CITY OF LOWELL

2020 HAZARD MITIGATION PLAN– MUNICIPAL VULNERABILITY PREPAREDNESS PLAN

DRAFT

Prepared by:

Weston & Sampson

transform your environment

westonandsampson.com

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY ES-1

TABLE OF CONTENTS i

LIST OF FIGURES iii

LIST OF TABLES v

LIST OF APPENDICES vii

1 INTRODUCTION 1-1
1.1 What is a Hazard Mitigation Plan? 1-1
1.2 What is the Municipal Vulnerability Preparedness Program? 1-2
1.3 Hazard Mitigation and Municipal Vulnerability Preparedness Planning in Lowell 1-3
1.4 Planning Process Summary 1-4
1.4.1 Core Team 1-4
1.4.2 Stakeholder Involvement: Community Resilience Building Workshop 1-5
1.4.3 Public Engagement 1-7
1.4.4 Report Layout 1-9
1.5 Planning Timeline 1-10

2 HAZARD MITIGATION AND CLIMATE ADAPTATION GOALS 2-1

3 COMMUNITY PROFILE, LAND USE AND DEVELOPMENT TRENDS 3-1
3.1 Community Profile 3-1
3.2 Societal Features 3-1
3.2.1 CRB workshop Discussion of Societal Features 3-2
3.3 Economic Features 3-3
3.4 Infrastructure Features 3-3
3.4.1 CRB Workshop Discussion of Existing Infrastructure 3-4
3.5 Environmental Features 3-5
3.5.1 CRB workshop Discussion of the Environment 3-6
3.6 Land Use 3-6
3.7 Recent and Potential Development 3-7
3.8 Critical Facilities and Vulnerable Populations 3-10

4.0 HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES 4-1
4.1 Statewide Overview of Hazards 4-1
4.1.1 Massachusetts State Hazard Mitigation and Climate Adaptation 4-1
4.1.2 Federally Declared Disasters in Massachusetts 4-2
4.1.3 Impacts of Climate Change 4-3
4.1.4 Top Hazards as Defined in the CRB Workshop 4-3
4.2 Flood-Related Hazards 4-4
4.2.1 Areas Vulnerable to Flooding 4-5
4.2.2 Historic Flood Events in Lowell 4-9

DRAFT

4.2.3 GIS Flooding Exposure Analysis 4-12
4.2.4 Dams and Dam Failure 4-25
4.2.5 Climate Change Impacts: Flooding 4-27
4.3 Wind-Related Hazard 4-28
4.3.1 Hurricanes and Tropical Storms 4-29
4.3.2 Tornadoes 4-32
4.3.3 Nor'easters 4-34
4.3.4 Thunderstorms and Related Wind Events 4-35
4.3.5 Climate Change Impacts: High Winds 4-37
4.4 Winter Storms 4-37
4.4.1 Heavy Snow and Blizzards 4-38
4.4.2 Ice Storms 4-40
4.4.3 Climate Change Impacts: Winter Storms 4-41
4.5 Geological Hazards 4-41
4.5.1 Earthquakes 4-41
4.5.2 Landslides 4-46
4.6 Fire-Related Hazards 4-46
4.7 Extreme Temperatures 4-48
4.7.1 Extreme Cold 4-49
4.7.2 Extreme Heat 4-50
4.7.3 Climate Change Impacts: Extreme Temperatures 4-53
4.8 Drought 4-54
4.8.1 Climate Change Impacts: Drought 4-58

5.0 EXISTING MITIGATION MEASURES 5-1
Summary of Existing Mitigation 5-2
Existing Multi-Hazard Mitigation Measures 5-2
Existing City-Wide Mitigation for Flood Related Hazards 5-5
Existing Dam Mitigation Measures 5-7
Existing City-Wide Mitigation for Wind-Related Hazards 5-7
Existing City-Wide Mitigation for Winter-Related Hazards 5-8
Existing City-Wide Mitigation for Drought-Related Hazards 5-8
Existing City-Wide Mitigation for Fire-Related Hazards 5-8
Existing City-Wide Mitigation for Extreme Temperature-Related Hazards 5-9
Existing City-Wide Mitigation for Geologic Hazards 5-9
Existing City-Wide Climate Mitigation Measures 5-10

6.0 STATUS OF MITIGATION MEASURES FROM THE 2015 DRAFT PLAN 6-1
Implementation Progress on the Previous Plan 6-1

DRAFT

7.0 HAZARD MITIGATION AND CLIMATE ADAPTATION STRATEGY 7-1
7.1 Identification of Hazard Mitigation and Climate Adaptation Strategies 7-1
7.2 Regional Partnerships 7-11
7.3 Potential Funding Sources 7-11
8.0 Plan Adoption And Maintenance 8-1
8.1 Plan Adoption 8-1
8.2 Plan Implementation 8-1
8.3 Plan Maintenance 8-1
8.3.1 Tracking Progress and Updates 8-1
8.3.1 Continuing Public Participation 8-1
8.3.2 Integration of the Plans with Other Planning Initiatives 8-1
8.4 Process of Updating 8-2

9.0 LIST OF REFERENCES 9-1

LIST OF FIGURES

Figure 1-1. FEMA Hazard Mitigation Planning Saves Money Graphic (FEMA, 2018a) 1-1
Figure 1-2. Comparison of the MVP and HMP Processes (Weston & Sampson, 2020) 1-3
Figure 1-3. A screenshot of Lowell's "Community Health and the Economy" Webinar 1-6
Figure 1-4. Images of Local Features. Photos from City of Lowell 1-7
Figure 1-5. an introductory slide from a video shared in Spanish 1-8
Figure 1-6. A screenshot of Lowell's virtual Public Listening Session webinar 1-9
Figure 1-7. HMP- MVP Planning Process Timeline 1-10
Figure 3-1 Societal Features of Lowell – City Hall and Lowell National Historical Park 3-3
Figure 3-2: Infrastructure Features – One of the many canals in the City of Lowell 3-4
Figure 3-3: Environmental Features of City of Lowell 3-5
Figure 3-4: Land use data for Lowell 3-6
Figure 4-1. Lowell Hazard Risk 4-2
Figure 4-2: top hazards defined by Lowell's workshop participants 4-3
Figure 4-3: an infographic visualizing potential impacts of increasing precipitation 4-5
Figure 4-4: an infographic of anticipated increases in precipitation due to climate change 4-8
Figure 4-5. Changes in Frequency of Extreme Downpours 4-27
Figure 4-6. Projected Change in Spring Precipitation 4-28
Figure 4-7: an infographic visualizing potential impacts of extreme storms 4-29
Figure 4-8. 2014 Seismic Hazard Map- Massachusetts 4-44
Figure 4-9: Wildfire Hazard Areas Statewide 4-47

DRAFT

Figure 4.10. Middlesex County Fires: Townsend is outlined in red 4-48
Figure 4-11: an infographic visualizing anticipated temperature changes 4-49
Figure 4-12. Windchill Temperature Index and Frostbite Risk 4-49
Figure 4-12. Windchill Temperature Index and Frostbite Risk 4-50
Figure 4-13: an infographic visualizing potential impacts from increasing temperatures 4-51
Figure 4-14. Populations Potentially Vulnerable to Heat Related Health Impacts 4-51
Figure 4-15. Heat Index Chart 4-52
Figure 4-16. Massachusetts Extreme Heat Scenarios 4-54
Figure 4-17. Statewide Drought Levels Using SPI Thresholds, 1850 to 2012 4-55
Figure 4-18. Massachusetts Drought Status, September 2019 4-57
Figure 7-1. Environmental high priority action items 7-1
Figure 7-2. Societal high priority action items 7-2
Figure 7-3. Infrastructural high priority action items 7-3

LIST OF TABLES

Table 1-1. FEMA Grants 1-2
Table 1-2. City of Lowell's Core Team Members 1-4
Table 3-1. Population Demographics 3-2
Table 3-2. Societal Features as Identified in the CRB Workshop 3-2
Table 3-3. Economic Statistics 3-3
Table 3-4. Infrastructure Features as Identified in the CRB Workshop 3-5
Table 3- 5. Environmental Features as Identified in the CRB Workshop 3-6
Table 3-6. Current and Future Developments in Lowell 3-7
Table 3-7. Category 1 – Emergency Response Facilities 3-11
Table 3-8. Category 2 – Non-Emergency Response Facilities 3-14
Table 3-9. Category 3 – Vulnerable Populations and Community Facilities 3-16
Table 4-1: Flood insurance data and repetitive loss data for Lowell 4-7
Table 4-2: Locally Identified Areas of Flooding 4-8
Table 4-3: Flooding Events in Lowell (2000-2019) 4-10
Table 4-4. Previous Federal and State Disaster Declarations- Flooding 4-11
Table 4-5. Critical Facilities Located within the FEMA Flood Zone 4-13
Table 4-6. Census Block with High Concentrations of Vulnerable Populations 4-14

DRAFT

Table 4-7. Census Block with High Concentrations of Environmental Justice Community 4-17
Table 4-8. Developed Parcels in 100-Year FEMA Flood Zone 4-19
Table 4-9. Developed Parcels in 500-Year FEMA Flood Zone 4-19
Table 4-10. Recently Developed Parcels in the 100-Year FEMA Flood Zone 4-20
Table 4-11. Recently Developed Parcels in the 500-Year Flood Zone..... 4-22
Table 4-12. Developable, Vacant Land in the 100-Year FEMA Flood Zone..... 4-23
Table 4-13. Developable, Vacant Land in the 500-Year FEMA Flood Zone..... 4-24
Table 4-14. Potential Development in the 100-Year FEMA Flood Zone..... 4-24
Table 4-15. Potential Development in the 500-Year FEMA Flood Zone..... 4-25
Table 4-16. Inventory of Dams in Lowell 4-26
Table 4-17. Hurricane Records for Eastern Massachusetts, 1938 to 2019 4-30
Table 4-18. Saffir/Simpson Scale..... 4-30
Table 4-19. Estimated Damages in Lowell from Category 2 and Category 4 Hurricanes..... 4-31
Table 4-20. Enhanced Fujita Scale 4-33
Table 4-21. Tornado Records for Middlesex County..... 4-34
Table 4-22. Nor'easter Events for Massachusetts, 1978 to 2020 4-35
Table 4-23. Previous Federal and State Disaster Declarations for Severe Storms 4-36
Table 4-24. Previous Federal and State Disaster Declarations 4-38
Table 4-25. NESIS Categories 4-39
Table 4-26. Severe Winter Storm Records for Massachusetts 4-40
Table 4-27. Richter Scale and Effects 4-41
Table 4-28. Historical Earthquakes in Boston and Surrounding Area, 1727-2020..... 4-42
Table 4-29. Estimated Damage in Lowell from Magnitude 5 and 7 Earthquakes..... 4-45
Table 4-30. Landslide Volume and Velocity 4-46
Table 4-31. Middlesex County Heat Occurrences, 1998-2018..... 4-53
Table 4-32. Droughts in Massachusetts Based on Instrumental Records..... 4-56
Table 5-1. FEMA's Types of Mitigation Actions..... 5-1
Table 6-1. Status of Mitigation Measures from the 2015 HMP 6-1
Table 7-1. Priority Hazard Mitigation and Climate Adaptation Actions.....7-2
Table 7-2: Funding Opportunities for Resiliency Projects.....7-12

DRAFT

LIST OF APPENDICES

Appendix A ..... Core Team Materials

Appendix B ..... Additional Hazard Data

Appendix C ..... CRB Workshop Materials

Appendix D ..... Public Engagement

Appendix E ..... Plan Adoption

Appendix F ..... FEMA Approval

DRAFT

EXECUTIVE SUMMARY

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

Planning Process

Planning process for the Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) is completed through the following steps.

1) Convene a core team of municipal department heads who provided key input through meeting, online surveys, and interviews.
2) Create a set of hazard mitigation and climate adaptation goals.
3) Engage the public through a Community Resilience Building Workshop and online public engagement techniques.
4) Establish a list of critical facilities and assets.
5) Conduct a vulnerability and risk assessment of historic hazards and the potential impact of climate change.
6) Document the City's capacity to mitigation and respond to hazard.
7) Develop an action and implementation strategy.
8) Seek public feedback on the final document.

Hazard Mitigation and Climate Adaptation Goals

The City endorses the following set of hazard mitigation and climate adaptation goals.

- Prevent loss of life, injury, public health impacts and property damages resulting from all identified natural hazards and projected hazards under climate change.
- Build and enhance local mitigation capabilities to ensure individual safety, reduce damage to public and private property, and ensure continuity of emergency services.
- Increase cooperation and coordination among private entities, City officials and Boards, neighboring communities, State agencies and Federal agencies.
- Increase awareness of the benefits of hazard mitigation and climate resiliency measures through outreach and education.
- Identify and seek funding for measures to mitigate or eliminate each known significant hazard area and reduce the impacts of climate change.
- Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards today and under climate change projections.

DRAFT

- Integrate hazard mitigation planning and climate change projections as an integral factor in all relevant municipal departments, committees, and boards.

Vulnerability and Risk

Among the communities of Middlesex County, hazard mitigation and climate adaptation planning tend to focus on flooding and winter storms because they are the most likely natural hazards to impact these communities. However, the Lowell HMP-MVP Plan assesses the potential impacts to the City from a variety of natural disasters including:

- Flooding
- Extreme Winter Weather
- Extreme Temperature
- Wind and Microbursts

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

Hazard Mitigation and Climate Adaptation Strategy

Through the planning process, several hazard mitigation and climate adaptation measures were identified as high priorities. The high priority action items are described below.

Roads, Bridges, and Public Transit:

- Identify at-risk bridges and develop an emergency plan for each.
- Update snow removal plan and enforce rules for clearing sidewalks. Publish and make a more formal emergency plan regarding coordination with Police Department on a parking ban. Coordinate with schools, and other facilities that will be affected by the ban. Buy new plow equipment.
- Update tree pruning and maintenance program. Hire a City Arborist and work with the National Grid. Develop a list of appropriate street trees.
- Develop an emergency tornado response plan for the LRTA Bus system.
- Enforce rules for clearing the sidewalks within 24-48 hours after a snow event.
- Increase education and outreach programs on invasive species. Assess the types of invasive species that exist in Lowell and develop a long-term management plan.

Water Infrastructure Supply and Distribution

- Invest in aging infrastructure. Protect the distribution system from the freeze/thaw cycle and proactively secure funding to address breaks. Assess and track “hot spots” with frequent breaks and identify potential solutions.
- Floodproof the Water Plant Intake Station.
- Integrate new battery storage to the existing solar array and backup generator at the Water Treatment Plant. Consider a similar approach at the Wastewater Plant later.

DRAFT

Stormwater System (Drainage system, culverts, catch basins)

- Upgrade culverts near Clay Pitt Brook.
- Assess and map the entire drainage system.
- Ensure appropriate capacity of catch basins especially in the vulnerable areas.
- Develop a beaver management program that include working with beaver consultant, studying best practices for beaver deceivers.
- Continue to encourage low impact development (infiltration basins, rain gardens) and assess options for regulatory mechanisms.

Wastewater Infrastructure

- Assess floodproofing options for vulnerable pump and combined sewer overflow stations.
- Add backflow prevention to combined outfalls.

Canal System and Walls

- Conduct an inventory and assessment of the walls and identify needed repairs.
- Increase public education and outreach related to trash removal and encourage residents and visitors to avoid throwing trash in the canals.
- Participate in the ongoing Federal Energy Regulatory Commission (FERC) study and re-licensing process and review their materials.
- Manage trees along the canals through increased coordination with DCR.

Dams and Gate Houses (Pawtucket gate house and Francis Gate)

- Model and assess the impact of the 500-year flood on the gate houses and develop and overall response plan.
- Identify and address vulnerabilities of the earthen dam near Beaver Brook Bridge.
- Coordinate with dam operators and the hydropower entity on flood mitigation.

Public Health (vector-borne diseases)

- Develop public education and outreach related to risks of vector borne diseases and how to protect yourself.
- Expand the Mill City Grows mobile farmers market.
- Continue insect spraying for mosquitoes.

Shelters

- Increase capacity of homeless shelter during extreme cold events.
- Increase capacity of shelter system to allow for social distancing if needed.
- Inventory shelter supplies and increase staff, volunteers, and training. Develop contingency plans.
- Install alarms to alert when the food storage temperatures increases due to power or equipment failure.
- Identify potential short-term shelters for use during power outages.
- Develop a formal plan with the City, LTC, local organizations, and others to get the word out about risks and resources. Develop a contact or distribution list.

DRAFT

Residents at risk of isolation (include seniors, children, residents with disabilities, residents with limited English proficiency)

- Work with local partners to share information and get the word out.
- Translate announcements into multiple languages. Use accessible visuals.
- Partner with schools to share information with parents. Share information through a range of means, including digital, TV, and messaging signs.
- Develop a database of at-risk residents with emergency service providers and the senior center. Conduct wellness checks.

Residents with challenges to prepare or adapt (could include low-income residents, homeless people)

- Evaluate safe areas for informal housing (outside of flood-prone areas). Assess best practices.
- Work with social services and local organizations to provide support to residents experiencing homelessness.

Municipal and emergency services

- Update the existing Emergency Management Plan.
- Review available City resources and capacity, including emergency generators.

Housing

- Identify grants for climate-resilient housing, including floodproofing, fire resilience, and energy efficiency for denser and older housing.
- Provide short-term tenant support if an extreme event prevents residents from working and puts them at risk of eviction.

Local businesses

- Develop and share a toolkit for improving your business' resilience.
- Provide short-term support for local businesses, including mobile generators and refrigerated trucks during extended power outages.
- Assess ability of local businesses to assist with crisis response, including sewing masks or assisting with food production for food banks.

Waterbodies and wetlands

- Update the floodplain overlay district and local wetlands ordinance. In wetlands ordinance increase the size of buffer zones and treat buffer zones as protected areas.
- Study best practices, including recommendations from Massachusetts Association of Conservation Commissions.
- Coordinate with dam operator for mitigation potential to flood control.
- Develop plans for flood mitigation that coordinates with Hydropower entity, seek opportunities for reviewing and improving plan.
- Map at-risk banks and seek funding for combined trail and bank mitigation projects.
- Evaluate alternatives to salting/sanding. Identify snow storage locations and provide education on environmentally friendly snow clearing.

DRAFT

- Identify snow storage options for private landowners and provide education and outreach related to potentially harmful impact of dumping snow near waterbodies.

Development and land use regulations

- Integrate the Stormwater Team standards with Planning Office regulations.
- Evaluate options for setting maximum parking requirements
- Allow incremental increases in density to avoid greenfield housing development in Lowell and outside the City boundaries.

Next Steps

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

DRAFT

1 INTRODUCTION

The City of Lowell prepared a joint Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HM-MVP Plan) to create an action plan to reduce the impacts of natural hazards and climate change within the community and the region. The City Council adopted the Lowell HM-MVP Plan on DATE to update and replace the Hazard Mitigation Plan (HMP) for the Northern Middlesex Region 2015 Update.

1.1 What is a Hazard Mitigation Plan?

Natural hazards, such as earthquakes, hurricanes, and flooding, can result in loss of life, disruptions to everyday life, and property damage. Hazard mitigation is the effort to reduce the impact of these hazards through community planning, policy changes, education programs, infrastructure projects, and other activities (FEMA, 2020a). Hazard mitigation planning uses a stepped process with participation of a wide range of stakeholders to:

1. Define local hazards.
2. Assess vulnerabilities and risks.
3. Review current mitigation measures.
4. Develop priority action items.

Figure 1-1. FEMA Hazard Mitigation Planning Saves Money Graphic (FEMA, 2018a)

The resulting hazard mitigation plan (HMP) and action strategy save lives and money. For every dollar spent on federal hazard mitigation grants, an average of six dollars are saved (FEMA, 2018a). There are many additional benefits of mitigation planning. HMPs increase public awareness of natural hazards that may affect the community. They allow state, local, and tribal governments to work together and combine hazard risk reduction with other community goals and plans. HMPs focus resources and attention on the community's greatest vulnerabilities. The vulnerability assessment of an HMP documents data related to the National Flood Insurance Program (NFIP), such as repetitive loss sites, ongoing work by the community related to floodplain management.

By completing HMPs, municipalities also become eligible for specific federal funding and allow potential funding sources to understand a community's priorities (FEMA, 2019a). Hazard mitigation funding is available through the Federal Emergency Management Agency (FEMA). To be eligible for FEMA grants, local governments are required to prepare an HMP, that meets the requirements

established in the *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, as amended by the *Disaster Mitigation Act of 2000*.

Table 1-1. FEMA Grants

FEMA Grants	Purpose
Hazard Mitigation Grant Program (HMGP)	Helps communities implement hazard mitigation measures following a Presidential Major Disaster Declaration.
Pre-Disaster Mitigation Program (PDM)	Assists in implementing a sustained pre-disaster natural hazard mitigation program, in order to reduce risk to the population and structures from future hazard events.
Flood Mitigation Assistance (FMA) Program	Offers annual funding for planning and projects that reduce or eliminate flood damage to buildings insured under the National Flood Insurance Program (NFIP)
Public Assistance Grant Program (PA)	Provides supplemental grants so that communities can quickly respond and recover from major disasters or emergencies.
Fire Management Assistance Grant Program (FMAG)	Available for the mitigation, management, and control of fires on publicly or privately owned forests or grasslands.

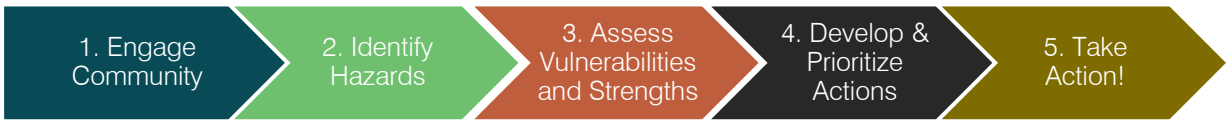
(FEMA, 2020b)

1.2 What is the Municipal Vulnerability Preparedness Program?

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

Community Resilience Building Workshop Guidebook

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



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

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

The first grant phase is the planning grant, which funds a planning process to identify priorities action items to address vulnerabilities and utilize strengths in preparation for climate change. The MVP planning process includes convening a team of municipal staff, engaging stakeholders in a Community Resilience Building Workshop following a guidebook developed by The Nature Conservancy and engaging the public. Communities that complete the planning grant program and prepare an MVP Plan become eligible for the second phase of MVP grant funding, the action grants, and receive increased standing in other state grant programs. MVP action grants provide funding for the implementation of priority climate adaptation actions as described in the MVP Summary of Findings. Since these action grants are only distributed to Massachusetts municipalities, they are much less competitive than similar grants awarded at the national level.

1.3 Hazard Mitigation and Municipal Vulnerability Preparedness Planning in Lowell

The City of Lowell received an MVP planning grant to simultaneously prepare an MVP Summary of Findings and an HMP. Many of the required steps of the MVP process also satisfy requirements for updating an HMP. As a result, the City created an action strategy that considers impacts based on both historic data and future climate change related threats, following the lead established by the Commonwealth when it adopted the first-ever Massachusetts State Hazard Mitigation and Climate Adaptation Plan (EEA and EOPSS, 2018).

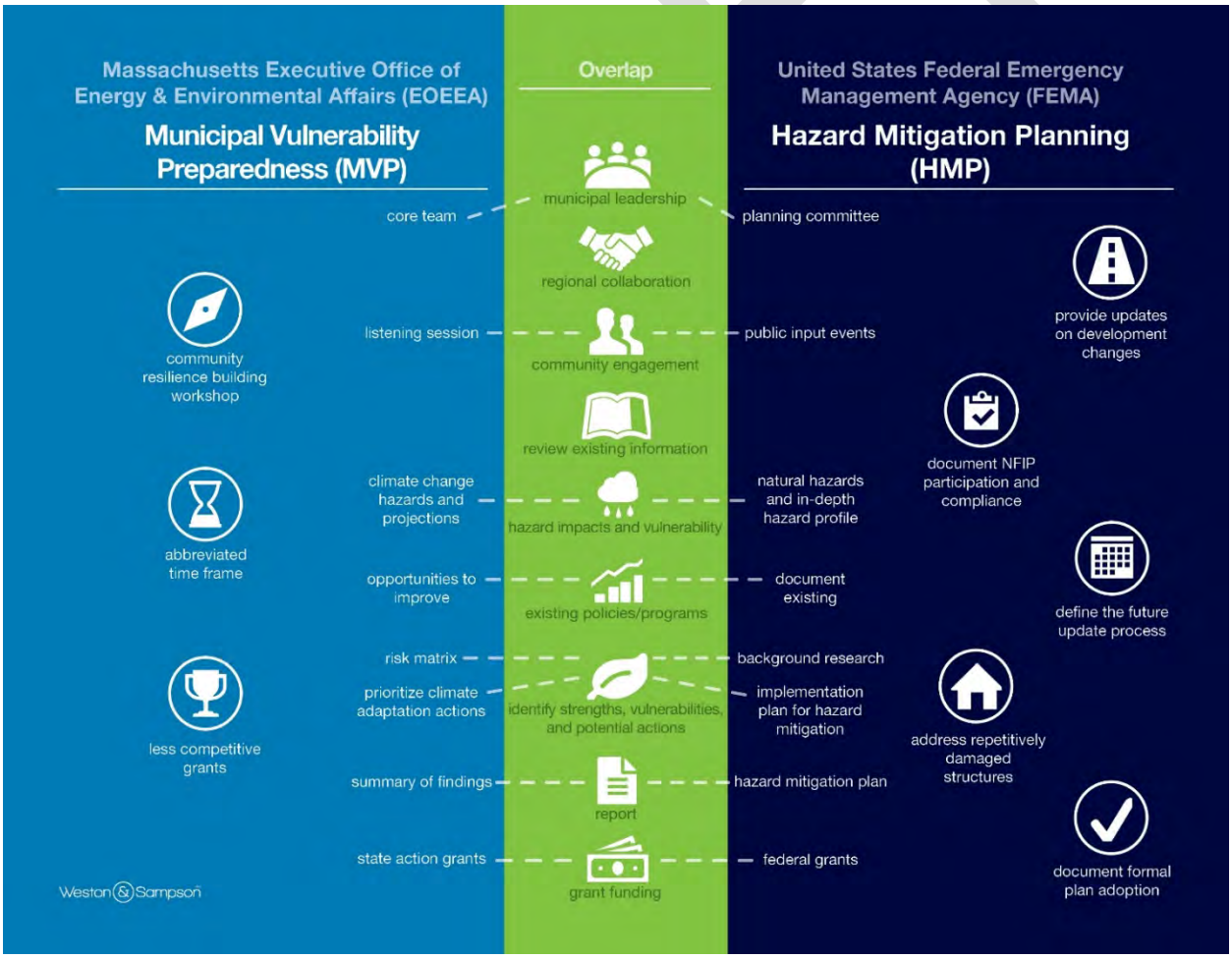


Figure 1-2. Comparison of the MVP and HMP Processes (Weston & Sampson, 2020)

1.4 Planning Process Summary

To prepare for the development of this HM-MVP Plan, the City convened a core team of municipal leaders to lead the process and provide local expertise. The City also followed the process described in the *Community Resilience Building Workshop Guidebook.* The guidebook provides a clear approach on how to organize the public process for mitigating the impacts of, and increasing resilience against, natural hazards and climate change. An important aspect of the natural hazard and climate change impact mitigation planning process is the discussion it promotes among community members about creating a safer, more resilient community. Developing a plan that reflects the City's values and priorities is likely to build greater community support and result in greater success in implementing mitigation strategies to reduce risk.

Federal regulations for HMP approval also guided the process. Most importantly, FEMA requires that stakeholders and the general public have opportunities to be involved in the planning process and its maintenance and implementation. Community members can therefore provide input that can alter the content and outcomes of the mitigation plan. The planning and outreach strategy used to develop this HM-MVP Plan had three tiers: 1) the core team, with representation from municipal leadership at the City, 2) stakeholders who could be vulnerable to, or provide strength against, natural hazards and/or climate change, and 3) the public, who live and work in the City.

