natural disaster, and how to access information during an emergency. Review materials annually and update as needed.	Multiple-Hazards	Police Department, Fire Department, Highway Department, Town Administrator	Low	Town, WRHSAC	S	Medium	Obsolete. The committee has decided that an extensive town program is not needed. There are many resources available for public education around home preparedness available from MEMA, FEMA, and other sources. The Town website will now include links to these other sources.
Local Plans & Regulations	Seek funding and technical assistance to investigate whether there is beaver activity occurring near the wellhead of the Gill Elementary School, and if it is contributing to the high coliform levels in the well. Determine mitigation actions to address the contamination and seek funding to implement.	Flood, Dam Failure	Select Board, Town Administrative Assistant, Conservation Commission, Gill Elementary School	Low	Town, Gill-Montague Regional School District, MassDEP S.319 Grants	S, I, E	High	Complete. A water purification system was installed and this issue is no longer relevant.
Local Plans & Regulations	To reduce the risk to property, infrastructure, and the population, seek technical assistance to develop regulations for new driveway openings and curb cuts, including grade and design standards, taking into consideration the topography and growth pattern of the Town.	Hurricanes and Tropical Storms, High Wind Events	Planning Board, Highway Department	Low	Town, FRCOG Local Technical Assistance	S, I, E	High	Complete. The Highway Department reviews all new driveways and their approval is needed before a permit is issued.

Table 4-4: Gill Completed or Obsolete 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**
Critical Facilities & Infrastructure	Seek funding to hire an engineer to determine retrofitting measures for municipal buildings (such as the Town Hall) and emergency shelters to better withstand the impacts from an earthquake. Prioritize projects and seek funding to implement.	Earthquake	Building Inspector, Emergency Management Director, Select Board	Medium	Town	S	Medium	Obsolete. The committee feels this action item is no longer relevant nor necessary for the Town.
Critical Facilities & Infrastructure	Seek funding to increase the staff of the Fire Department's inspection and safety unit.	Wildland Fire	Fire Department	Low	Town, Rural Fire Assistance	S, I, E	Low	Complete. The town has hired a fire inspector.
Critical Facilities & Infrastructure	Identify existing shelters located outside of the 100 year floodplain that are equipped with an auxiliary power supply and are earthquake resistant. (For example, only the newer classroom addition of the Gill Elementary School was built after earthquake resistant design standards were created in the State Building Code and currently no auxiliary power supply is available.) Disseminate this information to appropriate town departments	All-hazard	Emergency Management Director, Building Inspector	Low	Town	S, I, E	Medium	Obsolete. The committee no longer considers this a relevant action item.
Critical Facilities & Infrastructure	Inventory supplies at existing shelters. Establish MOUs with local or neighboring vendors for supplying shelters with potable water, food and first aid supplies in the event of a natural disaster. (For example, potential resources include dining services and the O'Connor Health Center of the Northfield Mount Hermon School.)	All-hazard	Highway Department, Police Department, Fire Department, Emergency Management Director	Low	Town	S	Low	Obsolete. Gill will participate with the regional shelter in Greenfield and Montague and will not open a shelter in its town.
Education & Awareness	Investigate using social media, such as Facebook and Twitter, for communicating information with the public during and after an emergency.	All-hazard	Emergency Management Director, Police Department, Fire Department, Highway Department, Town Administrator	Low	Town	S	Low	Complete. The Town now uses social media as one way to communicate emergency information to the public.

5: PLAN ADOPTION AND MAINTENANCE

PLAN ADOPTION

The Franklin Regional Council of Governments (FRCOG) provided support to the Gill Multi-Hazard Mitigation Committee as they underwent the planning process. Town officials such as the Emergency Management Director and the Town Administrator 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 Gill Multi-Hazard Mitigation Plan was completed, copies were disseminated to the Committee for comment and approval. The Committee was comprised of representatives of Town 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 Multi-Hazard Mitigation Plan for the Town of Gill were distributed to Town boards and officials, and to surrounding towns for review. Copies were made available at the Town Hall and the library, and a copy of the plan was also posted on the Town 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 on [enter date], and on [enter date], the Gill Board of Selectmen voted to adopt the plan (see Appendix C).

PLAN MAINTENANCE PROCESS

The implementation of the Gill Multi-Hazard Mitigation Plan will begin following its approval by MEMA and FEMA and formal adoption by the Gill Board of Selectmen. Specific Town 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 Gill Multi-Hazard Mitigation Planning Committee will oversee the implementation of the plan.

Monitoring, Evaluating, and Updating the Plan

The measure of success of the Gill Multi-Hazard Mitigation Plan will be the number of identified mitigation strategies implemented. In order for the Town to become more disaster resilient and better equipped to respond to natural disasters, there must be a coordinated effort between elected officials, appointed bodies, Town employees, regional and state agencies involved in disaster mitigation, and the general public.

Implementation Schedule

Annual Meetings

The Gill Multi-Hazard Mitigation Planning 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 Town 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 Gill Town Administrator and the Emergency Management Director.

Bi-Annual Progress Report

The Town Administrator will prepare and distribute a biannual progress report in years two and four of the plan. Members of the Local Planning 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 Town Administrator 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 Town Administrator 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 town'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 Planning Committee should begin the process by the end of Year 3. This will help the town 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 Gill Multi-Hazard Mitigation Plan will be forwarded to MEMA and to FEMA for approval.

As is the case with many Franklin County towns, Gill'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
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 towns 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

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
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
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

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
Community Forest Stewardship Implementation Grants for Municipalities	Municipalities that manage a town 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
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 town 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 towns 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 towns 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

Table 5-1: Potential Funding Sources for Hazard Mitigation Plan Implementation				
Program	**Type of Assistance**	**Availability**	**Managing Agency**	**Funding Source**
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
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

2014 Multi-Hazard Mitigation Plan

The Town of Gill has taken steps to implement findings from the 2014 Multi-Hazard Mitigation Plan into the following policy, programmatic areas and plans: the update to the Gill Open Space & Recreation Plan (OSRP); implementation of the Regional Shelter Plan; and initiating use of social media for public communication about emergencies. The 2011 OSRP is in the process of being updated and incorporates flood mitigation and stormwater management recommendations from the 2014 Plan. Since the 2014 Plan, Gill entered into agreements with the Town of Montague and City of Greenfield to use designated regional shelters in those communities. The Regional Emergency Planning Committee (REPC), which Gill participates in, is in the process of operationalizing the Regional Shelter Plan.

2020 Multi-Hazard Mitigation Plan

Upon approval of the Gill 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 Gill 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 / Highway Department
- Planning Board
- Zoning Board of Appeals
- Conservation Commission
- Franklin County Regional Emergency Planning Committee
- Building Inspector/FCCIP
- Select Board

Some possible planning mechanisms for incorporating the Gill 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 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.

- Any future development of master plans and scenic byway plans could incorporate relevant material from this plan into sections such as the Natural Resources section and any action plans.
- When the Final Draft Multi-Hazard Mitigation Plan for the Town of Gill is distributed to the Town 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. Current Subdivision Rules and Regulations and Zoning Bylaws should be reviewed and revised by the EMD, Planning Board and Select Board based upon the recommendations of this plan. Technical assistance from the FRCOG may be available to assist in the modification of Gill's current Bylaws.

Continued Public Involvement

The Town of Gill 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 Town 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.