1.4.1 Core Team

The City convened the core team to act as a steering committee for the development of the HM-MVP Plan. The core team met online on March 19, 2020 to plan for the Workshop, review public comments, develop the mitigation plan, and transition to implementation of the plan's mitigation strategies. More information on these meetings is included in Appendix A.
The core team established goals for the plan, provided information on hazards affecting the City, identified critical infrastructure, identified key stakeholders, reviewed the status of existing mitigation measures, and developed proposed mitigation measures for this plan. Members of the core team are listed in Table 1-2.

Table 1-2. City of Lowell's Core Team Members

Name	Title
Alex Magee	Assistant to the City Manager
Christine Clancy	Commissioner of Public Works
Craig Thomas	Deputy Director
Daniel Larocque	Deputy Police Superintendent
Diane Tradd	Director
George Rose*	(former) Deputy Director Office of Emergency Management
Jeff Winward*	(former) Fire Chief
John Gleason*	(former) Interim City Engineer
Kara Keefe Mullin	Assistant City Manager
Katherine Moses	Energy Manager
Maryann Ballotta	Director Public Safety Research and Development
Mark Young	Executive Director of Water and Wastewater Utilities
Paul LaChance	Deputy Director Office of Emergency Management

* Core Team members who were serving in their roles at the time of report writing. The City will document future changes to the Core Team in the next update of the MVP-HMP.

The core team developed the invitation list for the Community Resilience Building Workshop at which key stakeholders were invited to help identifying City's hazards, vulnerabilities, strengths, and proposed actions to mitigate the impacts of natural hazards and climate change. The core team sought to include municipal leaders as well as politicians, local boards and commissions, representatives from local nonprofit organizations, local universities, other local jurisdictions, regional organizations, and state government. The core team was also interviewed to update the status of the previous hazard mitigation plan and to weigh in the prioritization of the action items through a survey. The core team also suggested or provided reports, maps, and other pertinent information related to natural hazards and climate change impacts in Lowell. These included:

- *Hazard Mitigation Plan for the Northern Middlesex Region, 2015 Update,* (Northern Middlesex Council of Governments, 2015)
- Massachusetts Climate Change Projections (NECSC, 2018)
- Massachusetts Climate Change Adaptation Report (EEA, 2011)
- Massachusetts State Hazard Mitigation and Climate Change Adaptation (EEA and EOPSS 2018)
- Local Mitigation Plan Review Guide, October 2011 (FEMA, 2011)
- National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRM) for Middlesex County, MA (FEMA, 2016)
- City of Lowell Open Space & Recreation Plan Final 2019-2023 (Lowell, 2019)
- Sustainable Lowell 2025 (Lowell, 2013)
- City of Lowell, Massachusetts Master Plan Update Existing Condition Report (Lowell, 2011)
- National Center for Environmental Information (NOAA)
- National Water Information System (USGS)
- US Decennial Census (US Census Bureau, 2010)
- American Community Survey (US Census Bureau, 2018)

1.4.2 Stakeholder Involvement: Community Resilience Building Workshop

Due to the public health crisis surrounding COVID-19, the Community Resilience Building (CRB) Workshop could not be conducted in person. Instead, the City hosted a series of three online webinars organized around three different topic areas:

1. April 27, 2020: Infrastructure Assets Webinar
2. April 29, 2020: Natural Resources and Land Use Webinar
3. April 30, 2020: Community Health and the Economy Webinar

Stakeholders with subject matter expertise and local knowledge and experience, including public officials, regional organizations, neighboring communities, environmental organizations, and local institutions, were invited to engage in these events. During these webinars, Weston & Sampson provided information about natural hazards and climate change, including the top four hazards impacting Lowell. Participants were invited to comment on and edit pre-selected infrastructural, societal, and environmental features in the City that are vulnerable to or provide strength against these challenges. Participants also identified and prioritized key actions that would improve the City's resiliency to natural and climate-related hazards. Community representatives who were invited and those who participated in the process are presented in the Appendix C with the materials from the Workshop.

DRAFT

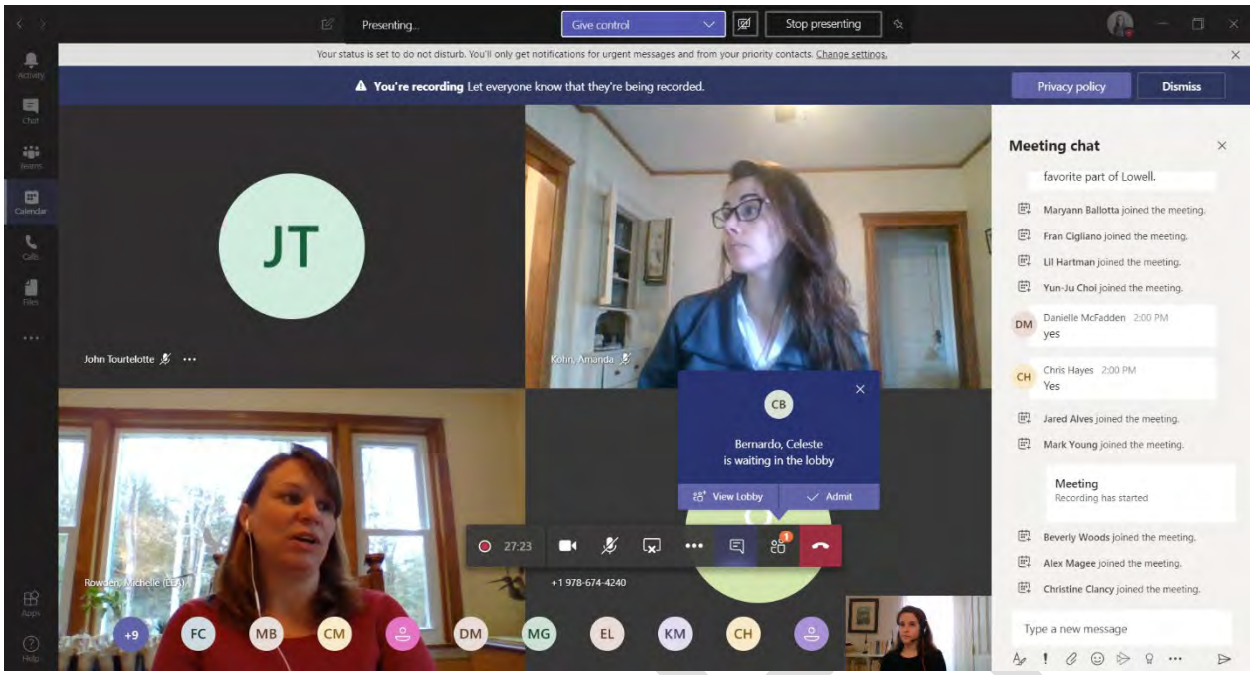


Figure 1-3. A screenshot of Lowell's "Community Health and the Economy" Webinar

The broad representation of local and regional entities that participated in these webinars ensures the HMP-MVP Plan aligns with operational policies and hazard mitigation strategies at different levels of government and implementation. A summary of key participants at each webinar is included below:

1. April 27, 2020: Infrastructure Assets Webinar
    - Municipal staff members from the City Manager's Office, Police Department, Development Services, Economic Development, Public Works Department, Department of Planning & Development, Parks & Recreation Department, and Water and Wastewater Utilities
    - Regional representatives, including from the National Park Service and Northern Middlesex Council of Governments,
    - Representatives from local organizations, including the Lowell House and Lowell Parks and Conservation Trust
2. April 29, 2020: Natural Resources and Land Use Webinar
    - Municipal staff members from the Public Works Department, Development Services, Department of Planning & Development, Water and Wastewater Utilities, Veteran's Services, City Manager's Office, Economic Development, and Cultural Affairs & Special Events
    - Members of boards and commissions, including the Sustainability Council
    - Regional representatives, including the National Park Service, Northern Middlesex Council of Governments, the MVP Regional Coordinator, National Grid, MA Division of Ecological Restoration, and Massachusetts House of Representatives
    - Representatives from local organizations, including Lowell Parks and Conservation Trust, Friends of Tyler Park, Greater Lowell Interfaith Association, and Coalition for a Better Acre

3. April 30, 2020: Community Health and the Economy Webinar
    - Municipal staff members from Economic Development, Veteran's Services, Development Services, Senior Center, Police Department, Cultural Affairs & Special Events, Water and Wastewater Utilities, City Manager's Office, and the Public Works Department
    - Members of boards and commissions, including the Sustainability Council
    - Representatives from local organizations, including the Greater Lowell Chamber of Commerce, Coalition for a Better Acre, and Lowell Plan
    - Regional representatives including from the Massachusetts House of Representatives, the MVP Regional Coordinator, and the National Parks Service

For each of these webinars, leadership from neighboring communities of Billerica, Chelmsford, Dracut, Dunstable, Pepperell, Tewksbury, Tyngsborough, and Westford were invited to participate in the workshop but were unable to attend.

Figure 1-4. Images of Local Features. Photos from City of Lowell

1.4.3 Public Engagement

The Lowell MVP-HMP project included an expanded scope to conduct a more robust outreach effort. The in-person engagement strategies outlined in the original contract were modified in response to the public health crisis surrounding COVID-19. As a solution, the project team identified virtual and social distancing strategies for each of the three main goals in the expanded scope; including providing translation services, working with key partners, and reaching parents and families. More information is included in the sections below.

Translation Services

The project team worked with translators to provide Spanish, Portuguese, and Khmer translations of project materials. These materials included:

- A project webpage on the City website serving as a depository of project information, including translated materials
- Videos summarizing the project, to be shared on the project webpage and social media platforms
- Online surveys to collect public input on climate hazards and climate adaptation priorities
- Language-specific breakout rooms were offered during the Virtual Public Listening Session Webinar hosted on May 28, 2020. Although these services were not requested in advance, translators still attended the webinar to assist attendees if needed.

Figure 1-5. an introductory slide from a video shared in Spanish giving an overview of the project and inviting residents to complete an online survey

Key Partners and Neighborhood Groups

The project team worked with the City, including Lowell's Neighborhood Liaison, to identify key neighborhood groups to conduct direct outreach to share information on the project and identify overlaps between their missions and climate resilience. As part of this direct outreach, the team also shared links to the project webpage and online videos and surveys so that the groups could distribute this information using their mailing lists and social media platforms. The project team prioritized sharing resources with these groups and rather than burdening them with extra work during the difficult time surrounding COVID-19. For example, the team provided sample social media posts and draft emails for spreading the word as part of these resources.

Reaching Parents and Families

The project team coordinating with the City, including Lowell's Neighborhood Liaison and contacts at the school system, to identify existing outreach efforts during COVID-19 that the project could plug-into. For example, the school system created meal and study packet pickup locations for students learning from home. Therefore, the project team created, printed, and shared a promotional flyer advertising the Virtual Public Listening Session at these locations.

Public Listening Session

Due to the public health crisis surrounding COVID-19, the two required public listening sessions could not be conducted in person. As a solution, and to gather information from the general public and educate the public on hazard mitigation and climate change, the City pursued the below approach:

1. Getting the word out: this first step consisted of the outreach campaign described above, which involved multiple videos, surveys, and the publicity surrounding these materials

2. **Getting input:** this second step involved hosting and recording a Virtual Public Listening Session Webinar. More information on this webinar is included below.

The project team planned the webinar to maximize participation and engagement. Translation support was advertised before the listening session and translators attended the webinar to assist attendees if needed. Registrants for the webinar were entered into a giveaway for five $50 gift cards to local restaurants. Step-by-step instructions for joining the virtual webinar were shared with attendees in advance, and moderators were on-hand to assist participants with troubleshooting. The webinar started with an icebreaker that allowed attendees to introduce themselves, share their favorite thing about the City of Lowell, and test out the webinar's audio and "chat" function. The staffing plan for the meeting included a main facilitator to present information and encourage discussion, and a second facilitator to help field questions and moderate the webinar chat. The team also created a presentation that prioritized dynamic, accessible visuals over text-heavy slides.

The webinar presented information related to the MVP program, climate change in Lowell, local strengths and vulnerabilities, existing mitigation measures, and priority action items for future climate adaptation. The webinar also directed attendees to project's webpage, which includes resources such as an online hazard map, informational videos, and online surveys. The videos and surveys are in English, Spanish, Portuguese, and Khmer. More information about the virtual listening session, including a summary of survey responses, is available in Appendix D.

Figure 1-6. A screenshot of Lowell's virtual Public Listening Session webinar

1.4.4 Report Layout

The report presents the results and input derived from the core team, CRB workshop, and listening session in addition to the documentation of features, hazard profiles, and a vulnerability assessment. Features are assets or characteristics of the City that may contribute to the City's resilience or may be a considered a vulnerability. Features are categorized into several types—societal, economic, infrastructure, land use, and environmental. The strength and vulnerability of these features are

generally documented in Chapter 3, but Chapter 4 provides a more detailed assessment of the City's vulnerability and strengths by hazard type. The hazard types cover Flooding, Extreme Winter Weather, Wind and Microbursts, Extreme Temperatures along with Geological Hazards (earthquakes and landslides). Each hazard type's historic occurrences and impact, frequency, level of risk, and climate change projections are also described in each hazard profile. Chapter 5 lays out the existing mitigation measures the City is already taking. Chapter 6 provides an update of the progress made since the last HMP and Chapter 7 provides the action plan for moving forward. Chapter 8 describes the plan adoption and maintenance, and details on implementation.

1.5 Planning Timeline

The HM-MVP process proceeded according to the timeline below.

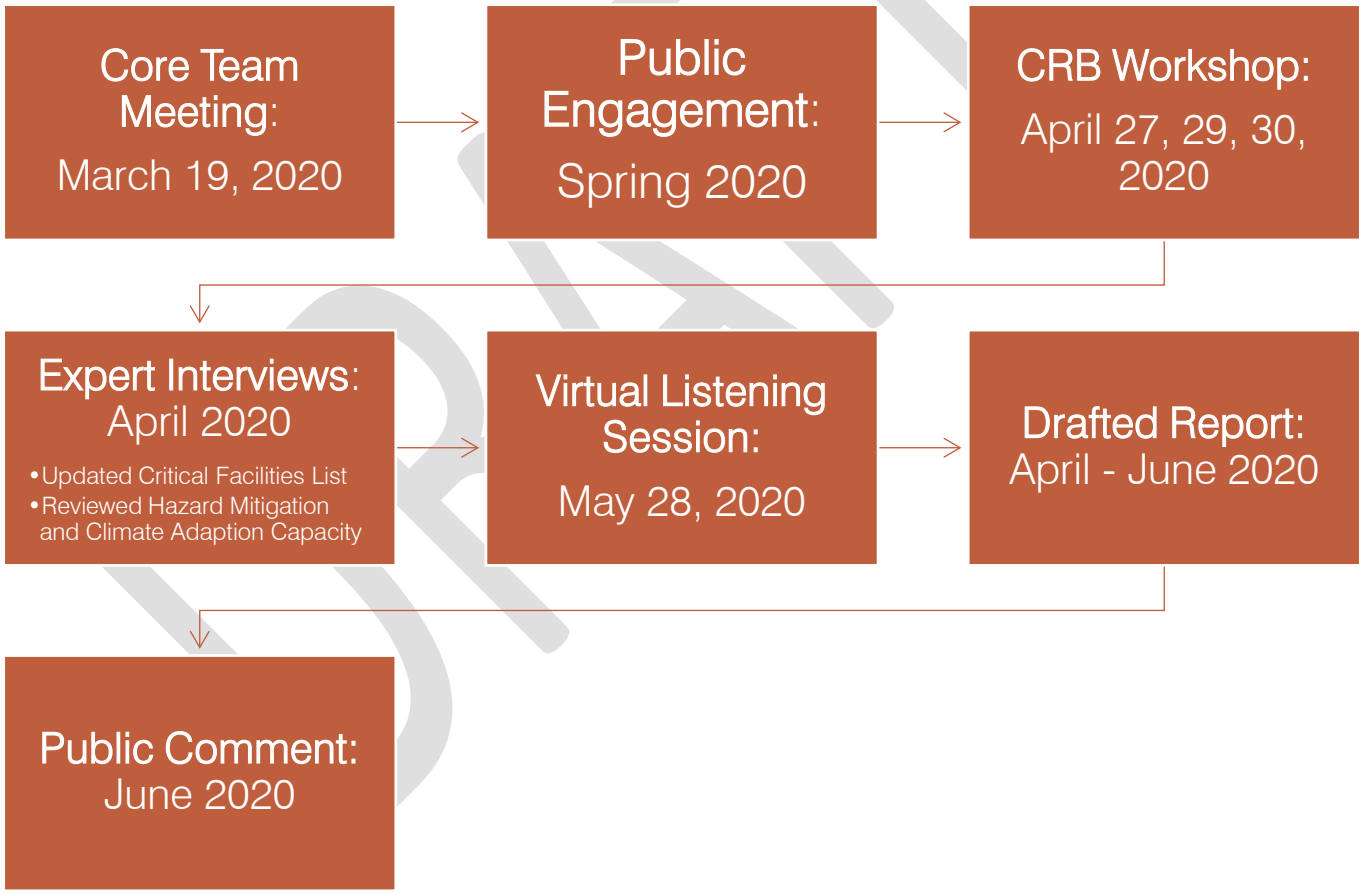


Figure 1-7. HMP- MVP Planning Process Timeline

2 HAZARD MITIGATION AND CLIMATE ADAPTATION GOALS

The City's core team convened to review and discuss the hazard mitigation and climate adaptation goals for the HM-MVP Plan. The following goals were developed and endorsed by the core team.

1. Coordination: Increase coordination between Lowell and Federal, State, regional, and local partners.
2. Protection: Develop programs and strategies to protect the following City features from natural hazards and climate change impacts:
    a. Cultural and historic resources
    b. Critical infrastructure, including transportation networks
    c. Public utilities, including electric power, water, and wastewater
    d. Public facilities and services
    e. Homes and businesses
    f. Future development
    g. Environmental features
    h. Vulnerable residents, including the elderly, young, homeless, low-income, and those with limited English proficiency
3. Planning: incorporate climate change and natural hazard considerations across City reports, planning efforts, departments, committees, and boards.
4. Public Outreach: Increase awareness and support for climate change and natural hazard mitigation among local organizations, businesses, and residents through outreach and education.
5. Capacity: Increase the City's capacity for responding to climate change impacts and natural hazard events through adequate staff, training, supplies, equipment, and guidance.
6. Funding: Identify and pursue funding to support the development and implementation of climate adaptation and hazard mitigation measures.

DRAFT

3 COMMUNITY PROFILE, LAND USE AND DEVELOPMENT TRENDS

3.1 Community Profile

Lowell is known for being one of the earliest planned industrial communities. The City is home to a diverse, multi-cultural population, including a large community of Latino and Cambodians residents (City of Lowell Open Space and Recreation Plan, 2019-2023). The City of Lowell supports sustainable neighborhood practices that promote public health, recreational opportunities, and community resilience.

Lowell has a rich historic past. Settled between the Merrimack and Concord Rivers, the City of Lowell began as a small New England town until it was incorporated in 1826 by Francis Cabot Lowell, a pioneer textile industrialist. The Lowell mills were one of the first mechanized industries that used domestic labor from surrounding towns to support the mills. This growth was further sustained by the completion of the Boston and Lowell Railroad in 1835. The textile industry is a vital part of Lowell's rich history that is well documented in literature.

Still standing, the large historical mill buildings continue to provide a focal point the community and tourism for the diverse, multicultural city. Opening of the Lowell National Historical Park, in 1978, gave the downtown a cultural hub that includes museums, local artists' studios as well as residential spaces. Today the City of Lowell's current economy is centered around technology, higher education, health care, tourism, and celebration of the arts (Sustainable Lowell, 2025).

Lowell is the fourth largest city in Massachusetts and is located miles 30 north of Boston in Middlesex County (Sustainable Lowell, 2025). Neighboring towns include Dracut, Tyngsborough, Chelmsford, and Tewksbury. Lowell is one of the more diverse cities in Massachusetts which began with the influx of refugees from Southeast Asia, specifically people from Cambodia in the 1970's (Ethnicity in Lowell, 2011).

The City of Lowell is governed by the mayor and City Council, who appoints City Auditor, City Clerk, and City Manager to serve the needs of the community. The City Manager is responsible for the administration of the City day-to-day affairs. The City maintains a website at www.lowellma.gov/.

3.2 Societal Features

Lowell is an ethnically diverse city. It is home to the second largest Cambodian refugee population in the U.S. (Cambodian Mutual Assistance Association of Greater Lowell, Inc.). There are 428 public safety personnel in Lowell, including 228 uniformed police officers, and 200 fire fighters. The Fire Department operates nine fire stations throughout the City. The City offers numerous social services including an active senior center, public library, and youth programming, and plans multiple yearly community events. Lowell's Annual Folk Festival is the most popular event that is been running for over three decades and attracts thousands of tourists from all over the Commonwealth. Lowell also has a National Historical Park which falls under National Parks system and attracts visitors all year. The Park is comprised of much of downtown, mill yards, and canal system and showcases Lowell's rich historical past.

The City's volunteer base and services are strengths that can be utilized for hazard mitigation planning, especially to reach the City's most vulnerable populations. Vulnerable populations are

people whose everyday stressors make it harder to adapt and recover when shocks or hazards occur. In Lowell, seniors, youth, disabled people, low-income individuals, and people with limited English language proficiency are considered vulnerable. Youth are the largest among the vulnerable groups by population size in Lowell, the percentage of youth compared to the total population is slightly higher than that of Massachusetts as a whole (Table 3-1). Lowell's growing population may also be considered a vulnerability, as well as a strength. To accommodate the increasing population, the capacity of Emergency Services also needs to grow.

Table 3-1. Population Demographics

	2018	Lowell	Massachusetts
	Population	111,670	6,902,149
	Under the Age 18	21.8%	19.8%
65+	Over Age 65	10.6%	16.5%
	Bachelor's degree or higher	23.0%	42.9%
$	Median household income	$51,987	$77,378
	Poverty Rate	20.7%	10.0%
	With a Disability	9.0%	7.9%
	Limited English-Speaking Skills	13.8%	5.9%
	Housing Units	41,303	2,882,739
	Owner-Occupancy Rate	42.4%	62.3%
	Burdened by Housing Costs*(Renter)	42.4%	39.6%
	Burdened by Housing Costs* (Mortgage)	26.2%	26.1%

(US Census Bureau, 2018)

* Burdened by Housing Cost: if the monthly housing cost is 35% or more than the household income

3.2.1 CRB workshop Discussion of Societal Features

Workshop participants identified those key societal aspects of Lowell that are most vulnerable to, or provide protection against, natural hazards and climate change impacts.

Table 3-2. Societal Features as Identified in the CRB Workshop

Vulnerabilities	Both Vulnerability and Strength	Strengths
• Public health (vector-borne diseases) • At risk of isolation (could include seniors, children, residents with disabilities, residents with limited English proficiency) • Challenges to prepare or adapt (could include low-income residents, residents experiencing homelessness) • Housing (low income and other)	• Shelters • Local businesses	• Municipal and emergency services • Non-profit community

DRAFT

Figure 3-1 Societal Features of Lowell – City Hall (left) and Lowell National Historical Park (right)

3.3 Economic Features

Lowell is an urban community that is easily accessible through major highways, has a well-educated workforce, and a strong educational system through University of Massachusetts at Lowell and several other schools. According to Massachusetts Executive Office of Labor and Workforce Development (EOLWD, 2019), LAUS data Lowell's labor force and employment levels have been consistently on the rise since 2012. Six major businesses have opened offices in Lowell since 2015 such as Kronos, Macom, Metrigraphics, Markley Group, Somerset Industries, and Plenus Group (City of Lowell Open Space and Recreation Plan, 2019-2023). Industries in Lowell with the most employees (top employment industries) are Educational services, and health care and social assistance (United States Census Bureau, 2018). Lowell General Hospital and University of Massachusetts Lowell are the City's top two employers employing nearly 6000 people. Lowell's residents have relatively lower commute time to work compared to the average work commute time for the state of Massachusetts.

Table 3-3. Economic Statistics

	Lowell	Massachusetts
Labor Force	58,480	3,778,642
Unemployment Rate	7.1%	5.4%
Employed in Top Employment Industry	25.9%	28.2%
Mean travel time to work (minutes)	26.2	29.7

(United States Census Bureau, 2018)

3.4 Infrastructure Features

Lowell is a regional transportation hub for New England areas because of its convenient location at the intersections of Interstate Highways 93, Interstate 495, and Route 3. This network of roadway system directly connects Lowell to Boston and other towns in New England area. In addition, there is an MBTA stop in Lowell that provides commuter rail access to Boston, widespread network of

Figure 3-2: Infrastructure Features – One of the many canals in the City of Lowell (Photo: *Weston & Sampson)*

inter-city bus shuttles that serve Lowell and surrounding communities, and airport limousine services that provide easy access to Logan Airport. Lowell has six bridges within the City to travel across Merrimack River. All the bridges are extremely important for everyday commute within the City and therefore are heavily used. Roads and bridges are at risk of closure and increased wear by snow, ice, downed trees, and in some cases flooding.

The City is serviced by municipal drinking water. There are two water treatment facilities in Lowell, both of which treat and filter water from the Merrimack River. Each facility is connected to a network of pipes and pumps stations and serve approximately 200,000 residents (City of Lowell Open Space and Recreation Plan, 2019-2023). The water is stored in two underground storage tanks and three above ground storage tanks. The underground storage tanks are vulnerable to rising groundwater level. The treatment facilities also serve as back-up water supply for the neighboring towns of Dracut, Tyngsborough, and East Chelmsford frequently. Though the Merrimack River has been a reliable source of water even during drought, mechanical failure is the primary concern for the City's water distribution system. Much of the infrastructure including the pipes and underground structures have been serving the City for more than 50 years and are therefore in need for an upgrade. Their criticality to the community and the environment makes them a vulnerable asset.

The City of Lowell is served by the public sewer system and managed by the Lowell Wastewater Utility. This is a regional system that transports wastewater from Lowell and four other surrounding towns to Lowell's Duck Island wastewater treatment facility before discharging the purified water into the Merrimack River. 60% of City's sewage system are combined sewage/stormwater lines since a significant portion of the sewage system was built in the early 1900s. It is an operational challenge to manage large fluctuations in flow through the combined lines and therefore rising water level or a large storm system can pose great threat to the sewage system. Backup power of all critical facilities providing water and sewer is essential. All pump stations in Lowell have back up power. Emergency services are generally well equipped; however, they could be delayed if critical roadways and bridges were flooded. See Section 3.8 for more information on critical facilities in Lowell.

3.4.1 CRB Workshop Discussion of Existing Infrastructure

Workshop participants identified those key infrastructure features in Lowell that are most vulnerable to, or provide protection against, natural hazards and climate change impacts. As noted below, the majority of the existing infrastructure features were determined to be both a vulnerability and a strength.

DRAFT

Table 3-4. Infrastructure Features as Identified in the CRB Workshop

Vulnerability	Both Vulnerability and Strength	Strengths
• Public buildings (including schools) • Roads, bridges, and public transit • Stormwater system (drainage system, culverts, catch basins) • Canal system and walls • Poor Condition of Dams and gate houses (Pawtucket gate house and Francis Gate)	• Energy resilience • Communications (fiber optic, internet, phone, cell) • Wastewater infrastructure	• Source of Water supply • Recertified dams

3.5 Environmental Features

Figure 3-3: Environmental Features of City of Lowell (Photo: *Weston & Sampson*)

The City has a total land area of around 14.5 square miles out of which 0.9 square miles area is occupied by surface water. The Merrimack River bisects Lowell and the Concord River merges with Merrimack in Lowell. The confluence area serves as a recreational area and can be a potential source of tourism after completing the Concord River Greenway. The riversides also add a scenic landscape to Lowell along with providing areas for many cultural and historic resources. These two rivers are primary sources of riverine flooding in the area. Other perennial streams (Beaver Brook, Black Brook, Clay Pit Brook, Scarlet Brook, Flagg Meadow Brook, River Meadow Brook, Hales Brook), canals (Eastern Canal, Pawtucket Canal, Northern Canal, Western Canal, Hamilton Canal), and multiple wetlands and swamps are sources of localized flooding. Nonpoint source pollution is a concern within many of the waterbodies (stormwater runoff, yard fertilizers, etc.). Recharge is the only natural way of replenishing the groundwater in Lowell. Therefore, over withdrawal of groundwater could be a potential problem. The City does not have any specific areas for groundwater recharge since the primary source of drinking water is the water from Merrimack River. Stony Brook aquifer and some other designated aquifers get their water from the wetlands.

Different species of flora are predominant in Lowell; hardwood species (pine, maple, oak, birch) dominate the upland communities, and herbaceous plants (grasses, clover, carrot, yarrow, sweet fern, dandelion) dominate the meadow communities. 548 acres of the 1000 acres of Lowell-Dracut-Tyngsborough State Forest is within Lowell City limits. The forest hosts multiple certified vernal pools, out which sixteen are located in the City. According to the Massachusetts Natural Heritage and

Endangered Species Program and the City of Lowell Open Space and Recreation Plan (2019-2023) Lowell used to have six historical rare plant species, and currently have eight rare and endangered animal species.

Similar to many New England municipalities, owing to its industrial heavy culture, Lowell has some major environmental concerns from past industrial uses (City of Lowell Open Space and Recreation Plan, 2019-2023). Silresim Superfund Site in Lowell has been designated as one of the most highly contaminated sites in New England. There are multiple Brownfield sites in the City from auto service and gas stations, and from former dry cleaners, mills, railroads, and landfills. Historically Lowell has been receiving multiple Federal and state funded grants to assess and clean-up its Brownfields sites. The City's Brownfield Program is constantly evolving and is an ongoing effort from the Department of Planning and Development. Remediation of some of the older Brownfield sites created spaces for new housing and commercial areas, several new parks and recreational spaces, and various sections of public walkways and greenways. There are no active landfills in Lowell anymore. The former Westford Street Landfill has been capped and currently hosts 6000 solar panels that produces 1.5 megawatts of electricity.

3.5.1 CRB workshop Discussion of the Environment

Workshop participants identified those key environmental features in Lowell that are most vulnerable to, or provide protection against, natural hazards and climate change impacts.

Table 3- 5. Environmental Features as Identified in the CRB Workshop

Vulnerabilities	Both Vulnerability and Strength	Strengths
• Waterbodies and wetlands • Street trees and citywide tree canopy • Contaminated sites • Invasive species	• State forest and park trees • Development and land use regulations • Endangered species	• Parks and public spaces

3.6 Land Use

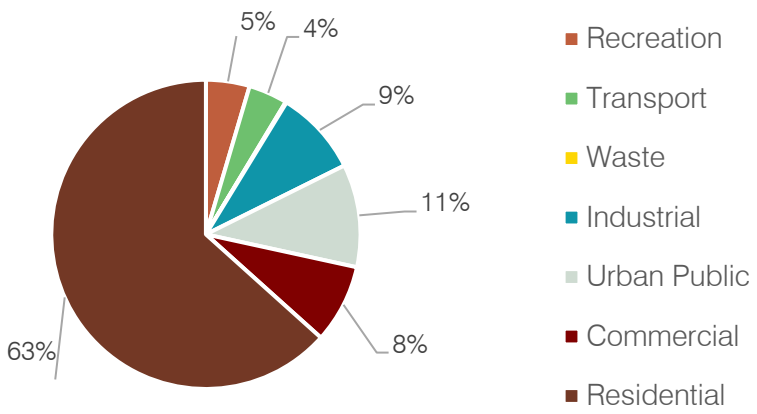


Figure 3-4: Land use data for Lowell (Data Source: Sustainable Lowell, 2025)

Lowell has approximately 9,316 acres. Most of the land is considered residential (63%) followed by Urban Public land (11%). Commercial accounts for 8% and industrial accounts for 9% of the land area. Transport and recreation account for 4% and 5% of land use respectively (Sustainable Lowell, 2025).

3.7 Recent and Potential Development

Lowell has experienced a boom of growth and development. Many underutilized or vacant parcels have been utilized. New development opportunities are concentrated around the downtown and urban renewal districts and Pawtucketville neighborhood (City of Lowell Open Space and Recreation Plan, 2019-2023).

MAPC's MassBuilds Database provides an inventory of recently constructed or planned developments. MassBuilds records housing projects with over 2000 housing units and commercial projects over 1,200,000 square feet for rural and suburban communities. The earliest development identified in Lowell from the MassBuilds Database was the Boott Mills East in 2002. The database included 62 residential developments, 20 commercial developments, and seven mixed-use development in the Lowell. The recently constructed (2019-2020) and planned developments in Lowell include a total of 1023 housing units, and 720,135 square feet of commercial and industrial/manufacturing space (Table 3-8).

Table 3-6. Current and Future Developments in Lowell

Name of Development	Year/Phase of completion	Project Type	# housing units	Sqft. commercial/ industrial
Sacred Heart School	2015	Residential	12	
MaCOM Expansion	2018	Commercial	0	50,000
Mill City Crossing (1400 Gorham Street)	Under Construction	Residential	47	
Millview Estates	2015	Residential	74	
Legacy Project- The Dahod Building	2012	Commercial	0	2,00,000
Gorham Street Apartments	2015	Residential	24	
University Crossing	2014	Commercial	0	2,30,000
Adie Way	2016	Residential	21	
80 Rogers Street	2015	Residential	25	
Counting House Lofts 109	2015	Residential	52	
Ecklund Drive	2015	Residential	30	
Unity Place Apartments	2011	Residential	23	
The Residences at Crosspoint	Under Construction	Residential	240	
Western Avenue Lofts	2012	Residential	50	
Boott Mills East	2002	Residential	154	
Boott Mills- West Phase II	2014	Residential	77	
Textile Museum Phase I	2018	Residential	12	
Textile Museum Phase II	Under Construction	Residential	33	
Appleton Mills	2012	Residential	130	

DRAFT

Name of Development	Year/Phase of completion	Project Type	# housing units	Sqft. commercial/ industrial
Lofts at Perkins Park Phase II	2009	Residential	41	
Challifoux Building	2016	Residential	47	
One City Square	Under Construction	Residential	11	
278 Central Street	Under Construction	Residential	10	
Edge of Merrimack	2017	Residential	156	
15 Kearney Square	2018	Residential	22	
Adden Building	2017	Residential	75	
Thorndike Exchange Phase I	2019	Residential	62	
Thorndike Exchange Phase II	Under Construction	Residential	75	
Mass Mills Phase III	Under Construction	Residential	70	
1 East Merrimack	Under Construction	Mixed-Use	42	915
43 Market Street	Under Construction	Residential	9	
279 Dutton Street	Permitted	Residential	4	
Winn Residential Development of Parcels 8 and 9 in Hamilton Canal Innovation District (HCID)	Under Construction	Residential	125	
15 Whipple Street	Applied	Residential	1	
66 State Street	Approved	Residential	2	
145-147 Woburn Street	Applied	Residential	1	
43 Willow Street	Approved	Residential	1	
246.1 Market Street	Applied	Residential	29	
464 Central Street	Applied	Residential	1	
1180 Middlesex Street	Applied	Residential	2	
19 and 20 Academy Drive	Approved	Residential	12	
39 Myrtle Street	Approved	Residential	9	
Waterhead Apartments	2020	Residential	71	
230, 234 Appleton Street	Approved	Residential	15	
Residences at the Franco	Under Construction	Residential	49	
357 Pawtucket Street	Approved	Mixed-Use	15	2,600
484 Merrimack Street	Approved	Mixed-Use	3	1,500
138 Middlesex Street	2020	Residential	1	
152 Jewett Street	2019	Residential	1	
142 Liberty Street	Approved	Residential	4	

DRAFT

Name of Development	Year/Phase of completion	Project Type	# housing units	Sqft. commercial/ industrial
153 Westford Street	Under Construction	Mixed-Use	24	1,500
160 Middlesex Street	2019	Residential	1	
408 E Merrimack Street	Approved	Residential	2	
23 Exeter Street	2019	Residential	1	
31 Fairgrove Avenue	2019	Residential	2	
36 Osgood Street	2019	Residential	1	
432 Suffolk Street	2019	Residential	2	
55 Parker Street	2019	Residential	1	
41 Ellis Avenue	Under Construction	Residential	4	
The Cottages by the Concord	Under Construction	Residential	3	
256 Trotting Park Road	Under Construction	Residential	1	
102 Appleton Street	Under Construction	Mixed-Use	4	2,648
25 Read Street	Under Construction	Residential	3	
493 & 509 Market Street	Under Construction	Mixed-Use	15	2,492
122 Sixth Street	Under Construction	Residential	1	
157 Billerica Street	Under Construction	Residential	3	
29-31 Paige Street	Under Construction	Mixed-Use	2	
755 School Street	Approved	Residential	1	
66 and 72 Manchester Street	Approved	Residential	4	
70 Fox Street	Under Construction	Residential	1	
22 Abbott Street	Under Construction	Residential	1	
12 Manchester Street	Under Construction	Residential	1	
268 Mt. Vernon Street and 5 Farnham Street	Approved	Commercial		22,000
Khmer Buddhist temple	Approved	Religious		16,800
165 Industrial Ave E	Approved	Commercial		18,240
Patriot Care Dispensary	2019	Commercial		31,064
Platinum Hydrolabs	Approved	Commercial		6,800

DRAFT

Name of Development	Year/Phase of completion	Project Type	# housing units	Sqft. commercial/ industrial
330 Jackson Street	Under Construction	Commercial		22,878
Domino's Pizza	2019	Commercial		6,000
Pure Industries	2020	Commercial		14,736
181 Stedman Street	Under Construction	Commercial		7,000
Lowell Legacy Hotel	Under Construction	Commercial		7,990
Market Basket/other retail	Under Construction	Commercial		84,500
Markley Group Data Center	Under Construction	Commercial		3,52,000
Hamilton Canal Innovation District (HCID) Garage	Under Construction	Commercial		49,800
UTEC	Under Construction	Commercial		28,465
Wellman Farm Inc.	Under Construction	Commercial		12,503
FourTwenty Industries Co.	Under Construction	Commercial		12,041
Compassion Eldercare	Under Construction	Commercial		12,324
Nationwide Tile	Under Construction	Commercial		3,339
Total			2,048	1,200,135

(MAPC, 2020 and Core Team Input)

3.8 Critical Facilities and Vulnerable Populations

Critical facilities are extremely essential components to the City's function and protecting them from natural hazards is paramount. Critical facilities range in function from: (a) resources that can be utilized to respond and recover from natural hazards; (b) facilities where additional assistance might be needed; and (c) hazardous sites that could be dangerous if it is compromised during a natural disaster. Critical facilities in the City of Lowell have been identified with help from knowledgeable City staff, MassGIS data, and existing plans. The Northern Middlesex Hazard Mitigation Plan (NMCOG, 2015) was especially helpful. Critical facilities and vulnerable populations have been broken into four categories: emergency response, nonemergency response, dangerous/hazard materials and facilities, and vulnerable populations and community facilities. Emergency response facilities that are necessary for the City in the event of a disaster. Nonemergency facilities are considered essential for the everyday operation.

DRAFT

Table 3-7. Category 1 – Emergency Response Facilities

Type	Name	Location
Public Safety	Police Station HQ and Communications Center (Police & Fire)	50 Arcand Drive
	Police Department Acre Precinct	597 Broadway Street
	Police Department Centralville Precinct	485 Bridge Street
	Police Department Lowell Housing Precinct	21 Salem Street
	Police Department Lower Highlands Precinct	671 Middlesex Street
	Police Department Downtown Precinct	50 Central St
	Police Department Office at Thorndike Exchange	165 Thorndike St
	Police Department Training	99 Middlesex Street
	Fire Department HQ/E3/L3/R (and Civic Center)	99 Moody Street
	Fire Department E1	795 Gorham Street
	Fire Department E2/L2	45 Branch Street
	Fire Department E4	198 High Street
	Fire Department E6/L4	284 West Sixth Street
	Fire Department E7	273 Stevens Street
	Fire Department FP	93 Mammoth Road (moving to 341 Pine Street)
	Fire Department TR	502 Rogers Street
	Fire Department E10	57 Old Ferry Road
	Fire Department E11/L1	743 Lawrence Street
Government Facilities	City Hall	375 Merrimack Street
	Lowell Justice Center	370 Jackson Street
	Health Department	341 Pine Street (in process of moving)
	John F. Kennedy Civic Center	50 Arcand Drive

DRAFT

Type	Name	Location
	City of Lowell Parks Dept.	133 Stedman Street
	Department of Public Works	1365 Middlesex Street
Communication and Utilities Infrastructure	Communications center	375 Merrimack Street/50 Arcand Drive
	Boott Hydro Power Plant	145 Pawtucket Street
	Lowell Wastewater Treatment Facility	451 First Street (Lowell/Lawrence Boulevard – route 110)
	Water Treatment Facility	815 Pawtucket Boulevard
	Water Department Intake Station	1194 Pawtucket Boulevard
	National Grid	School Street
	Comcast	12 Washer Street
	Verizon Switching Building	97-115 Appleton Street
Emergency Shelters	Lowell Senior Center	276 Broadway Street
	Robinson School	110 June Street
	Rogers School	43 Highland Street
	Reilly School	115 Douglas School
	Pawtucket Memorial School	West Meadow Road
	Pyne School	Boylston Street
	Stoklosa School	Broadway/School St
	Lowell Memorial Auditorium	East Merrimack Street
	Lowell Catholic	530 Stevens Street
	Middlesex Community College	East Merrimack Street
	St. Michael's Parish Hall (sold)	543 Bridge Street
	Fusion Center Concert Venue	4th Avenue
	St. Patrick's Parish Hall	Suffolk Street
	Immaculate Conception Parish Hall	East Merrimack Street

DRAFT

Type	Name	Location
	Tsongas Arena	300 Martin Luther King Way
Water and Wastewater Pump Stations	Intake Station	GIS: 1194 Pawtucket Blvd. Billing: 1002 Pawtucket Blvd.
	Wedge St. Tank	78 Wedge Street
	Stackpole Station	178 Stackpole Street
	10th Street Station	191 Mount Pleasant Street
	Newbridge Station	9 Aegean Lane
	Trotting Park Station	121 Trotting Park Road
	Beacon Street Station	197 Beacon Street
Wastewater Satellite Stations	School St Pump Station	25 School Street
	Appleton Mills Pump Station	219 Jackson Street
	Freda Pump Station	205 Freda Lane
	Trotting Park Pump Station	330 Trotting Park Road
	Cannington Pump Station	48 Cannington Street
	Varnum Pump Station	780 Varnum Street
	Pawtucket Pump Station	227 Pawtucket Blvd
	Princeton Pump Station	580 Princeton Blvd
	Rosemont Pump Station	45 Rosemont Street
	Lawrence Mills Pump Station	52 Lawrence Drive
	Chelmsford Pump Station	945 Chelmsford Street
	Pyne School Pump Station	145 Boylston Street
	Rivers Edge Pump Station	124 Adie Way
	First Street Diversion Station	500 1st Street Blvd
	Read Diversion Station	51 1st Street

DRAFT

Type	Name	Location
	West Diversion Station	408 Lakeview Ave
	Beaver Brook Diversion Station	161 Martin Street
	Walker Diversion Station	520 Pawtucket Street
	Merrimack Diversion Station	650 E Merrimack St
	Warren Diversion Station	126 Warren Street
	Tilden Diversion Station	300 Arcand Drive
	Kearney Square Siphon Station	50 Kearney Square

Table 3-8. Category 2 – Non-Emergency Response Facilities

Type	Name	Location
Transportation	Gallagher Trans. Terminal	101 Thorndike Street
Capped Landfill	Westford Street (Charter) Landfill	1264 Westford St
Parks, Public Space, and Recreation	Tsongas Arena	300 Martin Luther King Way
	Lowell Memorial Auditorium	50 East Merrimack Street
	Cawley Stadium	424 Douglas Road
	Eastern Canal Park	Bridge Street
	Lelacheur Park	450 Aiken Street
	Concord River Greenway	51 Davidson Street, 34 Merrill Street, Lawrence Street
	Spalding House Park	383 Pawtucket Street
	Jollene Dubner Park	36 Merrill Street
	Edwards Street Soccer Fields	26 Edwards Street
	Kittredge Park	68 Nesmith Street
	Coburn Park	845 Chelmsford Street
	Liberty Park	Arcand Drive
	Fusion Center	4th Avenue

DRAFT

Type	Name	Location
	Pollard Memorial Library	401 Merrimack Street
	Janas Memorial Ice-Skating Rink	Douglas Road
	Totman Street Conservation Land*	48 Totman Road
	Hawk Valley Farm*	End of Varnum Terrace
	Black Brook*	16 Nicole Drive
	Donahue Park*	95 Fairmont Street
	West Meadow Conservation*	Lauren Way
	Edwards Soccer Fields	Edwards Street
	North Common	413 Fletcher Street
	South Common	200 South Street
	Kerouac Park	75 Bridge Street
	Boarding House Park	40 French Street
	Merrimack Repertory Theatre	50 E Merrimack Street
City Garages	Ayotte garage	1 post office
	Early garage	135 Middlesex street
	John Street garage	75 John Street
	Leo Roy Garage	86 Market Street
	Lower Locks garage	90 Warren Street
	Hamilton Canal garage (under construction)	Canal District
Other facilities	UML Inn and Conference Center	50 Warren Street
	Lowell National Park Visitor Center	246 Market Street
	Cross Point Towers	900 Chelmsford Street

*Parks listed are also conservation land

DRAFT

Table 3-9. Category 3 – Vulnerable Populations and Community Facilities

Type	Name	Location
Housing Authority	Belvidere Heights	117 High Street
	Centralville Gardens	111 Hildreth Street
	City View Towers	657 Merrimack Street
	Concord River Mill	50 Stackpole Stret
	Faulkner Street	Lawrence Street
	Francis Gatehouse	735 Broadway Street
	Harold Hartwell Court	25 Temple Street
	Highland Parkway	580 Chelmsford Street
	North Common Village	21 Salem Street
	South Common Village	198 South Street
	Belvidere Heights	117 High Street
Schools	Middlesex Community College	33 Kearny Square
	UMass Lowell, Cumnock Hall	1 University Avenue
	UMass Lowell, Fox Hall	50 Pawtucket Street
	UMass Lowell, Reactor	205 Riverside Street
	UMass Lowell South Campus	Broadway Street & Wilder Street
	UMass Lowell, Coburn Hall	850 Broadway Street
	Lowell High School	50 French Street
	B.R.I.D.G.E. Program	73 Woburn Street
	Bailey Elementary School	175 Campbell Dr.
	Bartlett Community Partnership	79 Wannalancit Street
	Butler Middle School	1140 Gorham Street
	Cardinal O'Connell Early Learning Center	21 Carter Street
	Daley Middle School	150 Fleming Street
	Greenhalge Elementary School	149 Ennell Street
	Laura Lee Therapeutic Day School	235 Powell Street
	LeBlanc Therapeutic Day School	58 Sycamore Street
	Lincoln Elementary School	300 Chelmsford Street
	McAuliffe Elementary School	570 Beacon Street
	McAvinnue Elementary School	131 Mammoth Road
	Moody Elementary School	158 Rogers Street
	Morey Elementary School	130 Pine Street
	Murkland Elementary School	350 Adams Street
	Pawtucketville Memorial Elementary School	425 West Meadow Road
	Pyne Arts School	145 Boylston Street
	Reilly Elementary	115 Douglas Road
	Robinson Middle School	110 June Street

DRAFT

Type	Name	Location
	Shaughnessy Elementary School	1158 Gorham Street
	STEM Academy @ the Rogers School	43 Highland Street
	Stoklosa Middle School	560 Broadway Street
	Sullivan Middle School	150 Draper Street
	The Career Academy	125 Smith Street
	Wang Middle School	365 West Meadow Road
	Washington Elementary School	795 Wilder Street
Health and Aging Facilities	Northwood Rehabilitation and Health Care Center	1010 Varnum Avenue
	Lowell General Hospital	295 Varnum Avenue
	Saints Medical Center	1 Hospital Drive
	Walk-in Clinic	1230 Bridge Street
	Highland Medical	660 Middlesex Street
	Lowell Community Health Center	161 Jackson Street
	D'Youville Manor Nursing Home	Varnum Avenue
	Senior Center	276 Broadway Street
	Wingate Healthcare	500 Wentworth Ave
	Care One At Lowell	19 Varnum Street
	Fairhaven Nursing Home	476 Varnum Ave
	Town and Country Health Care Center	259 Baldwin Street
	Willow Manor Genesis Health Care	30 Princeton Blvd.
Hotels	30 Industrial Ave East	
	50 Warren Street	

DRAFT

4.0 HAZARD PROFILES, RISK ASSESSMENT & VULNERABILITIES

Each hazard profile in this chapter contains information on the areas vulnerable to the hazard, documentation of historic events, a risk and vulnerability assessment, and projected climate risk. The risk and vulnerability assessment examine both the frequency and severity of hazards, and their potential impact to the City of Lowell. Each hazard risk and vulnerability assessment use previous occurrences along with climate projections to determine areas that are at high risk and also the likelihood of occurrence of a hazard. The hazard profiles were updated with information from *2013 Massachusetts State Hazard Mitigation Plan* (MEMA and DCR, 2013), *2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan* (SHMCAP) (MA EOEEA and EOPSS, 2018), and additional research and assessment. Information obtained from the Core Team Meeting, CRB Workshop, and Listening Session provided local accounts of each hazard. In addition, a GIS assessment was conducted to analyze the potential impact of flooding in Lowell on current and future development. FEMA's Hazus software was used to model potential damage of hurricanes.

4.1 Statewide Overview of Hazards

4.1.1 Massachusetts State Hazard Mitigation and Climate Adaptation

The 2013 Massachusetts State Hazard Mitigation Plan (MEMA and DCR, 2013), and the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) (MA EOEEA and EOPSS, 2018) examined the natural hazards that have the potential to impact the Commonwealth. These plans summarize the frequency and severity of hazards of greatest concern. The frequency classification ranges from very low to high. Severity classifications are listed as a range from minor severity to catastrophic. The box below gives further definitions of the frequency and severity characterizations. The box below gives further definitions of the Frequency and Severity characterizations.

Definitions used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency

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

Severity

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

Not all hazards included in the 2018 State Hazard Mitigation and Climate Adaptation Plan or the 2013 Massachusetts State Hazard Mitigation Plan apply to the City of Lowell. Given Lowell's inland location, coastal hazards and tsunamis are unlikely to directly affect the City. Figure 4-1 illustrates the hazard risk assessment for the City of Lowell based on the data from the Hazard Mitigation Plan for the Northern Middlesex Region 2015 update (Table 47; pp. 127). The risk assessment is a weighted average of frequency, severity, extent of impact, and probability. As seen in Figure 4-1, Hurricanes have the most severe impact on Lowell followed by winter storms (Nor'easter, snowstorm, ice storm) whereas dam failure and landslides are relatively less hazardous. Given the smaller scale of wildfires that have occurred in Lowell's history and in the northeast region of the country, the City will focus on urban fires rather than wildfires. Therefore, it can be assumed that the entire City of Lowell and its critical facilities are susceptible during the occurrence of events such as high-wind events, hurricanes, winter storms, temperature extremes, and snow and ice. Flood risk from riparian flooding is elevated in the vicinity of the flood zones. Landslides are more likely in areas with more unstable soil types.

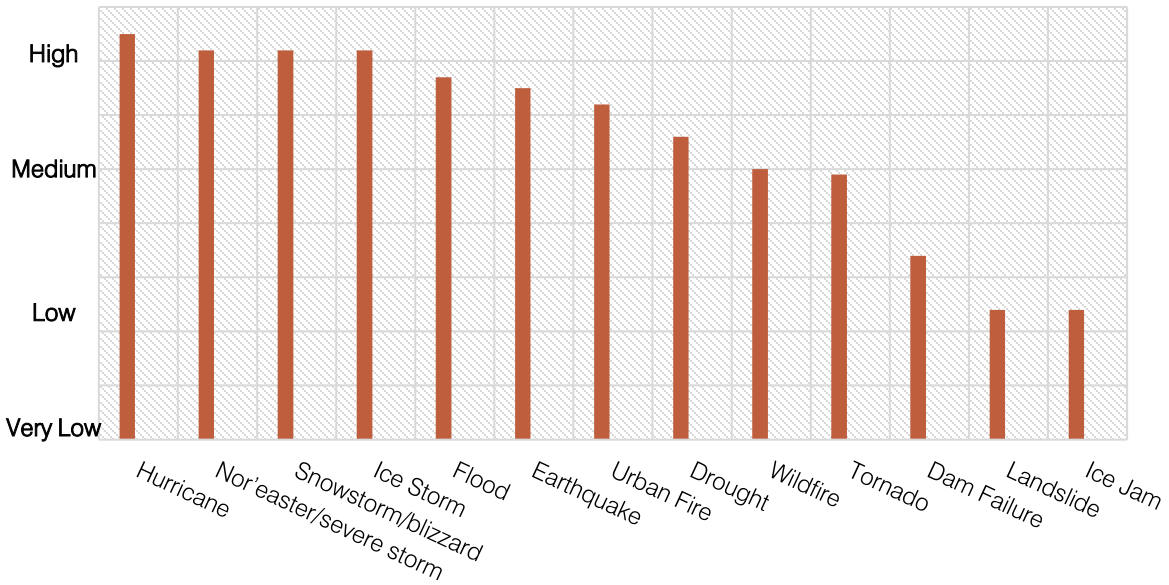


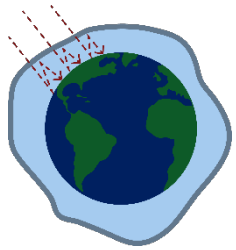
Figure 4-1. Lowell Hazard Risk

4.1.2 Federally Declared Disasters in Massachusetts

Tracking historic hazards and federally declared disasters that have occurred in Massachusetts, and more specifically Middlesex County, helps planners understand the possible extent and frequency of hazards. Massachusetts has experienced multiple type of hazards, including flooding, blizzards, and hurricanes. Since 1991, there have been 22 storms in Massachusetts that resulted in federal or state disaster declarations. Sixteen disaster declarations occurred in Middlesex County. Federally declared disaster opened additional FEMA grant opportunities for regional recovery and mitigation projects. The hazard profiles provided below contain further information about federally declared disasters.

4.1.3 Impacts of Climate Change

Many of the hazards that Lowell is currently experiencing are projected to worsen due to climate change. The Earth's atmosphere has naturally occurring greenhouse gases, like carbon dioxide (CO_2), that capture heat, which helps maintain the Earth's annual average temperature. When additional greenhouse gases are released through burning fossil fuels (oil, coal, and gas), the Earth's temperature increases. The global temperature increases impacts jet streams and climate patterns. The Massachusetts climate is expected to reflect historic climate patterns of states south of New England depending upon GHG emission scenarios. Climate change is likely to change Massachusetts's typically precipitation cycle, leading to more intense rainfall and storms and more episodic or flash droughts. Temperatures will increase in both summer and winter. Each hazard profiles includes more details on how the frequency and intensity of the hazard will shift with climate change and the anticipated impacts.



4.1.4 Top Hazards as Defined in the CRB Workshop

Workshop participants were asked to identify the four top hazards that Lowell faces. There was extensive discussion that lead to the selection of these top hazards. They were:

1. Flooding
2. Extreme Temperatures
3. Extreme Winter Weather
4. Wind and Microbursts

Figure 4-2: top hazards defined by Lowell's workshop participants

Most prevalent natural hazard for Lowell was identified as stormwater and riparian flooding. Workshop participants expressed concern that poorly designed stormwater management systems can cause localized flooding during extreme precipitation events. Regarding stormwater infrastructure, there was concern that there are several areas that suffer from recurring flooding in Lowell. Some of these areas could cut off access to vulnerable populations in the event of an extreme flood. Workshop participants believe that the following assessments are needed in order to reduce storm damages:

- Culverts near Clay Pit Brook: assess existing conditions.
- Assess and map the entire drainage system.
- Assess maintenance program for flooding caused by beavers, work with beaver consultant, and study best practices for beaver deceivers and other methods.
- Ensure appropriate capacity and size of catch basins in vulnerable areas.

DRAFT

- Continue to encourage low impact development (infiltration basins, rain gardens) and assess options for regulatory mechanisms.

Extensive discussion about winter storms and power outages resulting from windstorms took place during the portion of the workshop that introduced known and potential natural hazards and climate change impacts that currently occur or are predicted to occur in Lowell.

Lowell is a City with a large number of trees, which can be a great strength to the community, but can also be a challenge, especially in conjunction with overhead power lines and strong storms. The participants highlighted that it is necessary to work with the National Grid's arborist to assist with removal of hazard trees that threaten power lines and can also assist with a list of appropriate street trees.

4.2 Flood-Related Hazards

Flooding was among the four main hazards identified by participants during Lowell's CRB workshop. Flooding can be caused by various weather events including hurricanes, extreme precipitation, thunderstorms, nor'easters, and winter storms. Beaver dams also contribute to flood concerns in Lowell. Flooding events in Lowell have been classified as a high frequency event based on the historical occurrences. As defined by the Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA EOEEA and EOPSS, 2018), flood related disaster occurs once in three years (33% chance per year) in the Commonwealth. While Lowell is already vulnerable to inland flooding, the impacts of climate change will likely lead to increasingly severe storms and, therefore, increasingly severe impacts. The impacts of flooding include injury or death, property damage, and traffic disruption. Flood storage in riverfront parks, smart development, and stormwater infiltration can mitigate flooding.

Areas within the FEMA Flood Zones, repetitive loss sites, and local areas identified as flood prone are more vulnerable to the impacts of flooding. The following sub-sections provide more information on historic flooding events, potential flood hazards, locally identified areas of flooding, risk of dam failures, and a vulnerability assessment. This analysis of flood hazard areas was informed by the FEMA NFIP Flood Insurance Rate Maps (FIRMs), a GIS vulnerability assessment, information from Lowell City staff, and accounts of past flood events provided by participants during the Lowell CRB Workshop.

Flood hazards are also directly linked to erosion, which can compromise the stability of building foundations. This puts current and future structures, and populations located near steep embankments and along the Merrimack River, at risk. Erosion can also undercut streambeds and pose a risk to those walking along the banks. Structures or critical facilities located near the streams and lakes in Lowell may be considered at risk from fluvial erosion.

DRAFT

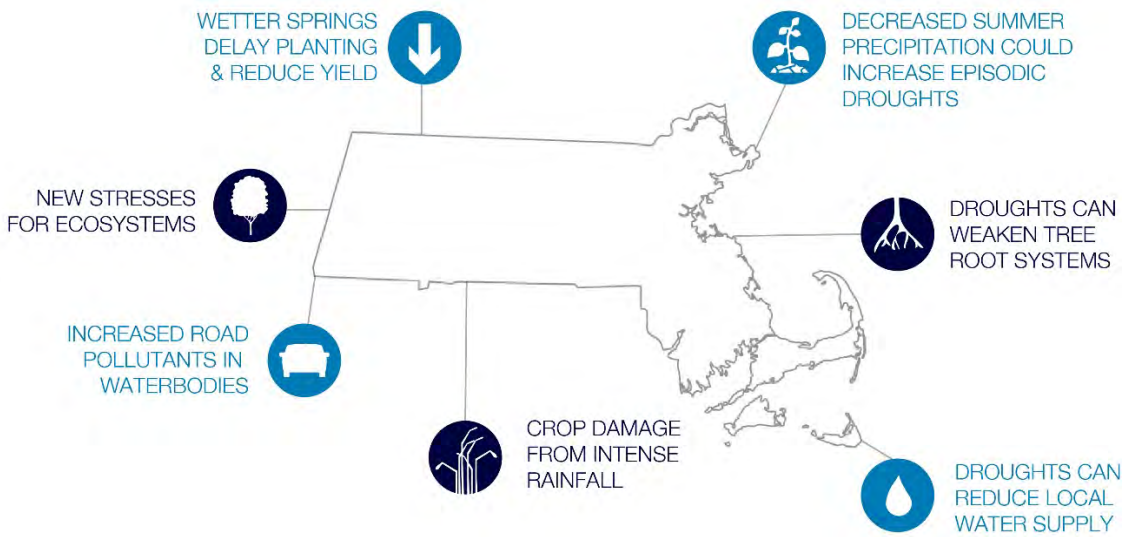


Figure 4-3: an infographic visualizing potential impacts of increasing precipitation (Weston & Sampson based on MA EOEEA, 2018)

4.2.1 Areas Vulnerable to Flooding

Along with areas adjacent to the streams or waterbodies, there are some low-lying areas in Lowell that flood every year. Flooding can be both riverine (topping the banks of streams, rivers, ponds) and from stormwater that is not properly infiltrated into the ground due to blocked or undersized drainage system.

<u>Riverine Flooding</u>
Riverine flooding has been a serious problem in Lowell historically due to its geographic location. Lowell sits at the confluence of Merrimack and Concord Rivers, and is home to a series of streams, ponds, and other waterbodies that include:

- Rivers: Merrimack, Concord
- Major streams: Beaver Brook, Black Brook, Clay Pit Brook, Scarlet Brook, Flagg Meadow Brook, River Meadow Brook, Hales Brook
- Canals: Eastern Canal, Pawtucket Canal, Northern Canal, Western Canal, Hamilton Canal
- Contiguous wetland: 10-25 acres of wetlands areas in the Lowell-Dracut-Tyngsborough State Forest, along the old Middlesex Canal, Black Brook, and portions of the Merrimack and Concord Rivers' floodplains. minor wetlands are near to Cross Point Towers, Wood Street, Westford Street, several locations along I-495, and near Cawley Stadium (Open Space and Recreation Plan, Lowell, 2019)

Flooding is more common during the spring when snowmelt water from higher elevation flows through the river followed by intense spring showers. Being an old and urban community, Lowell has some overly developed areas with substandard flooding regulations. Some of those constructions resulted in filling up the flood storage areas leading up to flooding. However, after the disastrous flooding in 2006 and 2007, FEMA has mapped the flood-prone areas in Flood Insurance Rate Map (FIRM).

FEMA Flood Zones

FEMA Flood Insurance Rate Maps (FIRM) designate areas likely to experience flooding. The FIRM delineates both the special flood hazard areas and the risk premium zones under the NFIP. This includes high risk areas that have a one percent chance of being flooded in any year (often referred to as the "100-year floodplain"), which under the NFIP, is linked to mandatory purchase requirements for federally backed mortgage loans. It also identifies moderate to low risk areas, defined as the area with a 0.2 percent chance of flooding in any year (often referred to as the "500-year floodplain"). The definitions of these flood zones are provided below. FEMA-designated flood zones for Lowell (FEMA, 2012) are included in Appendix C. The FEMA flood zone surrounds most of the water bodies and wetlands areas listed above.

Flood Insurance Rate Map Zone Definitions

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

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

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

Source: https://www.fema.gov/flood-zones

Repetitive Loss Sites

As defined by FEMA and the NFIP, a repetitive loss property is any insured property which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978 (FEMA and NFIP, 2018). It is important to remember that repetitive loss data does not fully represent the damage that Lowell sustains from flooding. Repetitive loss data only includes buildings that receive the FEMA designation, which does not include all buildings that have incurred flood damage.

Flooding events in Lowell can be classified as a high frequency event. As defined by the Massachusetts State Hazard Mitigation and Climate Adaptation Plan this hazard occurs once every three years (33% chance per year) in a disaster level. Table 4-1 illustrates the repetitive loss sites and flood insurance data for City of Lowell (Policy and Loss Data by Geography, FEMA, 07/31/2019). As seen in the table Lowell has 24 repetitive loss structures within the city (FEMA, 2019c). All of them are residential properties. 22 are located in FEMA AE, A1-30, AO, AH, A zone (100-year flood zone)

and only 15 of them are insured. Two buildings are located in the B, C, X zone (500-year flood zone) and one of them is insured. Out of 55 repetitive losses, 35 were insured properties.

Table 4-1: Flood insurance data and repetitive loss data for Lowell

Flood Insurance Data		Repetitive Loss (RL) Data	
Flood Insurance Policies in Force	1139	RL Buildings	24
Total Premium in Force	$920,459	RL Losses	55
Insurance in Force	$232,499,400	RL Payments (total)	$ 584,907.11
Number of Closed Paid Losses	241	RL Payments (building)	$579,661.68
Dollar Amount of Closed Paid Losses	$4,917,885	RL Payments (contents)	$5,245.43

(FEMA, 2019c)

Stormwater Flooding

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

Most stormwater systems in Massachusetts are aging and have been designed with rainfall data that is no longer accurate. Figure 4-4 shows how the amount of rainfall of design storm data has increased from 1961 to 2015, especially for the larger 24-hour, 100-year event. Green infrastructure or low impact development improvements can help reduce stress on the capacity of the existing stormwater system by increasing infiltration on site. A rain garden or pervious pavement are example strategies. Upsizing culvert with new rainfall data is also recommended. Lowell has a Phase II NPDES General Stormwater Permit for its Municipal Separate Stormwater System and discharges stormwater into the major waterbodies in the city (rivers, brooks, canals). The city also follows best management practices in order to mitigate negative effects of stormwater from the surface water system by separating them (Lowell Open Space and Recreation Plan, 2019).

DRAFT

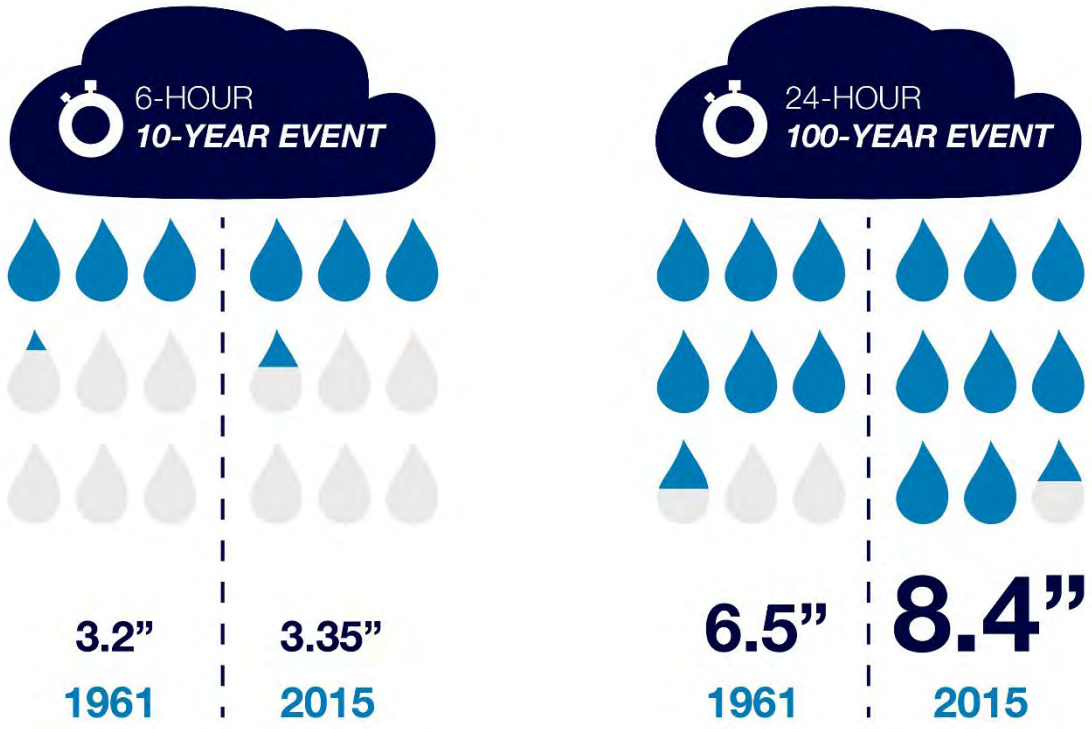


Figure 4-4: an infographic of anticipated increases in precipitation due to climate change. Engineers will need to design and size culverts with future precipitation data in mind (NOAA TP-40, 1961) and NOAA Atlas Volume 10 (2015)

DRAFT

Locally Identified Areas of Flooding

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

Table 4-2: Locally Identified Areas of Flooding

Name	Description
Beaver Brook dam area	The most common area of flooding
Townsend Avenue near Pawtucketville	Next to Clay Pit Brook and swamp, low area susceptible to flooding
Areas along Black Brook, Marginal Brook	Especially where it merges with the Merrimack River
Concord River Marginal Brook River Meadow Brook Beaver Brook Clay Pit Brook	Areas in the 100-year floodplain along these major waterways
Northern banks of the Merrimack River	Near the Water Treatment Plant and Rourke Bridge

Name	Description
Land around Black Brook and the Trull Brook tributary	Low lying areas between Phoenix Ave and Clark Road
Marsh Land	Wentworth Avenue/Douglas Road area

Also identified during the Workshop, some of the major streets where flooding occurs regularly.

- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

4.2.2 Historic Flood Events in Lowell

NOAA's National Centers for Environmental Information Storm Events Database (NOAA, 2019a) provides information on previous flood events for Middlesex County, including details of municipalities that were impacted by extreme events. The storms are categorized by event type, including flood and flash flood events. Flash Flood events are considered by the NOAA's National Centers for Environmental Information Storm Events Database as "a life-threatening, rapid rise of water into a normally dry area beginning within minutes to multiple hours of the causative event (e.g., intense rainfall, dam failure, ice jam)" (US Department of Commerce et al., 2018, p.A-15). Floods are considered, "any high flow, overflow, or inundation by water which causes damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, that poses a threat to life or property" (US Department of Commerce et al., 2018, p.A-20).

<u>Locally Significant Floods</u>

Since the 2000s, several significant floods have impacted the City of Lowell. Major floods events that affected the City are presented in the table below.

Table 4-3: Flooding Events in Lowell (2000-2019)

Date of Event	Flooding Type	Description
3/22/2001	Flood/Flash flood	Widespread flooding occurred on rivers and streams in eastern Massachusetts as a result of melting snow and heavy rainfall. The most severe flooding occurred in the Merrimack Valley, where flood damage was estimated at ten million dollars. The Concord River at Lowell crested at 8.94 feet.
8/7/2003	Flash flood	Slow moving thunderstorms brought torrential rainfall to parts of the Merrimack Valley, causing significant urban flooding in Chelmsford and Lowell. A spotter in Lowell reported nearly three inches of rain in one hour.
4/2/2004	Flood	Widespread minor to moderate flooding impacted many rivers in southern New England, as a result of 2 to 4 inches of rain over a three-day period. Flooding of mainstem rivers occurred along the Merrimack River in Lowell.
5/13/2006	Flood	Heavy rainfall over a 100-hour period caused widespread flooding across Middlesex County, exceeding flooding caused by the 1938 Hurricane and prompting the Governor to declare a State of Emergency.
3/14/2010	Flood	A stacked low pressure system moving southeast of Nantucket along with a strong southeasterly resulted in widespread rainfall totals of six to ten inches in eastern Massachusetts, prompting the Governor to declare a State of Emergency, followed by a federal disaster declaration for seven Massachusetts counties. Concord River at Lowell reached record flood stages within two to four days of the rain. Numerous basements flooded, streets were under water, trees were downed, and there was some minor structural damage to a few buildings.
3/29/2010	Flood	Four to seven inches of rain created by a low-pressure system fell across Middlesex County resulting in each of the seven gaged mainstay rivers in Middlesex County to rise above flood stage. Merrimack River at Lowell reached moderate flood
7/18/2017	Flood	Due to a cold front, several heavy downpours moved across the state near the front. Western Massachusetts and the Merrimack Valley were most affected. In Lowell multiple streets were under water; for e.g., intersection of Moore and Gorham Street, area of 131 South Street, intersection of South and Summer Streets, sections of the VFW Parkway.
10/30/2017, 8/17/2018	Flood	During both heavy rainfall events, flooding was reported at the junction of Gorham and Moore Streets in Lowell.

(Storm Events Database, NOAA, 2019)

DRAFT

Middlesex Flooding Events

NOAA's National Centers for Environmental Information Storm Events Database (NOAA, 2019) provides information on previous flood events for Middlesex County and the City of Lowell is in the Central Middlesex Zone. Middlesex County had 159 flood events between 2000 and 2019. Thirty of these events were flash floods. No deaths or injuries were reported. The property damage totaled $53.439 million dollars (not adjusted for inflation). Incredibly, flooding during March 2010 caused more than 80% of the total property damage reported during this time period (over $35 million dollars) and property damages ranged from $1,000 to $26 million in an individual town. Events like these are significant because climate change projections suggest that precipitation events will become increasingly frequent and severe.

Climate change projections suggest that precipitation events will become increasingly frequent and severe

Looking at Lowell's most severe hazard events can help us prepare for events intensified by climate change

Two events listed in the database were documented as county-wide impacts in May 2006 with $5 million in damages and in March 2010 with $26 million in damages. Lowell and neighboring Chelmsford were listed as having direct impacts. Although most of the flooding documented in the database did not directly affect Lowell, the monetary impact of flooding is a proxy for the potential damage that could occur. Damages that occur regionally can also have an indirect impact on Lowell due to regionally dependent utilities, supply of goods, transportation networks, and economic impacts, among other considerations.

Federally Declared Flood Disasters in Middlesex County

A disaster declaration is a statement made by a community when the needs required by a disaster or emergency is beyond the capabilities of that community. Eight disaster declarations were made in Middlesex County due to flooding between 2000 and 2015, as can be seen in Table 4-4 below.

Table 4-4. Previous Federal and State Disaster Declarations- Flooding

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms/Flooding October 20-25, 1996	DR-1142	FEMA Hazard Mitigation Grant Program	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
Heavy Rain and Flooding June 13-July 6, 1998	DR-1224	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms & Flooding March 5-April 16, 2001	DR-1364	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Flooding April 1-30, 2004	DR-1512	FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Essex, Middlesex, Norfolk, Suffolk, Worcester

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms and Flooding October 7-16, 2005	DR-1614	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Middlesex, Essex, Suffolk
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester

(MEMA, 2019; FEMA, 2018b; MA EOEEA and EOPSS, 2018)

4.2.3 GIS Flooding Exposure Analysis

Hazard location and extent of riverine flooding was determined using the current effective FEMA Flood Insurance Rate Map (FIRM) data for Lowell dated 2020. The FIRM is the official map on which FEMA has delineated both the special flood hazard areas and the risk premium zones applicable to the community under the NFIP. This includes high risk areas that have a one percent chance of being flooded in any year (often referred to as the 100-year floodplain), which under the NFIP, is linked to mandatory purchase requirements for federally backed mortgage loans. It also identifies moderate- to low-risk areas, defined as the area with a 0.2 percent chance of flooding in any year (often referred to as the "500-year floodplain"). For purposes of this exposure analysis, the following special flood hazard areas as identified in the City of Lowell's current FIRMs were included:

DRAFT

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

A flood exposure analysis was conducted for critical facilities and vulnerable populations throughout the municipality utilizing MassGIS data, FEMA flood maps, and information gathered from the municipality. Table 4-5 below displays critical facilities in Lowell that are located within either the 100-year or 500-year FEMA flood zone, and Table 4-6 shows all census blocks in Lowell that contain a high concentration of a vulnerable population.

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

Facility Name	Location	100-Year FEMA Flood Zone	500-Year FEMA Flood Zone
Northern Canal-Great Wall Dam	N/A	X	
Guard Locks Dam	N/A	X	
Lower Locks Dam	N/A	X	
Swamp Locks Dam	N/A	X	
Pawtucket Dam	N/A	X	
Middlesex Dam	N/A	X	
Wamesit Power Company Dam	N/A	X	
Edwards Street Soccer Fields	26 Edwards Street		X
Fire Department - Engine 10	57 Old Ferry Road	X	
Municipal Facility - Department of Public Works	1365 Middlesex Street		X
Nursing Home	1010 Varnum Avenue	X	
Nursing Home	500Wentworth Avenue	X	
Parks, Public Space, Recreation - Jollene Dubner Park	36 Merrill Street	X	
Parks, Public Space, Recreation - Black Brook	16 Nicole Drive	X	
Utilities - Boot Hydro Power Plant	145 Pawtucket Street	X	
Utilities - Water Department Intake Station	1194 Pawtucket Blvd	X	
Water and Wastewater Pump Stations	1194 Pawtucket Blvd	X	

DRAFT

Wastewater Satellite Stations - Princeton Pump Station	580 Princeton Blvd	X	
Wastewater Satellite Stations - Rosemont Pump Station	45 Rosemont Sreet	X	
Wastewater Satellite Stations - Lawrence Mills Pump Station	52 Lawrence Drive	X	
Wastewater Satellite Stations - Beaver Brook Diversion Station	161 Martin Street	X	
Wastewater Satellite Stations - Tilden Diversion Station	300 Arcand Dive	X	
Wastewater Satellite Stations - School St Pump Station	25 School Street		X
Wastewater Satellite Stations - Varnum Pump Station	780 Varnum Street		X
Wastewater Satellite Stations - Pawtucket Pump Station	227 Pawtucket Blvd		X
Wastewater Satellite Stations - Rivers Edge Pump Station	124 Adie Way		X
Wastewater Satellite Stations - Read Diversion Station	51 1st Street		X
Wastewater Satellite Stations - West Diversion Station	408 Lakeview Ave		X
Wastewater Satellite Stations - Hawk Valley Farm	End of Varnum Terrace		X

Twelve critical facilities identified in Lowell, are located within a FEMA 100-Year flood zone. None of the facilities are located within a 500-Year flood zone. These facilities are essential to the ongoing operations of the City, and it is important that they are protected so that they can continue to function even during times of a crisis. Out of these, Northwood Rehabilitation and Health Care Center and Wentworth Skilled Care Center house vulnerable populations.

During the workshop, stakeholders discussed concern around the location of vulnerable populations. Some of these community members rely on assistance and it is important that someone is able to access them if needed. It becomes a concern if the vulnerable populations are located within a flood zone or in an area that extreme flooding could isolate them from the rest of the City.

DRAFT

Of the 118 census blocks that have a high percentage of a vulnerable population, only 49 are located completely outside of 100-Year flood zone in Lowell.

Table 4-6. Census Block with High Concentrations of Vulnerable Populations Located within the FEMA Flood Zone

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
250173101001012	Elderly	2	0.6	26.0	0	0
250173101002002	Elderly	2	0.8	48.4	0	0
250173101002007	Elderly	14	1.1	7.9	0	0
250173105001003	Elderly	1	0.0	2.0	0.3	28.9
250173106011000	Elderly	11	1.0	9.3	0	0
250173106011004	Elderly	2	0	0	0.1	2.9
250173106011015	Elderly	45	29.8	66.2	7.3	16.3
250173106013002	Elderly	10	1.7	16.3	2.6	25.7
250173106013008	Elderly	4	3.8	100.0	0	0
250173106021019	Elderly	9	2.7	31.5	1.7	19.7
250173106021036	Elderly	3	0.2	5.8	1.5	59.2
250173107001005	Elderly	9	1.4	15.0	0.1	1.5
250173107003001	Elderly	12	1.4	12.2	0	0
250173114003000	Elderly	11	6.3	58.6	0	0
250173121001002	Elderly	9	2.0	22.6	0.4	4.4
250173122004018	Elderly	100	4.1	4.1	0	0
250173123002005	Elderly	3	0.8	29.1	0.8	31.6
250173123003002	Elderly	53	20.6	39.1	2.9	5.5
250173124001001	Elderly	4	0.9	23.5	0.6	15.6
250173124001007	Elderly	3	0	0	0.6	20.6
250173124001018	Elderly	9	0.2	2.7	0	0
250173125023012	Elderly	29	9.1	31.3	1.7	5.9
250173883002009	Elderly	6	0.2	2.6	0	0
250173883002023	Elderly	3	0.3	9.7	0	0
250173101002014	Minor	1	0.7	63.2	0	0
250173101003013	Minor	11	1.5	13.2	2.6	23.5
250173102003007	Minor	14	0	0	0.1	0.8
250173102003010	Minor	3	0	0	0.4	13.7
250173102003027	Minor	3	0	0	2.4	86.4
250173103005003	Minor	6	0	0	0.1	1.6
250173103005008	Minor	2	0	0	1.8	86.5
250173103005009	Minor	3	0	0	0.6	24.5
250173103005013	Minor	7	0	0	3.5	47.3
250173104001000	Minor	3	0	0	1.4	50.1

DRAFT

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
250173104001003	Minor	1	0	0	1.2	100.0
250173104001005	Minor	1	0	0	1.0	100.0
250173104001006	Minor	5	0	0	0.8	17.7
250173104001008	Minor	4	0	0	1.0	25.1
250173104001010	Minor	3	0	0	2.6	98.9
250173104001011	Minor	2	0	0	1.7	100.0
250173104001012	Minor	2	0	0	1.8	100.0
250173104001013	Minor	6	0.9	14.3	5.0	81.9
250173104001016	Minor	2	1.0	45.1	1.3	54.9
250173104002000	Minor	2	0	0	1.1	55.8
250173104002002	Minor	9	5.2	56.6	3.7	40.3
250173104002004	Minor	2	0.0	2.5	1.5	97.5
250173104002005	Minor	2	0.8	49.9	0.8	50.1
250173104002015	Minor	1	0	0	0.9	100.0
250173104002016	Minor	1	0	0	0.8	89.0
250173104002017	Minor	3	0	0	1.9	63.0
250173104002018	Minor	1	0	0	1.2	100.0
250173104002019	Minor	1	0	0	0.5	100.0
250173104003000	Minor	3	0	0	0.7	22.6
250173104003001	Minor	1	0	0	0.9	100.0
250173104003003	Minor	1	0	0	0.8	100.0
250173104003005	Minor	1	0	0	0.7	100.0
250173104003007	Minor	2	0	0	0.7	33.6
250173104003009	Minor	3	0	0	0.9	30.0
250173104003010	Minor	1	0	0	0.5	54.4
250173104003011	Minor	2	0	0	1.5	84.6
250173104003012	Minor	2	0.2	14.2	1.3	85.6
250173104003014	Minor	3	0	0	2.7	96.3
250173104003015	Minor	1	0.1	16.3	0.6	81.1
250173105001001	Minor	9	6.2	65.3	0.5	5.1
250173105001002	Minor	2	0.1	4.0	0.5	31.2
250173105001008	Minor	4	1.1	25.5	0.3	7.0
250173105001009	Minor	35	4.5	12.8	9.9	28.1
250173105001011	Minor	3	1.6	51.8	0.4	14.1
250173106011001	Minor	10	0.3	3.2	0	0
250173106012009	Minor	269	11.6	4.3	3.8	1.4
250173106012015	Minor	240	11.9	4.9	0	0
250173106013000	Minor	30	0	0	8.8	28.9
250173106013004	Minor	6	3.1	51.2	2.9	48.8

DRAFT

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
250173106013006	Minor	4	0.9	25.7	2.7	74.3
250173106013013	Minor	5	5.3	100.0	0	0
250173106021013	Minor	2	1.1	54.3	0.2	11.6
250173106021017	Minor	2	0.4	18.5	0.7	31.9
250173106021025	Minor	6	3.3	56.3	1.5	25.9
250173106021028	Minor	17	17.2	100.0	0	0
250173106024017	Minor	5	0	0	0.4	7.8
250173106024018	Minor	4	0	0	0.1	3.0
250173107001010	Minor	15	0.1	0.3	0	0
250173107001017	Minor	7	0.9	12.3	0	0
250173107002006	Minor	9	0	0	0.2	2.7
250173112001000	Minor	15	3.0	19.9	0	0
250173113003000	Minor	13	0.2	1.4	5.5	42.2
250173113003012	Minor	8	0	0	0.8	10.6
250173114001004	Minor	30	13.3	44.0	8.2	27.3
250173114002007	Minor	3	1.5	54.3	0	0
250173114003010	Minor	10	0	0	1.4	13.6
250173114003023	Minor	7	2.2	30.2	0	0
250173114004000	Minor	22	0	0	19.0	86.1
250173114004001	Minor	5	0	0	4.6	100.0
250173114004012	Minor	1	0	0	0.2	15.3
250173114004013	Minor	4	0.0	0.1	3.9	99.9
250173120001002	Minor	5	0.9	18.2	0	0
250173120002020	Minor	4	0.3	6.8	0	0
250173120002021	Minor	3	0.0	0.4	0	0
250173121001004	Minor	3	0.0	1.0	0	0
250173121001006	Minor	10	0.5	4.5	0	0
250173121003001	Minor	11	0.1	0.7	1.7	15.6
250173121003003	Minor	5	1.8	40.3	0.6	13.1
250173121003005	Minor	3	0.1	1.8	0	0
250173122001005	Minor	27	9.9	36.2	0.8	3.0
250173123001009	Minor	15	0.2	1.0	0	0
250173123001013	Minor	13	4.8	37.8	0	0
250173123002008	Minor	8	3.7	43.9	2.0	24.2
250173123002012	Minor	5	0.5	10.1	0.4	9.3
250173123002021	Minor	13	0.8	6.1	0.1	0.9
250173123002022	Minor	5	0	0	1.6	35.5
250173123002024	Minor	2	0.0	0.0	0	0
250173123002031	Minor	3	0.1	4.3	0.3	7.9

DRAFT

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
250173123003004	Minor	5	0.7	13.5	0	0
250173123003043	Minor	3	0	0	0.0	1.0
250173883002018	Minor	4	0.3	8.8	0	0
250173883002032	Minor	4	0.0	0.2	0	0
250173883003002	Minor	19	4.4	23.3	0.3	1.6
250173114002003	Minor and Elderly	4	0	0	4.4	100.0

"Minor" defines populations below the age of legal responsibility (under age 18)

As seen in Table 4-6, census blocks vary greatly by size. Census blocks which are larger in size with only a small percentage of the total area residing in a flood zone are likely to be less vulnerable than a smaller census block with the same percentage of total area in a flood zone. This is due to the greater availability of space for infrastructure outside of the flood zone in the larger census block. For example, 11.9% of the census block ending in 12015 is located within the 100-year flood zone. In comparison, 13.3% of the census block ending in 01004 is located in the 100-year flood zone. However, the total areas of the census blocks are 240 and 30 acres, respectively. Therefore, it is much more likely that infrastructure in the smaller census blocks will be impacted by flooding since there is likely less open space that can aid in flood mitigation.

While this may not be true for all census blocks, this goes to show that it is important to pay close attention to vulnerable populations within a community. Depending on developments within an area, vulnerable populations could be increasingly at-risk to flooding or other natural hazards due to their surrounding and landscape. Similar analysis was done to determine the location of Environmental Justice community within the flood zone (Table 4-7).

Table 4-7. Census Block with High Concentrations of Environmental Justice Community Located within the FEMA Flood Zone

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
0101807	MI	80	16.8	21.0	0	0
0101808	M	80	13.3	16.5	0	0
0101809	MIE	105	23.3	22.1	5.1	4.8
0101813	M	139	39.2	28.1	8.8	6.3
0101821	M	54	8.4	15.4	8.6	15.8
0101823	MI	41	9.2	22.6	21.5	52.7
0101824	M	66	32.8	49.9	23.6	35.9
0101825	M	61	22.9	37.3	24.7	40.3
0101827	M	138	61.4	44.4	15.4	11.1
0101831	M	336	149.5	44.5	48.5	14.4

Census Block Number	Vulnerable Populations	Total Area (acres)	Area in 100 Year Flood Plain	Percent in 100 Year Flood Plain	Area in 500 Year Flood Plain	Percent in 500 Year Flood Plain
0101832	M	857	24.4	2.8	38.3	4.5
0101833	M	137	66.1	48.2	29.9	21.8
0101835	M	243	155.7	64.1	30.2	12.4
0101838	M	251	0	0	1.9	0.7
0101840	MI	88	10.1	11.4	3.2	3.6
0101841	M	126	48.8	38.8	6.3	5.0
0101842	MI	68	16.1	23.5	0	0
0101845	MI	87	6.8	7.9	0	0
0101847	MI	57	3.0	5.2	0	0
0101848	M	57	1.0	1.7	0	0
0101852	M	71	1.4	1.9	7.6	10.7
0101854	M	163	77.0	47.4	24.1	14.8
0101855	M	85	16.5	19.4	10.9	12.9
0101856	MI	225	30.4	13.5	28.5	12.6
0101857	M	122	13.2	10.8	65.0	53.2
0101863	M	450	68.7	15.3	0	0
0101866	MIE	238	12.5	5.2	18.3	7.7
0101869	M	66	1.4	2.1	0	0
0101874	MIE	107	3.1	2.9	0	0
0101877	M	42	3.9	9.4	0	0
0101880	M	37	2.8	7.7	0	0
0101881	M	53	2.6	5.0	0	0
0101883	MI	59	13.6	23.0	0.5	0.9
0101885	M	85	4.3	5.1	3.2	3.8
0101887	M	223	40.9	18.4	8.3	3.7
0101889	M	97	0.2	0.2	0	0
0101890	MI	256	6.9	2.7	0	0
0101892	M	201	52.1	25.9	0	0
0101893	M	137	23.3	17.0	8.3	6.0
0101894	M	475	36.6	7.7	4.9	1.0
0101896	MI	49	7.5	15.1	1.6	3.2
0101897	MI	61	3.6	5.9	0	0
0103240	MIE	48	1.6	3.4	0	0
0103241	MIE	76	21.0	27.7	2.3	3.0

(M: Minority, I: Income; E: English Isolation)

As demonstrated by the table above, 44 census blocks containing Environmental Justice (EJ) communities are located within the 100-year and 500-year flood zones. These EJ populations are defined by the State as outlined below:

- Minority: 25% or more of the population identifies as a person of color

DRAFT

- Income: Households with an annual median income equal to or less than 65% of the state median
- English Isolation: 25% or more of households have limited English fluency

Additionally, the City's existing tax parcel and property value data, obtained from MassGIS, were used to estimate the number of parcels (developed and undeveloped), and buildings located in identified hazard areas along with their respective assessed values. The parcel data set provides information about the parcel size, land use type, and assessed value among other characteristics. The parcel data was also classified into various land use types based on the Massachusetts Department of Revenue's Property Type Classification Code, 2016.

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

Approximately 15% of the developed parcels in Lowell are located within a flood zone. Residential properties have the greatest building value located in both the 100-year flood zone and the 500-year flood zone. However, the percentage of commercial, industrial, and government-owned land in the 100-year flood zone is around 80%. These properties bring revenues to Lowell. If the infrastructure on these properties were to become compromised during a flood, it could lead to an economic hardship in the City. The tables below show the exposure of developed parcels in the City of Lowell.

Table 4-8. Developed Parcels in 100-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in the Flood Zone	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	17,951	3578	677	320	8.9	$182,608,000
Commercial	1,343	991	120	210	21.2	$71,151,800
Industrial	174	426	42	143	33.4	$108,696,600
Government	129	443	29	115	26.0	$106,646,300
Agricultural	N/A	N/A	N/A	N/A	N/A	N/A
Open Space	84	29	46	14.2	N/A	$5,515,000
Total	19,681	5468	914	803	14.7	$474,617,700

Table 4-9. Developed Parcels in 500-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in the Flood Zone	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Residential	17,951	3578	1067	292	8.2	$192,310,600
Commercial	1,343	991	134	240	24.2	$53,507,700
Industrial	174	426	19	107	25.1	$58,611,500
Government	129	443	15	139	31.2	$53,515,100
Agricultural	N/A	N/A	N/A	N/A	N/A	N/A
Open Space	84	29	23	7.3	N/A	$3,555,100
Total	19681	5468	1258	785	14.4	$361,500,000

Information about recent developments, or redevelopments, within the past 10 years (2010 – 2020) was obtained from MassBuilds (MAPC, 2020) and verified by the City's Energy Manager. An exposure analysis was done on these parcels. To determine the vulnerability of each parcel and building, a GIS overlay analysis was conducted in which the flood hazard extent zones were overlaid with the parcel data for recent developments and building footprint data (when available). These developments were overlaid with historic flood zones to determine these parcels vulnerability to flooding. They were categorized by land use type, and the exposure of each land use type was documented by the total area and percentage of parcels that overlap with a flood zone. The risk or impact of potential flooding was captured by summarizing the total property value in each parcel.

Although MassGIS parcel data is dated 2019, not all property values have been updated to reflect the most recent developments. Some limitations exist in the accuracy of the data resulting from delay in updates to the building and property value.

Table 4-10. Recently Developed Parcels in the 100-Year FEMA Flood Zone

Development Name	Development Address	Development Type	Total Area of Parcel (acres)	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
15 Kearney Square	15-17 Kearney Square	Residential	0.145	0.006	3.9	$259,800
	1 East Merrimack	Commercial	0.233	0.009	4.0	$353,300
Counting House Lofts 109	31 Jackson Street	Commercial	0.873	0.010	1.1	$1,473,900
	1488 Middlesex Street	Commercial	0.176	0.016	9.3	$51,200

Development Name	Development Address	Development Type	Total Area of Parcel (acres)	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
	850 Lawrence Street	Commercial	1.138	0.022	1.9	$311,700
One City Square	98 Central Street	Residential	0.085	0.026	31	$331,900
Domino's Pizza	90 Lakeview	Commercial	0.174	0.056	32	$5,200
Domino's Pizza	78 Lakeview	Commercial	0.147	0.147	100	$204,400
Hamilton Canal Innovation District (HCID)	350.4 Dutton Street	Government	3.670	0.062	1.7	$4,500
Appleton Mills	Appleton Mills	Residential	1.764	0.084	4.8	$311,800
	157 Billerica Street	Residential	0.594	0.091	15	$116,000
American Textile History Museum and Lofts	491 Dutton Street	Residential	2.290	0.112	4.9	$401,200
Compassion Eldercare	211 Plain Street	Commercial	4.518	0.201	4.5	$2,598,300
	193/239 Jackson St	Government	0.686	0.278	41	N/A
Lofts 27	Hamilton Mills	Residential	2.352	0.328	14	$81,800
The Cottages by the Concord	205 Billerica Street	Residential	0.910	0.435	48	$48,600
The EDGE Private Dorm Apartments	1 Merrimack Place	Commercial	1.706	0.445	26	$1,400
Mass Mills Phase III	170 Bridge Street	Residential	2.744	0.506	18	$6,487,500
Residences at the Franco	357 Pawtucket Street	Government	4.028	0.589	15	$5,064,600
Markley Group Data Center	2 Prince Ave	Industrial	14.282	0.794	5.6	$10,322,800
Western Avenue Lofts	Western Avenue	Industrial	4.209	0.846	20	$109,000
	130 John Street	Residential	2.211	1.423	64	$134,400
Market Basket/other retail	705 Pawtucket Blvd	Commercial	1.445	1.445	100	$490,200
Boott Mills East	141 John Street	Residential	2.349	1.598	68	$11,266,500

DRAFT

Development Name	Development Address	Development Type	Total Area of Parcel (acres)	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Market Basket/other retail	677 Pawtucket Blvd	Commercial	12.369	4.851	39	N/A
Total			0.145	0.006	3.9	$40,430,000

Table 4-11. Recently Developed Parcels in the 500-Year Flood Zone

Development Name	Development Address	Development Type	Total Area of Parcels (acres)	Area of Parcels in the Flood Zone (acres)	Percentage of Parcels in the Flood Zone	Property Value in the Flood Zone
Ecklund Drive	22 Ecklund Drive	Residential	0.144	0.087	61	N/A
Ecklund Drive	18 Ecklund Drive	Residential	0.116	0.008	6.8	N/A
	157 Billerica Street	Residential	0.594	0.284	48	$116,000
Markley Group Data Center	2 Prince Ave	Industrial	14.28	1.800	13	$10,322,800
Millview Estates	1975 Middlesex Street	Residential	4.829	1.612	33	$224,700
	1488 Middlesex Street	Commercial	0.176	0.160	91	$51,200
Market Basket/other retail	677 Pawtucket Blvd	Commercial	12.37	6.0	48	N/A
Domino's Pizza	78 Lakeview	Commercial	0.147	0.000	0.002	$204,400
Domino's Pizza	90 Lakeview	Commercial	0.174	0.118	68	$5,200
Legacy Project-The Dahod Building	295 Varnum Ave	Commercial	65.2	0.564	0.87	$109,100
Lofts at Perkins Park Phase II	39 Perkins Street	Residential	0.816	0.102	12	$5,807,800
Total			0.144	0.087	61	$16,841,200

N/A: Building and property values have not yet been updated.

To further resiliency in the City, a flood exposure analysis was completed on all vacant, developable parcels. The analysis was conducted utilizing MassGIS data (2019), FEMA flood maps, and

information from the City. The result of this analysis will bring light to future flooding that could occur on these parcels if they were to be developed.

The output of the ArcGIS overlay analysis showed all vacant, developable parcels that intersected with a flood zone. The number of parcels was totaled for each land use type within each of FEMA flood zones. While nearly 820 acres of land in Lowell are vacant and developable, of that land 35% is located within the 100-year flood zone and an additional 22% in the 500-year flood zone. It is recommended that as the City expands development, additional analysis be conducted on these parcels to reduce damage from flooding.

Table 4-12. Developable, Vacant Land in the 100-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in the Flood Zone (acres)	Percentage of the Parcels in the Flood Zone
Residential	535	160	73	59	37
Commercial	114	49	23	24	48
Industrial	84	80	16	19	23
Government	523	528	158	182	34
Agricultural	N/A	N/A	N/A	N/A	N/A
Open Space	3.00	3.58	2.00	3.52	98
Total	**1259**	**820**	**272**	**286**	**35**

Table 4-13. Developable, Vacant Land in the 500-Year FEMA Flood Zone

Land Use Type	Total Number of Parcels	Total Area of Parcels (acres)	Number of Parcels in Flood Zone	Total Area of Parcels in the Flood Zone (acres)	Percentage of the Parcels in the Flood Zone
Residential	535	160	65	29	18
Commercial	114	49	10	17	34
Industrial	84	80	5	10	12
Government	523	528	68	127	24
Agricultural	N/A	N/A	N/A	N/A	N/A
Open Space	3.00	3.58	1.00	1.52	42
Total	**1259**	**820**	**149**	**184**	**22**

Planned development noted by MassBuilds (MAPC, 2020) were reviewed and updated by the City's Director of Economic Development. These parcels were overlaid with FEMA flood zone maps to determine the vulnerability to flooding. They were categorized by development type. The exposure of potential development within each land use type was documented by the area and percentage of parcels that overlap with a flood zone. Of all the planned developments in Lowell, 8 are located in

the 100-year flood zone and one is located in the 500-year flood zone. This can be seen in Tables 4-14 and 4-15 below.

Table 4-14. Potential Development in the 100-Year FEMA Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	Percentage of the Parcels in the Flood Zone
	110 Canal St	Government	0.34	0.05	15
	48 Townsend Ave	Residential	0.38	0.38	100
	58 Townsend Ave	Residential	0.20	0.20	100
	66 Townsend Ave	Residential	0.21	0.21	100
	810 Varnum Ave	Government	0.28	0.28	100
Market Basket Retail Development	677 Pawtucket Blvd	Commercial	12.37	4.85	39
	246.1 Market Street	Residential	1.43	0.01	0.38
	800 Varnum Ave	Residential	6.61	6.61	100
Total			**0.34**	**0.05**	**15**

Table 4-15. Potential Development in the 500-Year FEMA Flood Zone

Development Name	Development Address	Land Use Type	Total Area of Parcels (acres)	Total Area of Parcels in the Flood Zone (acres)	Percentage of the Parcels in the Flood Zone
Market Basket Retail Development	677 Pawtucket Blvd	Commercial	12.4	6	48
Total			**12.4**	**6**	**48**

This planned development is located adjacent to a water resource area which can aid in flood storage and mitigation but could also become a hazard to adjacent infrastructure during a heavy rain or flood event. The existing 100-year flood elevation and future flood elevations should be considered during the design of the new developments. Resiliency measures, such as additional flood storage or flood protection, elevation above base flood level should be included in the design of the new developments.

4.2.4 Dams and Dam Failure

Dam failure is defined as a collapse of an impounding structure resulting in an uncontrolled release of impounded water from a dam (DCR, 2017a). Dam failures during flood events are of concern in

Massachusetts, given the high density of dams constructed in the 19th century (MEMA and DCR, 2013).

There are two types of dam failures that can occur. Catastrophic failure occurs when there is a sudden, rapid, uncontrolled release of impounded failure. The other is design failure, which occurs as a result of minor overflow events. Dam overtopping occurs when floods exceed the capacity of the dam and can occur as a result of inadequate spillway design, or other outside factors such as settlement of the dam crest or backage of spillways. Thirty-four percent of all dam failures that occur in the United States are a result of overtopping (MA EPEEA and EOPSS, 2018).

Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage (MEMA and DCR, 2013). Although dam failure does not occur frequently in Lowell, it can cause property damage, injuries, and potentially fatalities. These impacts can be at least partially mitigated through advance warning to communities impacted by a dam failure. In addition, the breach may result in erosion on the rivers and stream banks that are inundated.

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

There have been no recorded dam failures in Lowell, and although dam failure is classified as a very low frequency event in the City, a dam failure can still present a high level of risk and could result in a catastrophic event with extreme damage and loss of life. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan (MA EOEEA and EOPSS, 2018), a very low frequency hazard may occur less frequently than once in 100 years (less than a 1% chance per year). This summary table includes the hazard classification for each dam, which is defined by DCR as described below:

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

DRAFT

According to City officials and the Massachusetts Department of Conservation and Recreation's (DCR) Office of Dam Safety, there are 8 dams in Lowell. Information related to these dams is summarized in Table 4-16. Out of which Guard Locks and Lowell Reservoir Dam are High Hazard dams. Lowell Reservoir Dam was last inspected on 05/2018 and it is due for another inspection on 05/2020.

Table 4-16. Inventory of Dams in Lowell

Dam Name	Primary Owner	Hazard Code	Regulatory Authority
Northern Canal-Great Wall	DCR - Dept. of Conservation & Recreation	Low Hazard	FERC Jurisdiction
Guard Locks	DCR - Dept. of Conservation & Recreation	High Hazard	FERC Jurisdiction
Lower Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard	FERC Jurisdiction
Swamp Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard	FERC Jurisdiction
Pawtucket Dam	Boott Hydropower, Inc. c/o Enel North America, Inc.	Low Hazard	FERC Jurisdiction
Lowell Reservoir Dam	City of Lowell, Lowell Regional Water Utility	High Hazard	Office of Dam Safety
Middlesex Dam	City of Lowell, Lowell Regional Water Utility	N/A	Non-Jurisdictional - Other
Wamesit Power Company Dam	Centennial Island Hydroelectric Company, A Mass. Lim. Part.	Low Hazard	FERC Jurisdiction

As of February 2017, all dams classified as high hazard potential or significant hazard potential were required to have an Emergency Action Plan (EAP) (MA, 2020). This plan must be updated annually and submitted to the Commissioner and the Massachusetts Emergency Management Agency. The plan should also be retained by the dam owned and the City in which the dam is located. Guidelines and a template were established by the Office of Dam Safety to ensure that all EAPs follow the proper format.

4.2.5 Climate Change Impacts: Flooding

Lowell's average annual precipitation is 47 inches (US Climate Data, 2020). Extreme rain and snow events are becoming increasingly common and severe particularly in the Northeast region of the country (Figure 4-5). Regional increases in heavy precipitation events exceed the rest of the US by a 74% increase in the heaviest 1% of all precipitation events since 1958. The eastern region of Massachusetts has shown an increase in heavy precipitation of two inches or more since 1970. Annual maximum daily precipitation in the area has also increased by up to 2 inches since 1970 (UMass, 2019).

DRAFT

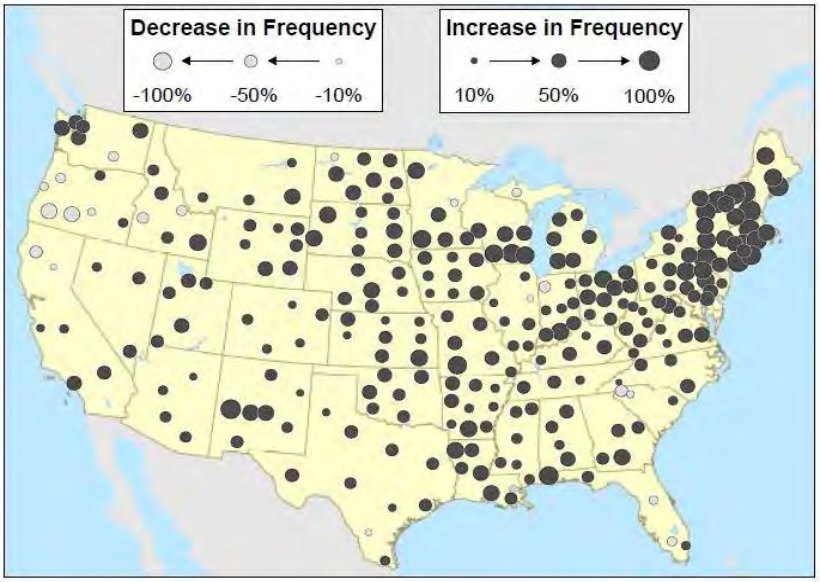


Figure 4-5. Changes in Frequency of Extreme Downpours

(Madsen and Willcox, 2012, page 19)

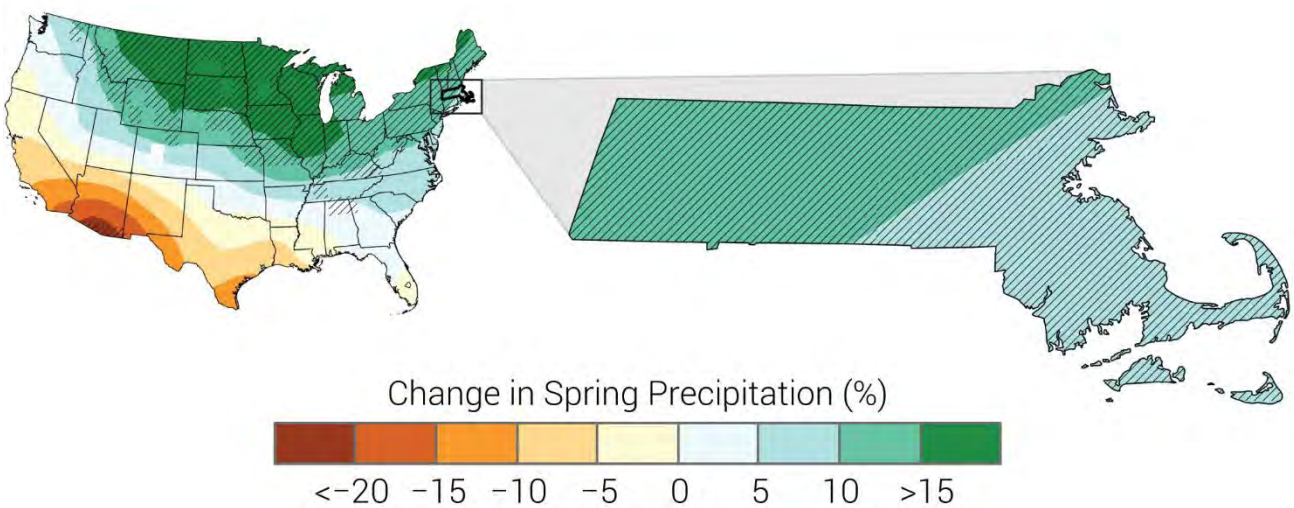


Figure 4-6. Projected Change in Spring Precipitation "Projected change in spring precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents portions of the state where the majority of climate models indicate a statistically significant change. Precipitation in the spring is projected to increase in Massachusetts by mid-century. Data from CICS-NC and NOAA NCEI" (NOOA and Department of Commerce, 2017)

4.3 Wind-Related Hazard

High winds can occur during hurricanes, tropical storms, tornadoes, nor'easters, and thunderstorms. The entire planning area is vulnerable to the impacts of high wind. All current and future buildings including critical facilities and populations are considered to be vulnerable during

high wind events. Wind may down trees and power lines. High wind and storm events cause property damage and hazardous driving conditions. While Lowell's current 100-year wind speed is 110 mph, climate change will likely increase events and severity.

Extreme winds can take down trees and branches that cause service disruptions. An identified issue during storms in Lowell is the damage to power and phone wires from overhanging trees that have not been trimmed by National Grid or the phone or cable companies. The utilities' tree maintenance program should be upgraded to reduce the risk associated with tree damage to utility lines. Lowell is disproportionally affected by power outages due to downed trees because the City's power is sourced from a National Grid station located in Westford, MA, and all power must be brought to Lowell through an aboveground power line corridor, much of which is wooded. High winds and heavy snow loads caused significant power line damage in Lowell during a nor'easter in 2018. Falling trees and branches can also block traffic and emergency routes. This is a regional issue that affects cities and communities beyond Lowell.

During Lowell's MVP Workshop in -April 2020 attendees discussed the impact of past storms on power systems and service disruption. Attendees described how power outages due to high winds are common in Lowell.

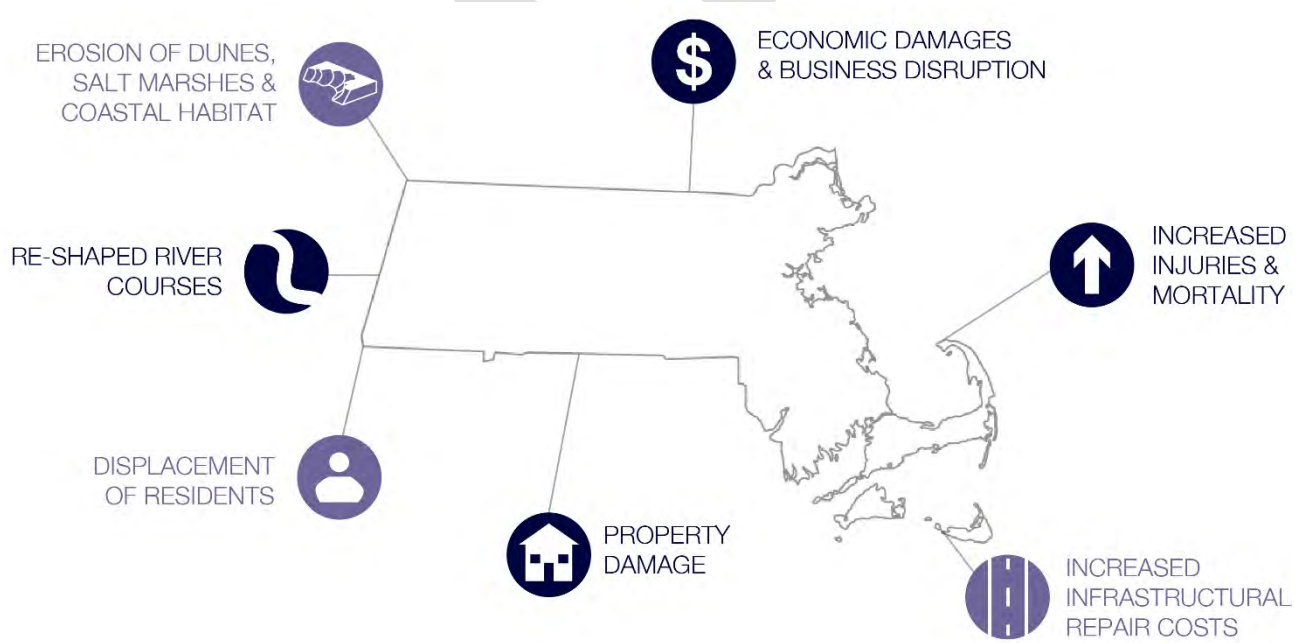


Figure 4-7: an infographic visualizing potential impacts of extreme storms, including high wind events (Weston & Sampson based on MA EOEEA, 2018)

4.3.1 Hurricanes and Tropical Storms

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

hurricanes. Wind gusts associated with hurricanes may exceed the sustained winds and cause more severe localized damage (MA EOEEA and EOPSS, 2018).

When hurricanes and tropical storms occur, they will impact the entire planning area. All existing and future buildings including critical facilities and populations are at risk to the hurricane and tropical storm hazard (including critical facilities). Hurricane events have a large spatial extent and would potentially affect all of Lowell's infrastructure and buildings. Impacts include water damage in buildings from building envelope failure, business interruption, loss of communications, and power failure. Flooding is a major concern as slow-moving hurricanes can discharge tremendous amounts of rain on an area.

The official hurricane season runs from June 1 to November 30. However, storms are more likely to occur in New England during August, September, and October (MA EOEEA and EOPSS, 2018).

The region has been impacted by hurricanes throughout its history, starting with the Great Colonial Hurricane of 1635. Between 1851 and 2012, Massachusetts experienced 13 hurricanes and two named tropical storms. The most recent FEMA disaster declaration in Massachusetts due to a hurricane was Hurricane Sandy in 2012 (FEMA, 2018b). Hurricanes that have occurred in the region since 1938 are listed in Table 4-17.

Table 4-17. Hurricane Records for Eastern Massachusetts, 1938 to 2019

Hurricane Event	Date
Great New England Hurricane*	September 21, 1938
Great Atlantic Hurricane*	September 14-15, 1944
Hurricane Doug	September 11-12, 1950
Hurricane Carol*	August 31, 1954
Hurricane Edna*	September 11, 1954
Hurricane Diane	August 17-19, 1955
Hurricane Donna	September 12, 1960
Hurricane Gloria	September 27, 1985
Hurricane Bob	August 19, 1991
Hurricane Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011
Hurricane Sandy	October 29-30, 2012
Hurricane Jose	September 20, 2017
Hurricane Florence	September 18, 2018
Tropical Storm Dorian	September 7, 2019

* Category 3
(NOAA, 2020)

The Saffir/Simpson scale categorizes or rates hurricanes from 1 (minimal) to 5 (catastrophic) based on their intensity. This is used to provide an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on context (MA EOEEA and EOPSS, 2018). More information is included in Table 4-18.

Table 4-18. 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 are severe, there are extensive glass failures, and entire buildings could fail.

(MA EOEEA and EOPSS, 2018) (table originally created by NOAA)

Hurricane damage in Lowell was estimated using a hurricane modeling software. Hazus Multi-Hazard (Hazus) is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. The Hazus hurricane model allows users to input specific parameters in order to model a defined hurricane magnitude, which is based on wind speed. The largest hurricane ever witnessed in Massachusetts was a Category 3 hurricane, which occurred in 1954. For the purpose of this analysis to estimate potential damage, both a category 2 and a category 4 hurricane were modeled. Although there have been no recorded Category 4 hurricanes recorded in Massachusetts, storm was modeled to show the impact that could occur from an extreme scenario, something that could possibly happen in the future due to climate change.

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

Table 4-19. Estimated Damages in Lowell from Probabilistic Category 2 and Category 4 Hurricanes

	Category 2	Category 4
Building Characteristics		
Estimated total number of buildings	24,205	24,205
Estimated total building replacement value (Year 2014 $) (Millions of Dollars)	$12,011	$12,011
Building Damages		
# of buildings sustaining minor damage	416	2,849
# of buildings sustaining moderate damage	48	538
# of buildings sustaining severe damage	1.89	24.67
# of buildings destroyed	0	4.84
Population Needs		
# of households displaced	0	71
# of people seeking public shelter	0	41
Debris		
Total debris generated (tons)	5,945	27,666
Tree debris generated (tons)	2,112	7,506
# of truckloads to clear building debris (@25 tons/truck)	153	806
Value of Damages (Thousands of dollars)		
Total property damage	$34,964.13	$171,264.59
Total losses due to business interruption	$1,754.59	$16,430.33

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

Hurricanes are a City-wide hazard in Lowell and are considered a medium frequency event. The average number of hurricane or tropical storm events is one every two years (MA EOEEA and EOPSS, 2018).

4.3.2 Tornadoes

A tornado is a narrow, violently rotating column of air that extends from the base of a cloud to the ground. Tornadoes are the most violent of all atmospheric storms (MA EOEEA and EOPSS, 2018). According to the 2018 SHMCAP, 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
- Increasing wind speed in the lowest 10,000 feet of the atmosphere (i.e. 20 mph at the surface and 50 mph at 7,000 feet)

- Very warm, moist air near the ground, with unusually cooler air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornadoes can be spawned by tropical cyclones or the remnants thereof, and weak tornadoes can even form from little more than a rain shower if air is converging and spinning upward. The most common months for tornadoes to occur are June, July, and August. There are exceptions: The Great Barrington, Massachusetts, tornado in 1995 occurred in May; and the Windsor Locks, Connecticut, tornado in 1979 occurred in October (MA EOEEA and EOPSS, 2018).

The Fujita Tornado Scale measures tornado severity through estimated wind speed and damage. The National Weather Service began using the Enhanced Fujita-scale (EF-scale) in 2007, which led to increasingly accurate estimates of tornado severity. Table 4-20 provides more detailed information on the EF Scale.

Table 4-20. Enhanced Fujita Scale

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

(MEMA and DCR, 2013)

Massachusetts averages 1.7 tornadoes per year. The most tornado-prone areas of the state are the central counties. Tornadoes are comparatively rare in eastern Massachusetts, although Middlesex County is considered an at-risk location (MA EOEEA and EOPSS, 2018). The most devastating tornado in Massachusetts in the history of recorded weather occurred in Worcester in 1953, it killed 94 people, injured more than 1,000, and caused more than $52 million in damages (more than $460 million in current dollars). Some more recent tornadoes in Massachusetts occurred in 2011 in Springfield, 2014 in Revere, and 2016 in Concord (Morrison 2014; Epstein 2016). Monson also experienced a tornado in 2011. Yarmouth and Barnstable experienced tornadoes in 2019. There have been 18 recorded tornados in Middlesex County since 1955 (NOAA, 2019). One fatality and six injuries were reported. Table 4-21 below provides additional information.

Tornadoes present a City-wide hazard and the damages would depend on the track of the tornado. However, tornado damage could be high due to the prevalence of older construction and the density of development. Structures built before current building codes may be more vulnerable. Evacuation, sheltering, debris clearance, distribution of food and other supplies, search and rescue, and emergency fire and medical services may be required. Critical evacuation and transportation routes

may be impassable due to downed trees and debris, and recovery efforts may be complicated by power outages.

Table 4-21. Tornado Records for Middlesex County

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

(NOAA, 2019a)

Tornado events in Lowell are a low frequency event. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Massachusetts experiences an average of 1.7 tornados per year. Tornados are difficult to simulate well in climate models because of their small size when compared to other weather events. However, it is predicted that the frequency of tornados in eastern Massachusetts will rise in the future due to climate change.

4.3.3 Nor'easters

A nor'easter is characterized by large counterclockwise wind circulation around a low-pressure center that often results in heavy snow, high winds, waves, and rain along the East Coast of North America. The term nor'easter refers to their strong northeasterly winds blowing in from the ocean. These winter weather events are among the season's most ferocious storms, often causing beach erosion, flooding, and structural damage (MA EOEEA and EOPSS, 2018).

Nor'easters generally occur in Lowell on at least an annual basis, typically in late fall and early winter. Some years bring four or more nor'easter events. This is currently the most frequently occurring natural hazard in the Commonwealth. The storm radius is often as much as 100 miles and sustained wind speeds of 20 to 40 mph are common, with short-term gusts of up to 50 to 60 mph. Nor'easters

DRAFT

are commonly accompanied by a storm surge equal to or greater than two feet. High surge and winds during a hurricane can last from 6 to 12 hours, while these conditions during a nor'easter can last from 12 hours to three days (MA EOEEA and EOPSS, 2018). Previous nor'easters events are listed in Table 4-22. The severe Coastal Storm in 1991 led to a federal disaster declaration.

Table 4-22. Nor'easter Events for Massachusetts, 1978 to 2020

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

(NOAA, 2019a)

Some of the historic events described in the "Flood-Related Hazards" section of this report were preceded by nor'easters, including the 1991 "Perfect Storm." The Blizzard of '78 was a notable storm. More recently, the blizzard of 2013 left nearly 400,000 Massachusetts residents without power (EOEEA, 2018). A series of winter storms in March 2018 also caused significant snowfall amounts (including Winter Storm Riley on March 2, Winter Storm Quinn on March 8, and Winter Storm Skylar on March 13). A FEMA Major Disaster Declaration was issued to provide recovery assistance to Massachusetts counties including Middlesex (FEMA-DR-4379-MA-March 13-14, 2018).

The City of Lowell is vulnerable to high winds, snow, and extreme rain during nor'easters. These impacts can lead to property damage, downed trees, power service disruptions, surcharged drainage systems, and localized flooding. These conditions can impact evacuation and transportation routes and complicate emergency response efforts. Due to its inland location, Lowell is not subject to the coastal hazards often associated with nor'easters.

Nor'easters in Lowell are high frequency events and are currently the most frequently occurring natural hazard in the state. Based on historic record, high-impact snowstorms occur at approximately the rate of once per year (MA EOEEA and EOPSS, 2018).

4.3.4 Thunderstorms and Related Wind Events

Thunderstorms can include lightning, strong winds, heavy rain, hail, and sometimes tornados. Thunderstorms typically last for about 30 minutes and can generate winds of up to 60 mph. Thunderstorms are considered high frequency events in Lowell. Massachusetts experiences 20-30 thunderstorm days per year. Thunderstorms with little or no rainfall are rare in New England but have occurred (MA EOEEA and EOPSS, 2018).

Severe Storms or thunderstorms are typically less severe than other events discussed in this section. However, thunderstorms can cause local damage and are a City-wide risk in Lowell. Winds associated with thunderstorms can knock down trees resulting in power outages and blocked evacuation and transportation routes. Extreme rain during thunderstorms can cause inland flooding around waterbodies or due to surcharged drainage systems. During periods of drought, lightning from thunderstorm cells can result in fire ignition.

NOAA's National Centers for Environmental Information offers thunderstorm data for Middlesex County, which includes Lowell. Between 2008 and 2018, 278 thunderstorm events caused $3,208,000 in property damages. Three injuries and no deaths were reported. The severe thunderstorm on May 22, 2006 toppled trees in Tewksbury, Chelmsford, and Lowell and left 5,000 residents without power. Wind gusts reached 45 mph.

Table 4-23. Previous Federal and State Disaster Declarations for Severe Storms

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Severe Storms/Flooding October 20-25, 1996	DR-1142	FEMA Hazard Mitigation Grant Program	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
Heavy Rain and Flooding June 13-July 6, 1998	DR-1224	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms & Flooding March 5-April 16, 2001	DR-1364	FEMA Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms and Flooding October 7-16, 2005	DR-1614	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Storms and Flooding May 12-23, 2006	DR-1642	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Middlesex, Essex, Suffolk
Severe Storm and Flooding March 12-April 26, 2010	DR-1895	FEMA Public Assistance; FEMA Individual & Households Program; FEMA Hazard Mitigation Grant Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester

(NCEI and NOAA, Storm Events Database: Middlesex County)

NOAA's National Centers for Environmental Information offers thunderstorm data for Middlesex County, which includes Lowell. Between 2008 and 2019, 248 thunderstorm events caused $3,014,000 in property damages. Two injuries and no deaths were reported. Winds associated with thunderstorms can knock down trees resulting in power outages and blocked evacuation and transportation routes. Extreme rain during thunderstorms can cause inland flooding around waterbodies or due to surcharged drainage systems.

Thunderstorms are considered high frequency events in Lowell. According to the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Massachusetts experiences 20-30 thunderstorm days per year.

4.3.5 Climate Change Impacts: High Winds

Lowell's current 100-year wind speed is 96 mph for a risk category 1 wind (ASCE 7 Hazard Tool: Lowell, Massachusetts). Climate change will likely increase the number of extreme wind events and their severity. Additionally, rising sea temperature could lengthen the hurricane season and fuel stronger hurricane events. The National Climate Assessment Report notes that hurricane "intensity, frequency, and duration have all increased since the early 1980s." This source predicts the continuing intensity and associated rainfall with rising temperatures. This would result in greater losses due to increased flooding, associated building damages and business interruption impacts (Walsh and Wuebbles, 2014). The anticipated increase in frequency and intensity of severe thunderstorms may also increase the risk of tornadoes (MA EOEEA and EOPSS, 2018).

4.4 Winter Storms

Winter-storm events are atmospheric in nature and can impact the entire planning area. All current and future buildings and populations are considered to be at risk of winter storms, which have a variety of potential impacts. Heavy snow loads may cause roofs and trees to collapse leading to structural damage. Deaths and injury are also possible impacts. Additional impacts can include road closures, power outages, business interruption, business losses (i.e., due to road closures), hazardous driving conditions, frozen pipes, fires due to improper heating, and second-hand health impacts caused by shoveling (such as a heart attack). Public safety issues are also a concern, as streets and sidewalks can become difficult to pass. This issue may be especially difficult for vulnerable populations such as elderly people who may have trouble crossing at intersections due to large accumulations of snow. Impassable streets can also complicate emergency response efforts during an extreme event.

Winter storms are a potential City-wide hazard in Lowell. These events can include wind, heavy snow, blizzards, and ice storms. Blizzards and ice storms in Massachusetts can range from an inconvenience, to extreme events that cause significant impacts and require a large-scale, coordinated response. Examples of winter storms that warranted disaster declarations are summarized in Table 4-24 below.

DRAFT

Table 4-24. Previous Federal and State Disaster Declarations

Disaster Name and Date of Event	Disaster Number	Type of Assistance	Counties Under Declaration
Blizzard January 7-13, 1996	DR-1090	No funding reported	All 14 Massachusetts Counties
Severe Winter Storm and Flooding December 11-18, 2008	DR-1813	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm and Snowstorm January 11-12, 2011	DR-1959	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk
Severe Storm and Snowstorm October 29-30, 2011	DR-4051	FEMA Public Assistance; FEMA Public Assistance Snow Removal; FEMA Hazard Mitigation Grant Program	Berkshire, Franklin, Hampden, Hampshire, Middlesex, Worcester
Severe Winter Storm, Snowstorm, and Flooding February 8-9, 2013	DR-4110	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	All 14 Massachusetts Counties
Severe Winter Storm, Snowstorm, and Flooding January 26-28, 2015	DR-4214	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Snowstorm March 13-14, 2018	DR-4379	FEMA Public Assistance; FEMA Hazard Mitigation Grant Program	Essex, Middlesex, Norfolk, Suffolk, Worcester

4.4.1 Heavy Snow and Blizzards

A blizzard is a winter snowstorm with sustained wind or frequent wind gusts of 35 mph or more, accompanied by falling or blowing snow that reduces visibility to or below a quarter of a mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions but are not a formal part of the criteria. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20°F. A severe blizzard is categorized as having temperatures near or below 10°F, winds exceeding 45 mph, and visibility reduced by snow to near zero (MA EOEEA and EOPSS, 2018).

Winter storms include multiple risks, such as wind, ice, and heavy snow. The National Weather Service defines “heavy snow” as snowfall accumulating to 4" or more in 12 hours or less; or snowfall

accumulating to 6" or more in 24 hours or less (NOAA, 2019b). Winter storms can be combined with the nor'easters discussed previously in the "Wind-Related Hazards" section.

There is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS), developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service (Kocin and Uccellini, 2004), characterizes and ranks high-impact northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. NESIS has five categories, as shown in Table 4-25. The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economics. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score, which varies from 1 for smaller storms to over 10 for extreme storms. The raw score is converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events (MEMA and DCR, 2013).

Table 4-25. NESIS Categories

Category	NESIS	Value Description
1	1 – 2.499	Notable
2	2.5 – 3.99	Significant
3	4 – 5.99	Major
4	6 – 9.99	Crippling
5	10+	Extreme

(MA EOEEA and EOPSS, 2018)

The current winter snowfall record in Eastern Massachusetts is 108.6 inches during the 2014-2015 season (NOAA, 2015). The City provides standard snow plowing operations and clearing snow has not posed any significant challenges.

The "Blizzard of 1978" is a well-known winter storm that deposited more than three feet of snow and led to multiday closures of roads, businesses, and schools. Table 4-26 provides additional information on significant snow events.

NOAA's National Centers for Environmental Information Storm Events Database provide information for blizzards, winter weather, heavy snow, and winter storms. There were 250 winter events between 2000 and 2019 in Middlesex County totaling $2,059,000 dollars of damage. The greatest damage was during this time frame was a storm in 2011 causing $926,000 of damage. Most of the electric customers (99%) were out of electricity during a snowstorm in October 2011 (NMCOG, 2015). In March 2018, trees and wires were down on Fort Hill, Porter Street, Bridge Street, Richard Street, and on Billings Street during a heavy snowstorm (NOAA 2019a).

Table 4-1. Severe Winter Storm Records for Massachusetts

Type of Event	Date
Blizzard	February 1978
Blizzard	March 1993
Blizzard	January 1996
Severe Snowstorm	March 2001
Severe Snowstorm	December 2003
Severe Snowstorm	January 2004
Severe Snowstorm	January 2005
Severe Snowstorm	April 2007
Severe Snowstorm	December 2010
Severe Snowstorm	January 2011
Blizzard	February 2013
Blizzard	January 2015
Severe Snowstorm	March 2018

(NOAA, 2019a)

During Lowell's MVP Workshop, participants discussed past examples of severe winter weather. Participants discussed the opportunity for newer snow removal equipment. Participants discussed how the snow removal procedures could be updated, and adherence to the procedures could be more strictly enforced. Backup power sources are imperative to the City in the event of power outages due to severe winter weather.

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

4.4.2 Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects creating ice build-ups of ¼ inch or more that can cause severe damage. An ice storm warning, now included in the criterion for a winter storm warning, is for severe icing. This is issued when ½ inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the weighing down of power lines and trees. Icy roads can also complicate emergency response efforts during an extreme event. Ice storms are classified as medium frequency events in Lowell. Ice storms impact the Commonwealth on at least an annual basis.

Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. Sleet differs from hail: sleet is a wintertime phenomenon, while hail usually falls during thunderstorms in the spring and summer (MA EOEEA and EOPSS, 2018).

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

4.4.3 Climate Change Impacts: Winter Storms

There is evidence suggesting that nor'easters along the Atlantic coast are increasing in frequency and intensity. Future nor'easters may become more concentrated during the coldest winter months when atmospheric temperatures are still low enough to result in snowfall rather than rain (MA EOEEA and EOPSS, 2018).

Climate projections indicate that climate change will result in more precipitation during the winter in the Northeast (MA EOEEA, 2018a). This trend may result in more frequent and/or more severe winter storms.

4.5 Geological Hazards

Geologic hazards can include earthquakes, landslides, sinkholes, and subsidence. City officials did not identify any local areas that were previously recorded as being vulnerable to geologic hazards.

4.5.1 Earthquakes

An earthquake is the vibration, sometimes violent, of the earth's surface that follows a release of energy in the Earth's crust due to fault fracture and movement. The magnitude or extent of an earthquake is a seismograph-measured value of the amplitude of the seismic waves. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare the size of earthquakes. The Richter scale is the most widely known scale that measures earthquake magnitude. It has no upper limit and is not a direct indication of damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, can have the same magnitude as an earthquake in a remote area that causes no damage. Table 4-27 summarizes Richter scale magnitudes and corresponding earthquake effects (MA EOEEA and EOPSS, 2018).

Table 4-27. Richter Scale and Effects

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally, not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 km across where people live.
7.0-7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred meters across.

(Louie, 1996)

Earthquakes occur in New England, albeit infrequently as compared to other parts of the country. The first recorded earthquake was noted by the Plymouth Pilgrims and other early settlers in 1638. Of the over 5,000 earthquakes recorded in the Northeast Earthquake Catalog through 2008, 1,530 occurred within the boundaries of the six New England States, with 366 earthquakes recorded for Massachusetts between 1627 and 2008. The probability of a magnitude 5.0 or greater earthquake

centered in New England is about 10-15% in a 10-year period (MA EOEEA and EOPSS, 2018). A summary of historic earthquakes in the Boston area is included in Table 4-28 below.

Table 4-28. Historical Earthquakes in Boston and Surrounding Area, 1727-2020

Location	Date	Magnitude
MA - Cape Ann	11/10/1727	5
MA - Cape Ann	12/29/1727	NA
MA - Cape Ann	2/10/1728	NA
MA - Cape Ann	3/30/1729	NA
MA - Cape Ann	12/9/1729	NA
MA - Cape Ann	2/20/1730	NA
MA - Cape Ann	3/9/1730	NA
MA - Boston	6/24/1741	NA
MA - Cape Ann	6/14/1744	4.7
MA - Salem	7/1/1744	NA
MA - Off Cape Ann	11/18/1755	6
MA - Off Cape Cod	11/23/1755	NA
MA - Boston	3/12/1761	4.6
MA - Off Cape Cod	2/2/1766	NA
MA - Offshore	1/2/1785	5.4
MA - Wareham/Taunton	12/25/1800	NA
MA - Woburn	10/5/1817	4.3
MA - Marblehead	8/25/1846	4.3
MA - Brewster	8/8/1847	4.2
MA - Boxford	5/12/1880	NA
MA - Newbury	11/7/1907	NA
MA - Wareham	4/25/1924	NA
MA - Cape Ann	1/7/1925	4
MA - Nantucket	10/25/1965	NA
MA - Boston	12/27/1974	2.3
VA - Mineral	8/23/2011	5.8
MA - Nantucket	4/12/2012	4.5
ME - Hollis	10/17/2012	4.0
MA – Newburyport	2/20/2013	2.3
NH – Contoocook	10/11/2013	2.6
MA – FreeCity	1/9/2014	2.0
MA – Bliss Corner	2/11/2014	2.2
MA – off Northshore	8/18/2014	2.0
CT - Deep River Center	8/14/2014	2.7
CT – Wauregan	1/12/2015	3.3
CT – Wauregan	1/13/2015	2.6
RI – Newport	2/3/2015	2.0
NH – Epsom	8/2/2015	2.2
NH – Contoocook	3/21/2016	2.8
MA – Rockport Coast	6/1/2016	2.2

Location	Date	Magnitude
NH – Bedford	2/11/2017	2.2
NH – East Kingston	2/15/2018	2.7
ME – Cape Neddick	7/16/2018	2.1
MA – Nantucket	8/18/2018	2.4
MA – Templeton	12/21/2018	2.1
MA – Gardner	12/23/2018	2.2
RI – CharlesCity	3/1/2019	2.3
MA – Rockport	4/27/2019	2.1
MA – North Plymouth	12/3/2019	2.1

(USGS, 2020)

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

Lowell is located in an area with a PGA of 16 %g to 18 %g with a 2% probability of exceedance in 50 years (Figure 4-8). This is the fourth/fifth highest zone in the state: in other words, a moderate area of earthquake risk. Compared to the rest of the United States, Massachusetts overall has a low risk of earthquakes.

No earthquake epicenters have been recorded within Lowell. Although new construction under the most recent building codes generally will be built to seismic standards, much of the development in the City pre-dates the current building code. If an earthquake occurs, the entire region, not just the City, would face significant challenges. Earthquakes often trigger fires. The water distribution system may be disrupted, thus posing a risk for public health and safety.

A serious earthquake in Massachusetts is possible. These events can strike without warning and can have a devastating impact on infrastructure and buildings constructed prior to earthquake resistant design considerations.

DRAFT

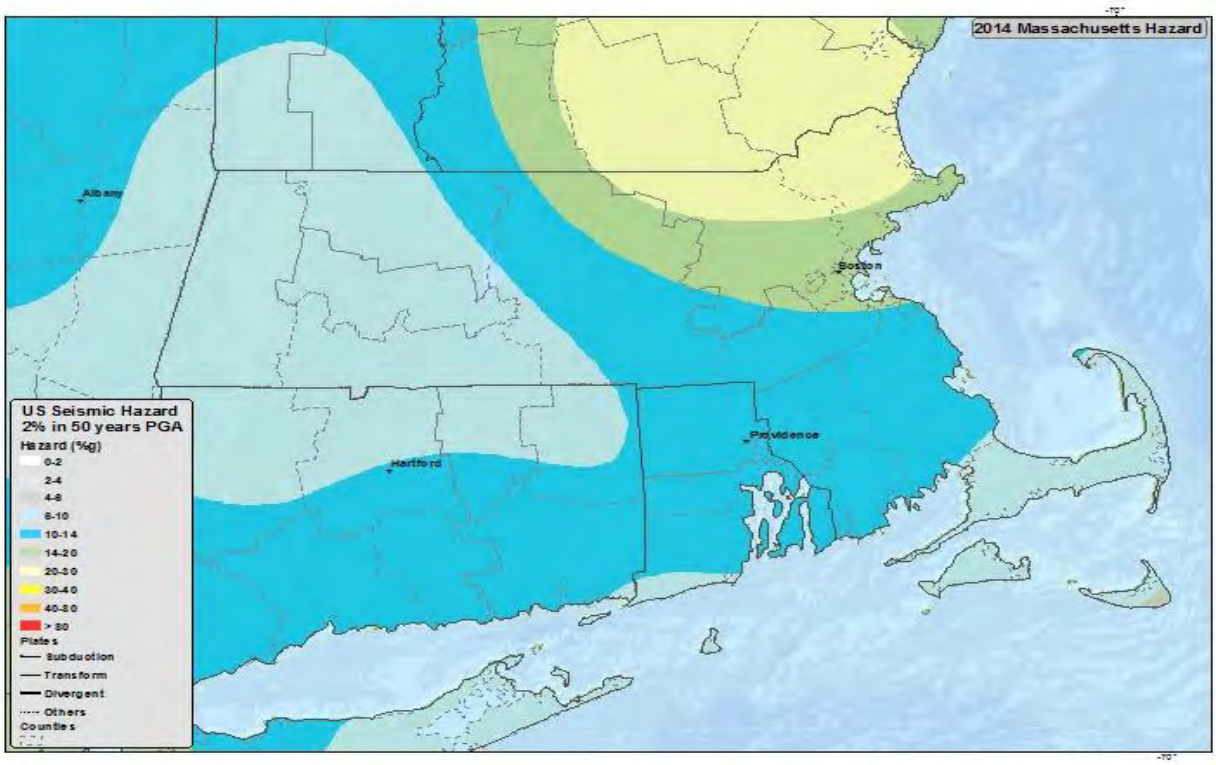


Figure 4-8. 2014 Seismic Hazard Map- Massachusetts

(USGS)

It can be assumed that all existing and future buildings and populations are at risk to an earthquake hazard. Impacts from earthquakes can be from slight to moderate building damage, to catastrophic damage and fatalities, depending on the severity of the earthquake event. Events may cause minor damage such as cracked plaster and chimneys, or broken windows, or major damage resulting in building collapse. Based on the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the degree of exposure "depends on many factors, including the age and construction type of the structures where people live, work, and go to school; the soil type these buildings are constructed on; and the proximity of these building to the fault location." Furthermore, the time of day exposes different sectors of the community to the hazard. Earthquakes can lead to business interruptions, loss of utilities and road closures which may isolate populations. People who reside or work in unreinforced masonry buildings are vulnerable to liquefaction. (Liquefaction is the phenomenon that occurs when the strength and stiffness of a soil is reduced by earthquake).

Potential earthquake damage was modeled for Lowell. Hazus Multi-Hazard (Hazus) is a GIS model developed by FEMA to estimate losses in a defined area due to a specified natural hazard. The Hazus earthquake model allows users to input specific parameters in order to model a defined earthquake magnitude, with the epicenter located at the center of the municipality. In this analysis, two earthquakes were modeled: a magnitude 5.0 and a magnitude 7.0 earthquake. While large earthquakes are rare in Massachusetts, there was a magnitude 5.0 earthquake recorded in 1963. There is a possibility for larger scale earthquakes to occur in Massachusetts at some point, therefore a magnitude 7.0 earthquake was modeled as well to demonstrate the damage that could occur.

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

Table 4-29. Estimated Damage in Lowell from Magnitude 5 and 7 Earthquakes

	Magnitude 5.0	Magnitude 7.0
Building Characteristics		
Estimated total number of buildings	24,000	24,000
Estimated total building replacement value (Year 2014 $) (Millions of dollars)	12,011	12,011
Building Damages		
# of buildings sustaining slight damage	6,893	832
# of buildings sustaining moderate damage	4,095	4,704
# of buildings sustaining extensive damage	1,330	6,320
# of buildings completely damaged	366	12,257
Population Needs		
# of households displaced	2,783	26,110
# of people seeking public shelter	2,000	18,542
Debris		
Building debris generated (tons)	400,000	2,800,000
# of truckloads to clear building debris (@25 tons/truck)	16,120	112,080
Building-Related Economic Loss (Millions of dollars)		
Income Losses	$303.73	$1653.46
Capital Stock Losses	$1551.89	$10858.67

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

Earthquakes are classified as a low-frequency event in Lowell. As defined by the 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, the probability of a magnitude 5.0 or greater earthquake centered in New England is about 10-15% in a 10-year period.

4.5.2 Landslides

Landslide include a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity, acting on an over steepened slope, is the primary reason for a landslide, there are other contributing factors. These contributing factors can include erosion by rivers or ocean waves over steepened slopes; rock and soil slopes weakened through saturation by snowmelt or heavy rains; earthquake created stresses that make weak slopes fail; excess weight from accumulation of rain or snow; and stockpiling of rock or ore from waste piles or man-made structures (USGS, 2019).

Landslides occur throughout the United States, causing an estimated $1 billion in damages and 25-50 deaths each year. Any area composed of very weak or fractured materials resting on a steep slope will likely experience landslides. Although the physical cause of many landslides cannot be removed, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards (USGS, 2019). Landslides can damage buildings and infrastructure and cause sedimentation of water bodies. Landslide intensity can be measured in terms of destructiveness, as demonstrated in Table 4-30.

Table 4-30. Landslide Volume and Velocity

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

Source: Cardinali et al., 2002

All of Lowell is classified as having a low risk for landslides. No significant landslides have been recorded for Lowell or Middlesex County (Appendix B of MA EOEEA and EOPSS, 2018). Landslides are classified as low frequency events in Lowell. These events can occur once in 50 to 100 years (i.e., 1% to 2% chance of occurring each year).

4.6 Fire-Related Hazards

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

Lowell is most susceptible to brushfire compared to a wildfire (or fire with a larger impact area). Brushfires and wildfires occur in the vegetative wildland, including grass, shrub, leaf litter, and

forested-tree fuels. Fires can be caused by natural events or human activity, which then can spread quickly, igniting brush, trees, and homes (MEMA and DCR, 2013). The State Hazard Mitigation and Climate Adaptation Plan (MA EOEEA and EOPPS, 2018) states:

> *"The ecosystems that are most susceptible to the wildfire hazard are pitch pine, scrub oak, and oak forests, as these areas contain the most flammable vegetative fuels. Other portions of the Commonwealth are also susceptible to wildfire, particularly at the urban-wildland interface…. 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."*

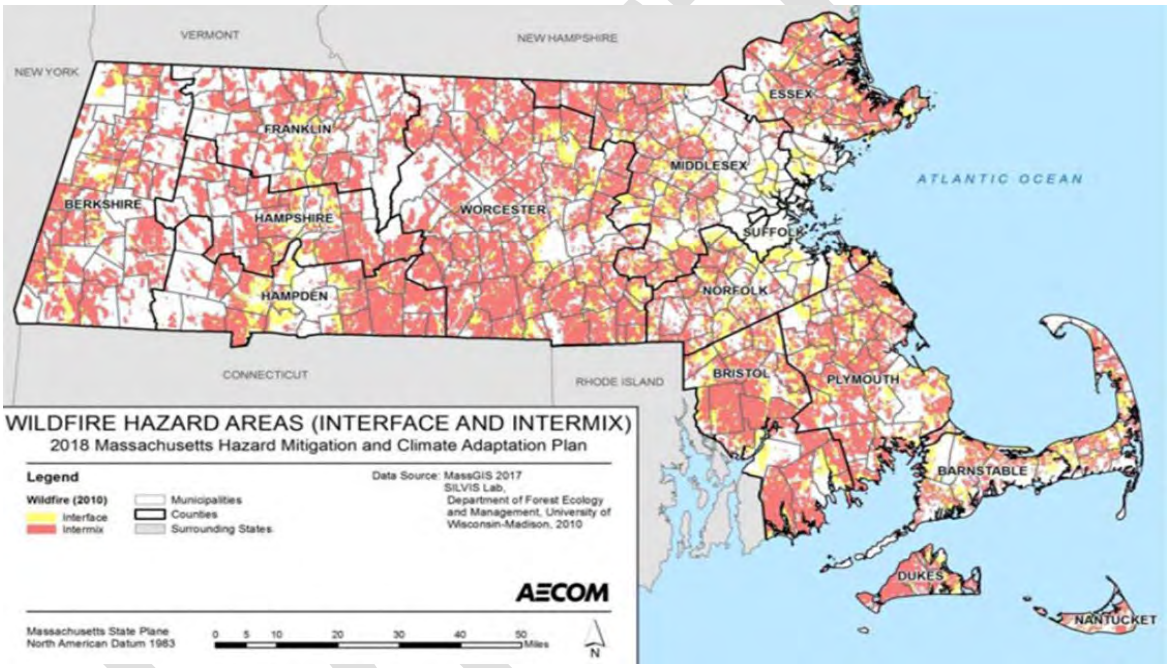


Figure 4-9: Wildfire Hazard Areas Statewide

Lowell has many intermix and a few interface areas, which are more vulnerable to fire hazards (Figure 4-9). The Dracut-Lowell-Lowell State Forest, managed by the Massachusetts Department of Conservation and Recreation, was also viewed as a more at-risk area in Lowell according to the Core Team.

Approximately 84% of brushfires are caused by humans (Balch et al., 2017). Lightning can also be a culprit, igniting a fire when striking dry tinder on the forest floor. Brush fires can lead to property damage and even death. Individuals whose homes or workplaces are located in brush fire hazard zones are more vulnerable to this hazard. The most vulnerable members of this population are those who would be unable to evacuate quickly, including those over the age of 65, households with young children under the age of 5, people with mobility limitations, and people with low socioeconomic status (MA EOEEA and EOPSS, 2018). Secondary effects from brush fire include contamination of

waterways; destroyed power, gas, water, and broadband lines. Brush fires can also contribute to flooding as they strip slopes of vegetation, thereby exposing them to greater amounts of runoff which may cause soil erosion and ultimately the chance of flooding. Additionally, subsequent rains can worsen erosion because brush fires burn ground vegetation and ground cover. Lowell has experienced 385 fires in 2017 and 383 fires in 2018. Most of them (>60%) were structure fires. According to Massachusetts Fire Incident Reporting System (2018), Lowell reports the highest number of fires in Middlesex County (Fig. 4-10).

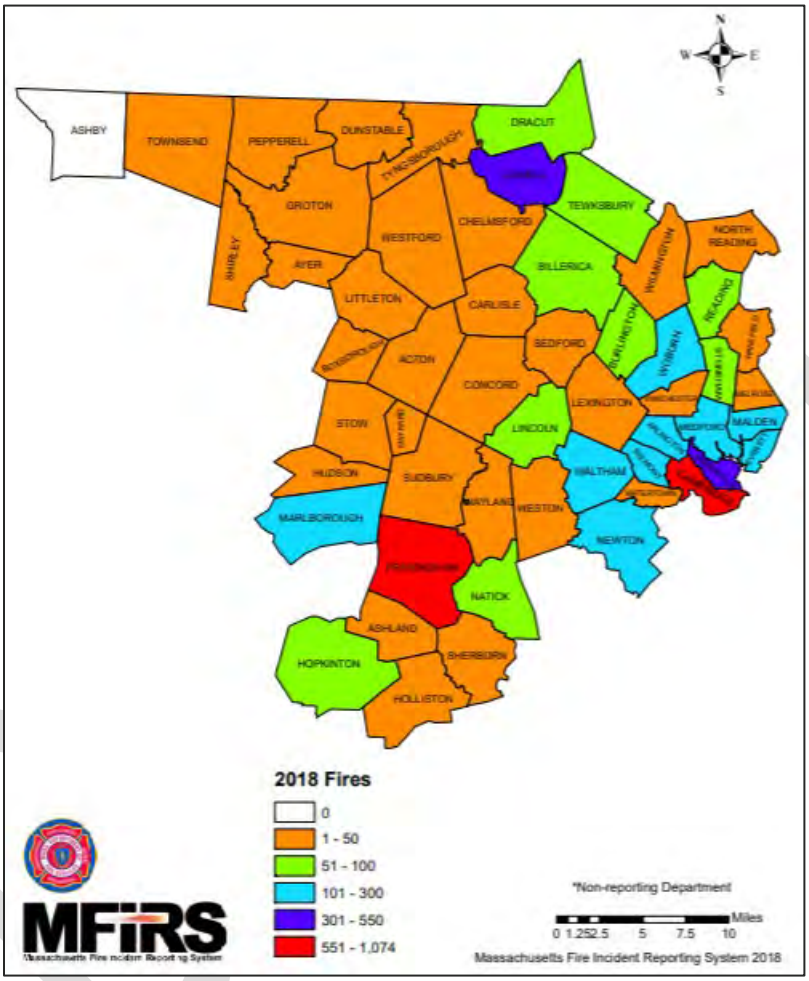


Figure 4.10. Middlesex County Fires: Townsend is outlined in red (MFIRS, 2018)

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

4.7 Extreme Temperatures

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

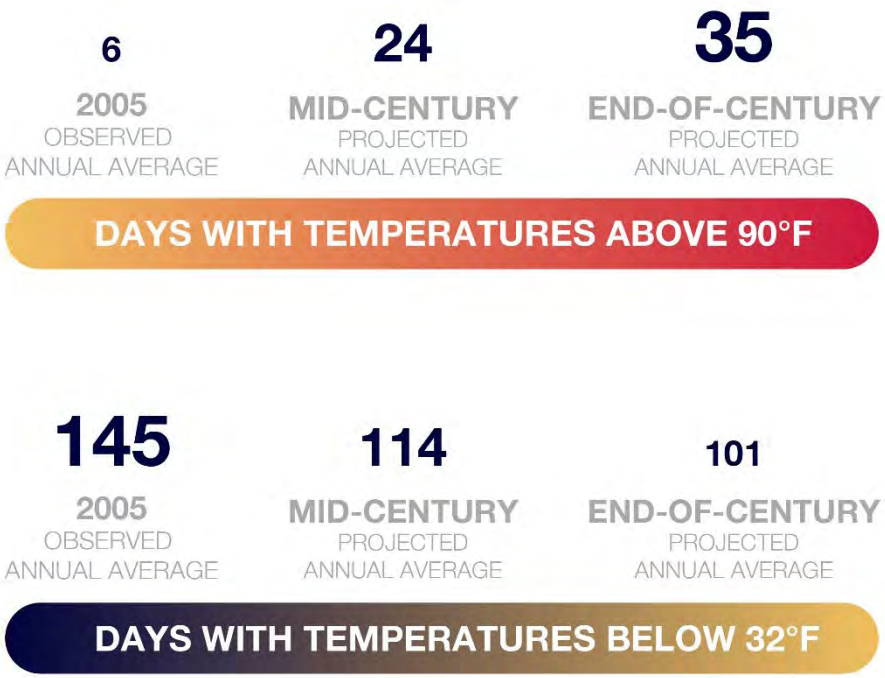


Figure 4-11: an infographic visualizing anticipated temperature changes (Weston & Sampson based on MA EOEEA, 2018)

The Massachusetts has four clearly defined seasons. Extreme temperatures fall outside of the ranges typically experienced during these seasons. Boston's average winter temperature, from December to February, is 32.2°F. Lowell's average summer temperature, from June to August, is 82°F (US Climate Data, 2020).

4.7.1 Extreme Cold

Extremely cold temperatures can create dangerous conditions for homeless populations, stranded travelers, and residents without sufficient insulation or heat. The homeless, the elderly, and people with disabilities are often most vulnerable. In Lowell, 10.6% of the population are over 65 years old and 9% percent of the population has a disability (US Census, 2018). Cold weather events can also have significant health impacts such as frostbite and hypothermia. Furthermore, power outages during cold weather may result in inappropriate use of combustion heaters, cooking appliances, and generators in poorly ventilated areas which can lead to increased risk of carbon monoxide poisoning.

NOAA's National Centers for Environmental Information Storm Events Database provides data for extreme cold events. Between 2000 and 2018, Middlesex County experienced three extreme cold and wind chill events, which caused no deaths, injuries, or property damage.

DRAFT

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

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

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

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

Where, T= Air Temperature (°F) V= Wind Speed (mph) *Effective 11/01/01*

Figure 4-12. Windchill Temperature Index and Frostbite Risk (National Weather Service)

4.7.2 Extreme Heat

Increased temperatures will impact all locations within Lowell. Projected heat days and heat waves can have an increased impact in densely settled urban areas. These can become "heat islands" as dark-colored asphalt and roofs store the heat from the sun. According to the Centers for Disease Control and Prevention, the populations most vulnerable to extreme heat impacts include the following:

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

Homeless people are increasingly vulnerable to extreme heat. The capacity of homeless shelters is typically limited. Impacts from heat stress can exacerbate pre-existing respiratory and cardiovascular conditions.

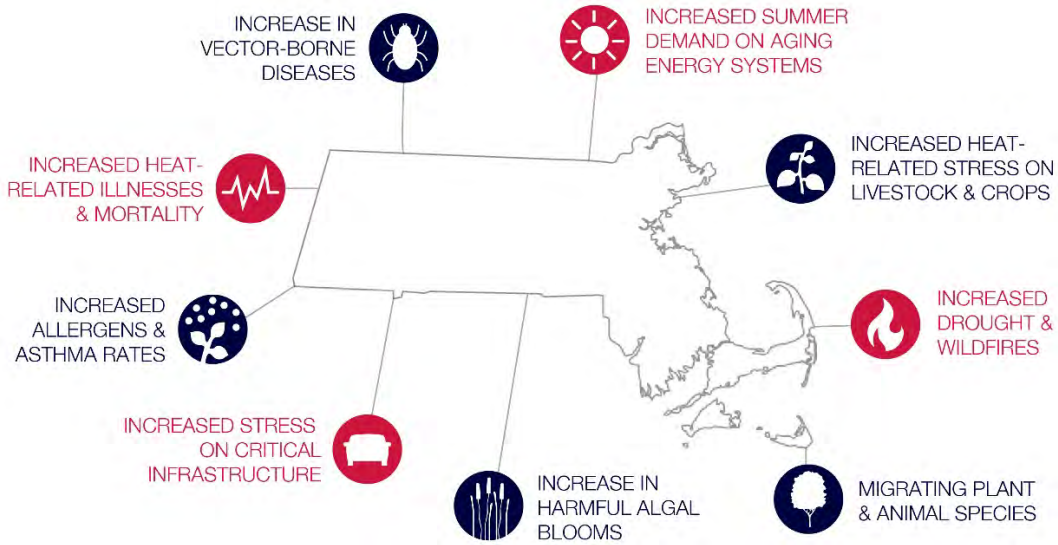


Figure 4-13: an infographic visualizing potential impacts from increasing temperatures (Weston & Sampson based on MA EOEEA, 2018)

Based on Figure 4-14, compiled by the Massachusetts Department of Public Health Bureau of Environmental Health (MA DPH 2019), there is at least one population vulnerability measure in each Census Tract (2010). The population vulnerability measures include low income, minimal English proficiency, nonwhite (Hispanic and non-Hispanic ethnicities), and elderly. Lowell has a population density of 8,090 per square mile.

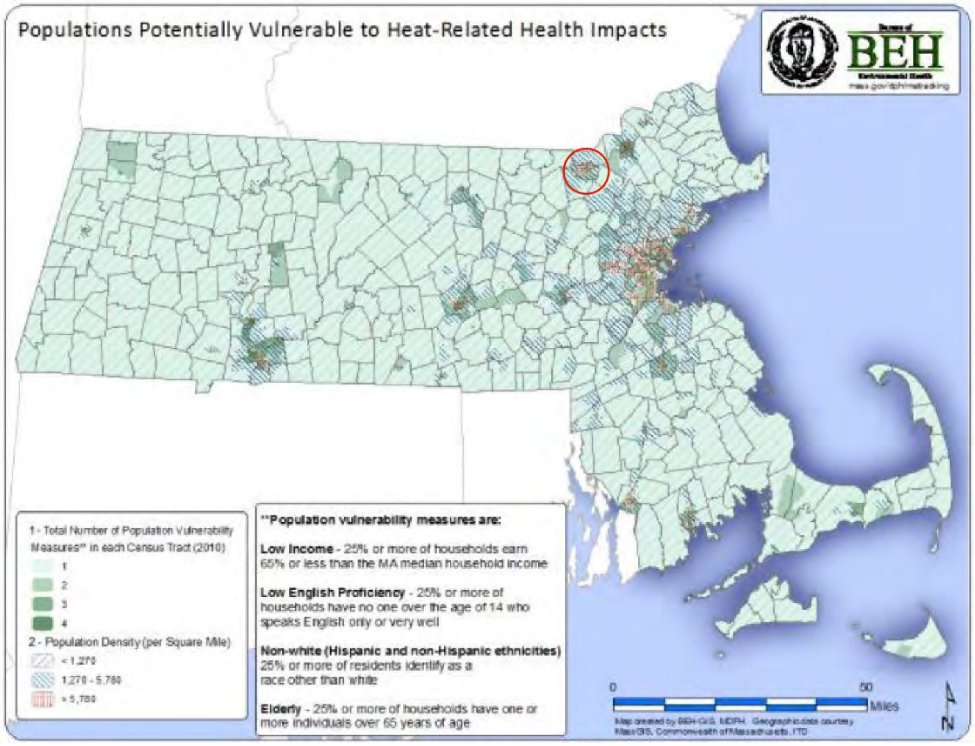


Figure 4-14. Populations Potentially Vulnerable to Heat Related Health Impacts. Lowell is circled in red (Massachusetts Department of Public Health, Bureau of Environmental Health, 2019)

On July 6, 2013, a postal worker in Massachusetts collapsed and died as the Heat Index reached 100°F (MA EOEEA and EOPSS, 2018). Because most heat-related deaths occur during the summer, people should be aware of who is at greatest risk and what actions can be taken to prevent a heat-related illness or death. The populations at greater risk are the elderly, children, and people with certain medical conditions, such as heart disease. However, even young and healthy individuals can succumb to heat if they participate in strenuous physical activities during hot weather. Some behaviors also put people at greater risk drinking alcohol, taking part in strenuous outdoor physical activities in hot weather, and taking medications that impair the body's ability to regulate its temperature or that inhibit perspiration (MA EOEEA and EOPSS, 2018).

The NWS issues a Heat Advisory when the Heat Index (Figure 4-15) is forecast to reach 100-104˚ F for two or more hours (https://www.weather.gov/bgm/heat). The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach or exceed 105˚F for two or more hours. Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. In Boston, over 50 people die each year due to heat-related illnesses. From 1979-2012, excessive heat exposure caused in excess of 8,000 deaths in the United States (MEMA and DCR, 2018). During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

Increased temperatures can lead to a longer growing season, which in turn leads to a longer pollen season. Warmer weather can also support the migration of invasive species and lead to an increase in vector-borne diseases. Increasing temperatures can also worsen air pollution, which can lead to negative health impacts such as respiratory problems.

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

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke or Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Figure 4-15. Heat Index Chart (Source: https://www.weather.gov/safety/heat-index)

The City of Lowell does not collect data on heat occurrences. The best available local data are for Middlesex County, through the National Environmental Information Center. NOAA's National Centers

for Environmental Information Storm Events Database provides data on excessive heat. Between 1998 and 2018, Middlesex County experienced three extreme heat days, which did not result in injury or property damage. One event did result in a single death in 2013 (Table 4-31).

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

Table 4-31. Middlesex County Heat Occurrences, 1998-2018

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

*Excess Heat Occurrences (105°F+)
(NOAA, 2019a)

4.7.3 Climate Change Impacts: Extreme Temperatures

Between 1961 and 1990, Boston metro area experienced an average of one day per year more than 100°F. That could increase to six days per year by 2070, and 24 days per year by 2099. This statistics holds true for most of the communities in Massachusetts including Lowell. Under these conditions by the end of the century, Massachusetts's climate would more closely resemble that of Maryland or the Carolinas (Figure 4-16). These changes in temperature would also have a detrimental impact on air quality and public health concerns including asthma and other respiratory conditions (Frumhoff et al., 2007).

DRAFT

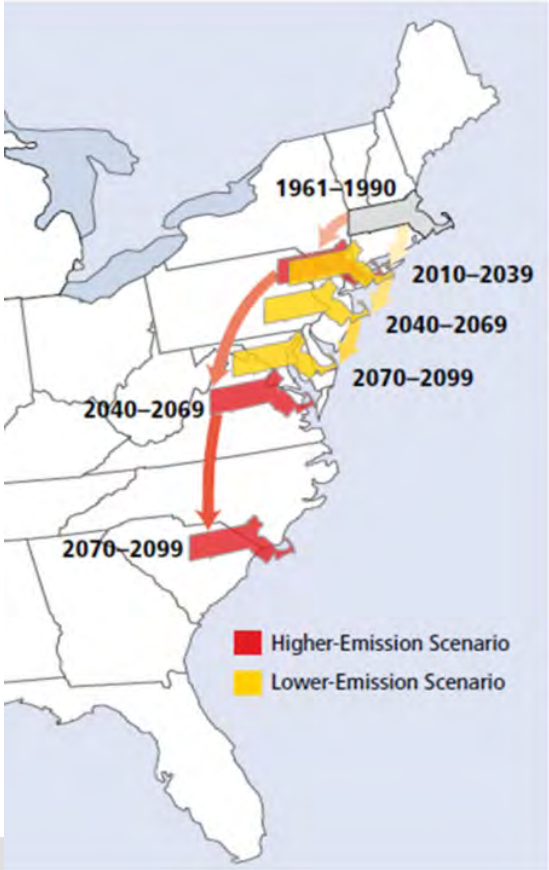


Figure 4-16. Massachusetts Extreme Heat Scenarios. (Frumhoff et al., 2007)

4.8 Drought

Drought is an extended period of deficient precipitation. Drought conditions occur in virtually all climatic zones, yet its characteristics vary significantly from one region to another since it is relative to the normal precipitation in that region. Agriculture, the water supply, aquatic ecosystems, wildlife, and the economy are vulnerable to the impacts of drought (MA EOEEA and EOPSS, 2018).

Average annual precipitation in Lowell is 47 inches per year (US Climate Data, 2020). Although Massachusetts is relatively small, it has a number of distinct regions that experience significantly different weather patterns and react differently to the amounts of precipitation they receive. In accordance with the Massachusetts Drought Management Plan (Massachusetts Water Resource Commission, 2019), the Drought Management Task Force will make recommendations to the Secretary of Energy & Environmental Affairs about the location and severity of drought in the Commonwealth. The Drought Management Plan divides the state into seven regions: Western, Central, Connecticut River Valley, Northeast, Southeast, Cape Cod, and Islands Region. Lowell is located within the Northeast region (MA EOEEA and EOPSS, 2019).

Five levels of drought have been developed to characterize drought severity: Normal, Advisory, Watch, Warning, and Emergency; these correspond to Level 0 – Normal, Level 1 - Mild Drought, Level 2 - Significant Drought, Level 3 - Critical Drought (was Warning), and Level 4 - Emergency

Drought (was Emergency), respectively, of the draft Drought Management Plan update. The drought levels are based on the severity of drought conditions and their impacts on natural resources and public water supplies.

The Drought Management Plan specifies the agency response and interagency coordination and communication corresponding to the various drought levels. During normal conditions, data are routinely collected and distributed. There is heightened vigilance with additional data collection during an advisory, and increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which use of emergency supplies become necessary or in which the Governor may exercise his authority to require mandatory water restrictions (MA EOEEA and EOPSS, 2019).

A variety of drought indices are available to assess the various impacts of dry conditions. The Commonwealth uses a multi-index system to determine the severity of a drought or extended period of dry conditions. A determination of drought level is based on six indices: Standardized Precipitation Index, Crop Moisture Index, Keetch-Byram Drought Index (KBDI), Groundwater levels, Stream flow levels, and Index Reservoir levels (MA EOEEA and EOPSS, 2019).

Drought level is determined monthly based on the number of indices which have reached a given drought level. A majority of the indices would need to be triggered in a region in order for a drought designation to move to a more severe level. Drought levels are declared on a regional basis for each of the six regions in Massachusetts. Drought levels may also be made county by county or be watershed specific. The end of a drought is determined by precipitation and groundwater levels since these have the greatest long-term impact on streamflow, water supply, reservoir levels, soil moisture and potential for forest fires (MA EOEEA and EOPSS, 2018).

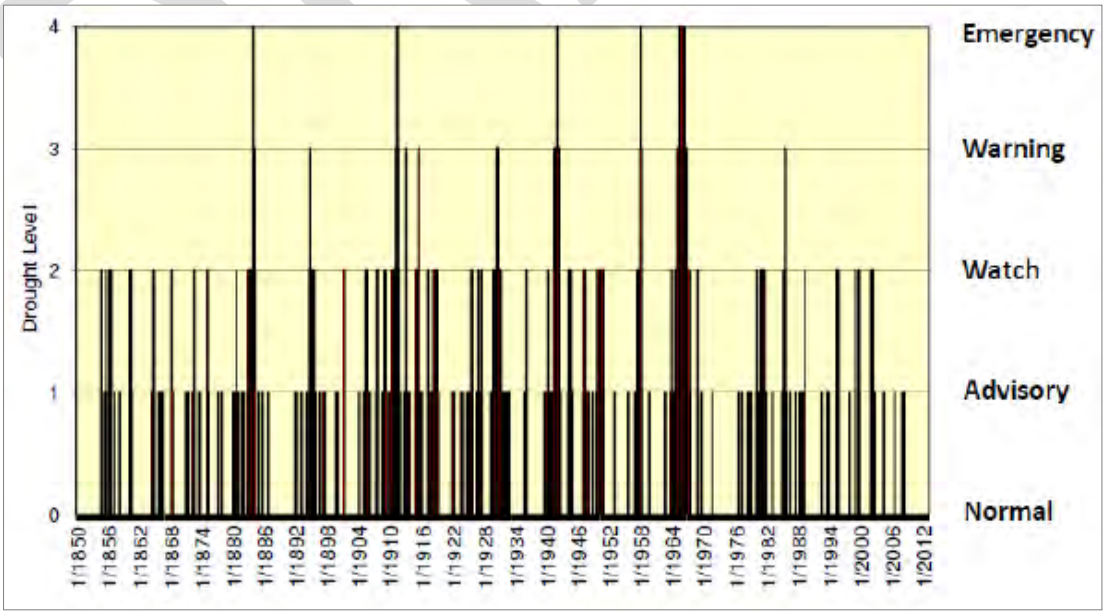


Figure 4-17. Statewide Drought Levels Using SPI Thresholds, 1850 to 2012

Figure 4-17 illustrates statewide drought levels in Massachusetts from 1850 to 2012, using the Standardized Precipitation Index (SPI). Table 4-32 below summarizes a history of Massachusetts droughts between 1879 and 2017.

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

Date	Area Affected	Recurrence Interval (years)	Remarks
1879 to 1883	–	–	–
1908 to 1912	–	–	–
1929 to 1932	Statewide	10 to >50	Water-supply sources altered in 13 communities. Multistate.
1939 to 1944	Statewide	15 to >50	More severe in eastern and extreme western Massachusetts. Multistate.
1957 to 1959	Statewide	5 to 25	Record low water levels in observation wells, northeastern Massachusetts.
1961 to 1969	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.
1980 to 1983	Statewide	10 to 30	Most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin. Multistate.
1985 to 1988	Housatonic River Basin	25	Duration and severity unknown. Streamflow showed mixed trends elsewhere.
1995	–	–	Based on statewide average precipitation.
1998 to 1999	–	–	Based on statewide average precipitation.
2001 to 2003	Statewide	–	Level 2 drought (out of 4 levels) was reached statewide for several months.
2007 to 2008	Statewide except West and Cape and Islands regions	–	Level 1 drought (out of 4 levels)

DRAFT

Date	Area Affected	Recurrence Interval (years)	Remarks
2010	Connecticut River Valley, Central and Northeast regions	–	Level 1 drought (out of 4 levels)
2014	Southeast and Cape and Islands regions	–	Level 1 drought (out of 4 levels)
2016-2017	Statewide	–	Level 3 drought (out of 4 levels).

(MA EOEEA and EOPSS, 2018)

There are five drought emergencies on record in Massachusetts: 1883, 1911, 1941, 1957, and 1965-1966. The 1965-1966 drought is considered the most severe Massachusetts drought in modern times, given its length. On a monthly basis over the 162-year period of record, there is a one percent chance of being in a Drought Emergency (MA EOEEA and EOPSS, 2018).

Drought Warning levels not associated with Drought Emergencies would have occurred in 1894, 1915, 1930,1985, 2016, and 2017. On a monthly basis over the 162-year period of record, there is a 2% chance of being in a drought Warning level (DCR, 2017b).

Drought Watches not associated with higher levels of drought generally would have occurred three to four times per decade between 1850 and 1950. The Drought Emergency declarations dominated the 1960s. There were no Drought Watches or above in the 1970s. In the 1980s, there was a lengthy Drought Watch level of precipitation between 1980 and 1981, followed by a Drought Warning in 1985. A frequency of drought Watches at a rate of three years per decade resumed in the 1990s (1995, 1998, 1999). In the 2000s, drought watches occurred in 2001 and 2002. There were six drought watches in Massachusetts in 2002, five drought watches in 2016, and two drought watches in 2017 (DCR 2017b, 1). Figure 4-18 presents an example of recent drought conditions in the six drought regions.

DRAFT

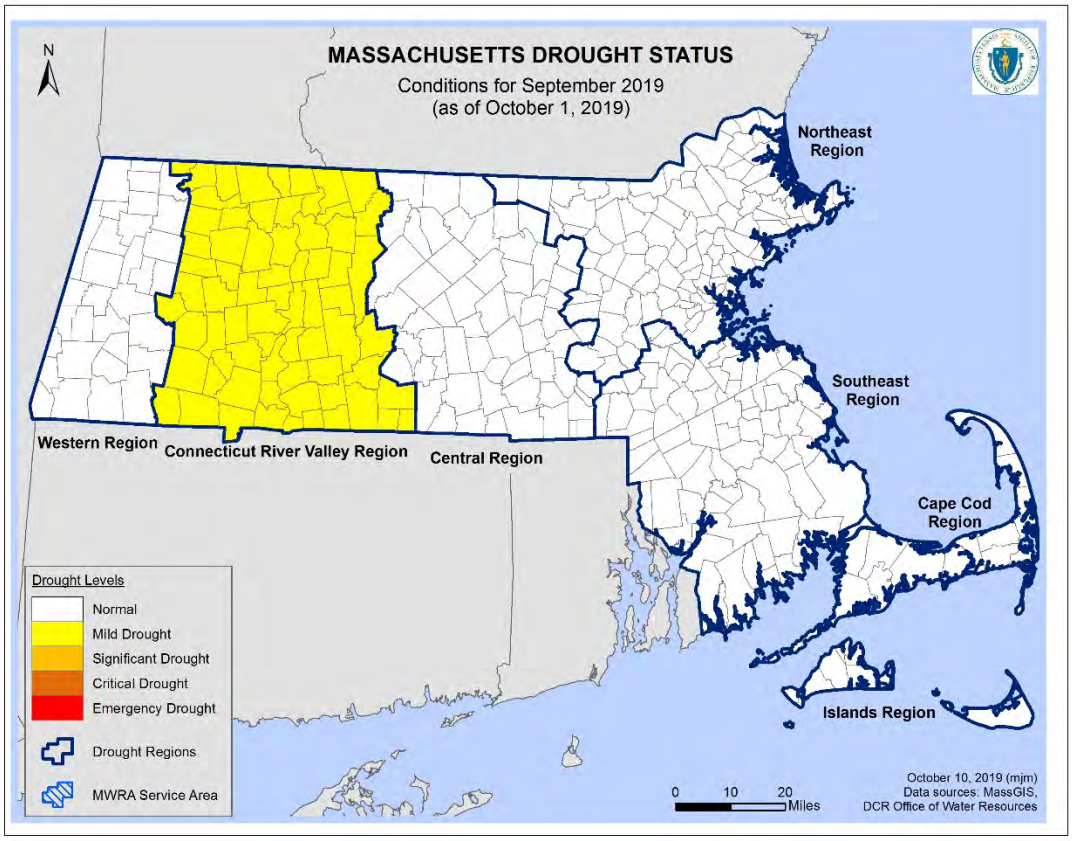


Figure 4-18. Massachusetts Drought Status, September 2019 ***(DCR, 2019)***

Drought is a potential City-wide hazard in Lowell and is a concern among stakeholders. As noted previously, temperature is projected to increase and may lead to exacerbated drought conditions especially in summer and fall months. Droughts can also increase fire risk: fires can be caused by lightning, and a 2014 study found that the frequency of lightning strikes could increase by more than 10% for every degree Celsius of warming (MA EOEEA and EOPSS, 2018). A long-term drought could lead to impacts to Lowell's wetlands and streams, and to the Merrimack River which is the main source of drinking water for the City.

Droughts are classified as a low-frequency, natural-hazard event. As defined by the 2013 Massachusetts State Hazard Mitigation Plan, these events can occur between once in 50 years to once in 100 years (a 1% to 2% chance of occurring per year).

4.8.1 Climate Change Impacts: Drought

Under climate change, drought conditions will be exacerbated with projected increasing air temperatures and changes in precipitation. Between 1970 and 2000, the median number of consecutive dry fall days in Massachusetts was 11.4 days. This is in comparison to a projected median of 13.5 consecutive days by the end of the century (MA EOEEA, 2018a).

5.0 EXISTING MITIGATION MEASURES

The City of Lowell is already implementing measures to mitigate local hazards. Chapter 5 documents the City's current operations and discusses potential improvements. FEMA's *Local Mitigation Planning Handbook* categorizes hazard mitigation measures into four types as displayed in Table 5-1 (FEMA, 2013). Lowell uses many of these tools, which are presented by hazard type.

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

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

(*FEMA*, 2013)

DRAFT

Summary of Existing Mitigation

There are numerous existing natural hazard mitigation measures already in place in Lowell. These were identified through feedback from the Core Team, CRB Workshop participants, and additional stakeholders' interviews. These mitigation measures are summarized below.

Existing Multi-Hazard Mitigation Measures

	Improvements
Greater Lowell Regional Emergency Planning Committee – Under the Emergency Planning and Community Right to Know Act of 1986, communities are required to establish Emergency Planning Committees to develop a response plan for chemical emergencies. Lowell is a part of Greater Lowell Regional Emergency Planning Committee (REPC), which includes Lowell, Billerica, Chelmsford, Dracut, Tewksbury, Tyngsboro, and Wilmington. In accordance with this legislation, the City of Lowell has identified locations where hazardous materials are stored, used, and transported. Lowell Emergency Management is the lead department, but Local Government and all City Departments work cooperatively during all phases of an incident.	None at this time
Comprehensive Emergency Management Plan (CEMP) Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. This plan addresses mitigation, preparedness, response, and recovery from a variety of natural and man-made emergencies. Included in this plan is important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. Lowell has a CEMP that is currently being updated and scheduled to be ready by the end of 2020. Lowell's CEMP included preparedness for all major emergencies - large structure and wildfires, major flooding, blizzards, civil unrest, hazardous materials incidents and also includes predetermined locations for shelters and evacuation routes. The City plans to establish a Local Emergency Planning Committee once the CEMP is finalized.	Update CEMP
List of Critical Facilities – The list of critical facilities was updated during this planning process. The City GIS system also contains information related to critical infrastructures.	Maintain an updated list of Critical Facilities
Regional Support from Surrounding Communities – Lowell has provided and received additional support from surrounding communities. The support is informally structured. The Lowell Emergency Management Director maintains contact with surrounding communities.	Formalize or document support systems to retain institutional knowledge and increase transparency in case of an emergency when additional support from other departments and

DRAFT

	municipalities may be needed.
MEMA Deployment – MEMA can deploy vehicles in the case of an emergency.	Available to the City in case of emergency
Salvation Army Emergency Assistance and Disaster Services – Assistance is offered by Salvation Army Emergency Assistance for families and individuals experiencing financial hardships, including food, clothing, and utility/heating assistance. Additionally, Service Units volunteers act as first responders and assist those impacted by fires, flood and other disasters using mobile kitchen truck, as part of the Salvation Army Disaster Services.	There is a local center at Lowell Corps Community Center
Certified Emergency Response Team (CERT) – A team of trained volunteers organized by the Fire Department who can be called upon to assist and respond during emergencies. Lowell does not have a CERT team, but there are other volunteer programs available.	Need to expand the volunteer base. Consider including CERT program.
Upper Merrimack Valley Medical Reserve Corp – The Upper Merrimack Valley MRC is one of 38 Medical Reserve Corps units in Massachusetts. The lead agency for this initiative is the Town of Westford's Health Department. It's a non-profit volunteer run organization that provide medical care, counseling, and other community services after a disaster. Seven communities in the Greater Lowell Area, including Lowell, are covered under this.	None at this time
CodeRED – The City of Lowell has the CodeRED system, which provides City officials the ability to deliver messages to targeted areas or the entire City quickly through a reverse calling system. Residents may update their CodeRED information on the City website.	Expand outreach to increase the number of residents receiving alerts.
Emergency Shelters – The Senior Center is the City's designated ADA approved FEMA shelter. If needed, most of the schools, Lowell Auditorium, and some of the Parish halls could be used as a shelter, but the newer schools would be the likely be best because they are ADA compliant. The Senior Center is also used as a warming and cooling facility.	Develop a shelter plan for pets. Upgrade Senior Center or find a new building to serve as a shelter. Expand outreach about location of emergency shelters.
Backup Generators – Every major building in the City has backup emergency generators, including the Senior Center, City Hall, Fire Stations, and the Police Station. Smaller generators are available if needed for residential homes or command posts.	Install backup generators at critical facilities, including schools, water utility, private entities (gas stations and grocery stores)

DRAFT

Buried Utilities – Although not required, many new developments have installed underground utilities. In certain areas in the Downtown and the Acre, there are buried utilities (5-10%). Most of them are above ground.	None at this time.
Permits for Construction – Permits are required from the Building Department to ensure the building code and utility connections are properly made. Public Works requires permits to ensure safe excavation, sewer connections, and other stormwater regulations are met. The Fire Department inspects certain aspects of all new construction for fire prevention safety.	None at this time
Multi-Department Review of Developments – Depending upon the type of development, extent of construction, and location, multiple departments, including the Planning Board, Building Department, Board of Health, Department of Public Works, Conservation Commission, the Fire Department, and Zoning Board of Appeals, may review site plans prior to approval.	None at this time
Massachusetts State Building Code – The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads.	None at this time
Open Space and Recreation Plan (OSRP) 2019-2023 –The City has a wealth of conservation areas and recreation spaces that help reduce urban heat island effect and provide flood storage among other climate resilient co-benefits. The OSRP aims to maintain, promote use, and increase the number of these spaces.	Update the next OSRP with more inputs on climate resilience and hazard mitigation.
Zoning Ordinance – Chapter 290 of the City Code of Ordinances, Zoning regulates the land use, size, height, bulk, location and use of structure. Zoning allows regulates or guides landscaping, open space, vehicle parking and loading. Zoning can be used as a tool to promote affordable housing, proper communication facilities, and smart development.	None at this time.
Rules and Regulations for Site Plan Review – Procedures and guidelines set forth by the Planning Board corresponding to the Section 11.4.2 of the Lowell Zoning Ordinance. Special permits are required for construction of large residential, commercial, institutional, municipal, and industrial developments or expansions.	Consider incorporating climate resilience into the site plan review process through the completion of a climate resilience design guideline or scoring system.
Communication Infrastructure – Available resources to reach the community is social media (Facebook, Twitter), City website, City manager's office, Code Red. Seniors can be reached through volunteers at the Senior Center.	More efficient efforts are required to reach the vulnerable populations.

DRAFT

Existing City-Wide Mitigation for Flood Related Hazards

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

Participation in the NFIP – Lowell participates in the National Flood Insurance Program (NFIP) (FEMA, 2019c). The NFIP is a Federal program administered by FEMA enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages. NFIP offers flood insurance to communities that comply with the minimum standards for floodplain management. NFIP uses a Community Rating System (CRS) to award communities that go beyond the minimum standards with lower flood insurance premiums for property owners. The incentives are awarded upon a credit system for various activities. Points are awarded to communities that prepare, adopt, implement, and update a comprehensive flood hazard mitigation plan using a standard planning process. Lowell is not currently eligible to participate in the CRS Program (as of May 2019) (FEMA, 2019c). Lowell participates in the NFIP with 1139 policies in force as of January 28th, 2020 (DCR, 2020). FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website. The City complies with the NFIP by enforcing floodplain regulations, maintaining up-to-date floodplain maps. City's flood control system was recertified in 2019 after some significant repairs on West Street Pump Station. As a result, some of the properties have been taken out of Flood Zone and thus do not require mandatory flood insurance anymore.	None at this time.
FEMA FIRMS – FIRMS or flood maps denote areas of the 100-year and 500-year floodplain, which is used for the NFIP and other regulatory controls. For example, the Building Inspector and the Lowell Conservation Commission enforce a federal law requiring elevation above the 100-year flood level of new and substantially improved residential structures in the floodplain. The floodplain notations are also used in wetland protection and floodplain control regulation. The FEMA FIRMS were last updated in 2010 and an updated was initiated in 2019. Substantial rewriting was done.	Once the new FEMA FIRMS are finished, update regulations referencing the old map. Consider requiring regulatory controls out to the 500-year floodplain to account for climate change.
Street Sweeping – The Department of Public works is responsible for street sweeping, which occurs daily from April 1st to end of November every year on a fixed schedule. There is a street sweeping crew dedicated for the task. Sweeping begins on the main lines of the city,	None at this time

DRAFT

followed by side streets on a ward-by-ward basis and the aim is to hit every street by the end of November.	
Stormwater System Maintenance – The Department of Public Works regularly clears debris from its catch basins. DPW is installing drainage improvements at various locations to reduce flooding on the roads. City is also doing a backwater study on Claypit Brook to seek funding to reduce repetitive flood losses. Culverts require repair and upgrades.	- Include stormwater systems in private housing developments - Enlarge undersized culverts to alleviate flooding at key locations such as Claypit Brook area
Stormwater – Sewer Separation Plan and Implementation – The City targets specific areas for stormwater separation.	Incorporate climate projections in the stormwater system upgrades.
Maintenance of Public Water Bodies – There is no municipal program in place. The Central River Power System cleans debris occasionally from canals and control structures including cleaning idle overflow channels. Department of Public Works is responsible for disposing the debris.	None at this time
NPDES Phase II Stormwater Program or Municipal Separate Storm Sewer System (MS4) Permit– The City continues to implement an aggressive NPDES stormwater program that includes measures for public education and outreach, illicit discharge detection and elimination, construction and post-construction controls, and City-wide good housekeeping and stormwater maintenance procedures. The City continues to implement its NPDES Phase II stormwater program, which includes public education programs. In addition, the City provides educational stormwater materials on the City website and annual mailings. The City also has a Stormwater Management Plan as part of their Small Municipal Separate Storm Sewer Systems (MS4) permit.	None at this time.
Massachusetts Stormwater Management Standards and Handbook – Massachusetts administers stormwater standards through provisions of the Wetlands Protection regulations, 310 CMR 10.00 for wetland notices of intent and surface water discharge permits. The local Conservation Commission and Planning Board regulates this at the local level. The Massachusetts Stormwater Handbook provide guidance on how to meet the regulations and manage stormwater pollution and is being currently updated by MassDEP.	None at this time
Stormwater Management Ordinance and Stormwater Management Rules and Regulations –Chapter 272 of City Ordinance entitled Water and Sewers was updated in 2018 by establishing a new Part 6, ARTICLE X entitled "Stormwater Management" to conform with the requirements of the MS4 permit. The rules and regulations require proper planning, implementation, and maintenance of stormwater	None at this time

DRAFT

management and erosion control measures and establishes minimum requirements and procedures to control the adverse effects of increased post-development stormwater runoff and nonpoint source pollution associated with new development and redevelopment.	
Floodplain Protection Overlay District (FPOD) – The City's FPOD (Article IX of the Zoning Ordinance) is defined by the 100-year floodplain as designated by FEMA. The Floodplain Overlay District regulates certain activities within a flood zone enhancing federal/state laws. The Floodplain Overlay District is enforced by the Building Inspector (municipal staff) and regulated by Board of appeals.	Considering increasing the FPOD to the 500-year floodplain to account for climate change.
Massachusetts Wetlands Protection Act and Local Wetlands Protection – The Commonwealths' Wetlands Protection Act (Chapter 131, Section 40 MGL) regulates the protection of resource areas in and around wetlands, including land subject to flooding. This regulates development and activity within a 100-foot buffer around wetlands, and a 200-foot buffer around riverfront areas. The Wetlands Protection Act is locally enforced by the Conservation Commission. The City further regulates wetlands through the City Wetlands Ordinance (Ch. 280, Sec. 1-13) and the rules are more conservative than the State's regulations.	The local Wetlands Protection Ordinance and corresponding Rules and Regulations could consider the incorporation of climate change.

Existing Dam Mitigation Measures

Dam and Levee Maintenance – Lowell completes regular maintenance on dams and levees when finances are available. The City did a recent reinforcement of the earthen levee.	None at this time
DCR Dam Safety Regulations and Inspections – All jurisdictional dams are subject to the Division of Conservation and Recreation's dam safety regulations (302 CMR 10.00). The dams must be inspected regularly, and reports filed with the DCR Office of Dam Safety. The latest inspection of the Lowell Reservoir Dam was done in May 2018 and the next one is scheduled in May 2020.	None at this time
Permits Required for Construction – State law requires a permit for the construction of any dam.	None at this time

Existing City-Wide Mitigation for Wind-Related Hazards

Massachusetts State Building Code – The City enforces the Massachusetts State Building Code whose provisions are generally adequate to protect against most wind damage. The code's provisions are the most cost-effective mitigation measure against	None at this time.

DRAFT

tornados given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages would be extremely high. City follows State Building Code and handles wind related damages based on need.	
Tree Maintenance – National grid has a program. Their crew trim and cut up trees that could be a potential threat to the power lines.	Expand maintenance program.

Existing City-Wide Mitigation for Winter-Related Hazards

Snow Removal Requirements – Ordinance Number 243-3 requires private property owners or occupants to clear snow from public sidewalks/alleys abutting their property.	Update snow removal plan and enforce rules for clearing sidewalks.
Snow Plowing and Deicing Operations – The Public Works Department provides standard snow plowing operations on main arterials, including salting. There is an existing fleet inventory, but the fleet needs to be upgraded as they are old (trucks are 2010 or prior). The City would like to replace equipment more often, at least one vehicle each year. They also hire contractors in case of heavy snow.	Replace old equipment
Snow Emergency Parking Bans – The City places parking restrictions when a snow emergency is declared.	None at this time.
Fuel Assistance – Available to renters and homeowners meeting income guidelines through the CTI Fuel Assistance Program.	None at this time

Existing City-Wide Mitigation for Drought-Related Hazards

Water Conservation – Water use restrictions are necessary in some communities. However, Lowell's water supply is adequate for the foreseeable future because the City receives its usable water from Merrimack River.	None at this time.

Existing City-Wide Mitigation for Fire-Related Hazards

Open Burning Permits – The Department of Environmental Protection (MassDEP) and the Lowell Fire Department limit open burning for public health and safety reasons. Pursuant to 310 CMR 7.07 (3) (e), Lowell is one of the 22 densely built and populated cities and towns in the Commonwealth where open burning is not permitted.	The City does not allow open burning. No improvements recommended at this time.
Public Education – The Fire Department offers public education to vulnerable populations. They provide education in school and in	Continue public education efforts and update materials,

DRAFT

senior centers. Structure fires are more common than wildfires in Lowell.	as necessary. Expand outreach into new forums.
Fire Department Services – There are currently multiple fire stations in Lowell. Fire Department is active and involved in emergency management. However, the City does not own a mobile emergency operations center; they borrow it from MEMA when needed.	Need a mobile emergency response center.
Statewide Fire Mobilization Plan – The state has a fire mobilization plan. Lowell falls under Northeast Region 1, District 6 (Northern Middlesex) and hosts one of the 6 special communications units that are located throughout the state. The fire mobilization plan includes plans of action in case of structure fire, wildfires, arranging ambulances, and details about 10 alarm run cards. City also participates in Mutual aid for structure fires.	Continue updating the plan based on City's needs and climate change..
"Senior SAFE" program – Lowell received a grant funding for FY 2020 for the Senior SAFE Program (S.A.F.E. and Senior SAFE Awards), which aids in providing fire safety to seniors through the fire department. It also aims to improve safety in senior housing.	Look to secure other grants for continued outreach to vulnerable populations.
Brush Clearing - Brush clearing to provide access to Emergency Service vehicles. It's an ongoing program done by the State.	None at this time.

Existing City-Wide Mitigation for Extreme Temperature-Related Hazards

Tree Maintenance by City – The City maintains street trees and numerous trees on public grounds, historic sites, conservation areas, park areas. Spring and fall are the City's planting seasons. Trees are also planted in residential areas, if requested. Dead trees are removed throughout the City.	Continue to plant trees in areas with less tree canopy. Consider incorporating "Greening the Greenways" Program through the State.
Heating and Cooling Shelter – The Lowell Senior Center is used as a heating or cooling facility. There are misting stations and pools that open up in Summer throughout the City.	Explore other areas to provide refuge to the heat, more shelters or other shade features.

Existing City-Wide Mitigation for Geologic Hazards

Massachusetts State Building Code for Seismic Standards – The State Building Code contains a section on designing for earthquake loads (780 CMR 1612.0). Section 1612.1 states that the purpose of these provisions is "to minimize the hazard to life to occupants of all buildings and non-building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake". This section goes on to state that due to the complexity of seismic design, the	None at the time

DRAFT

criteria presented are the minimum considered to be "prudent and economically justified" for the protection of life safety. The code also states that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, is not economically achievable for most buildings. Section 1612.2.5 establishes seismic hazard exposure groups and assigns all buildings to one of these groups according to a Table 1612.2.5. Group II includes buildings which have a substantial public hazard due to occupancy or use and Group III are those buildings having essential facilities which are required for post-earthquake recovery, including fire, rescue and police stations, emergency rooms, power-generating facilities, and communications facilities.	

Existing City-Wide Climate Mitigation Measures

Complete Street Implementation Plan – The City has developed a list of priority project to encourage walking and biking, which will reduce greenhouse gases. City of Lowell adopted the implementation plan in 2015 that allowed the City to get grant funding on their prioritization plan.	Continue to implement Complete Street Plan and build a multi-modal transportation system
Green Communities Program – Lowell was one of the first designated Green Communities in 2010. As part of this designation, The City is committed to adhering to several different criteria to help improve efficiency and reduce carbon footprint.	None at this time.
Strategic Energy Management Partnership: Last fall, the City entered into a Strategic Energy Management Partnership (SEMP) with National Grid to help enable additional energy efficiency projects.	Continue to evaluate projects that will save energy
Green Communities Partnership: This is a partnership with UMass Lowell to make Lowell the greenest city with the greenest campus in the Commonwealth. There was supposed to be a grant program associated with the initiative. However, the COVID situation caused the grant to be cancelled for this year.	Apply for next year's grant program
100% Renewable Resolution: In August 2017, the Lowell City Council passed a non-binding resolution to move the City toward the goal of 100% renewable energy by 2035. This resolution has several areas that help to make progress in reducing fossil fuel usage and increasing renewable energy.	Continue to employ methods to reduce usage of fossil fuels

DRAFT

Mitigation Capabilities and Local Capacity for Implementation

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

DRAFT

6.0 STATUS OF MITIGATION MEASURES FROM THE 2015 DRAFT PLAN

Implementation Progress on the Previous Plan

During interviews with Weston & Sampson, Lowell staff and core team members reviewed the mitigation measures identified in the 2015 Northern Middlesex Region Hazard Mitigation Plan. These members felt it was important to determine which mitigation measures were still relevant and whether each measure had been implemented or deferred. Of those measures that had been deferred, they were then evaluated to determine whether the measure should be deleted or carried forward into this 2020 HMP-MVP Plan. The decision on whether to delete or retain a particular measure was based on the members' assessment of the continued relevance or effectiveness of the measure and whether the deferral of action on the measure was due to the inability of the City to take action on the measure. Table 6-1 summarizes the status of the mitigation measures, along with the priority of these measures. The plan is intended to assist the City in prioritizing the proposed measures, which will provide guidance on how to best allocate the City's limited resources.

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

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Implement stormwater/CSO separation measures citywide.	**In progress.** The City does not do CSO separation anymore. But Stormwater separate measures are underway.	Yes
Dredge and re-channel marsh between Phoenix Avenue and Wentworth Avenue and between Douglas Road and Clark Road (Tewksbury).	**Not applicable.** Adopted other ways that are less expensive and less intrusive to the wetland	No
Install drainage improvements at various locations to reduce roadway flooding.	**In progress.** Culverts need to be fixed.	Yes
Pursue mitigation funding to reduce repetitive flood losses along Black Brook and Clay Brook.	**In progress.** Backwater study was done on Claypit brook.	Yes
Work with MassDOT to repair or replace structurally deficient bridges.	**In progress.** Works with other agencies in addition to MassDOT.	Yes
Work with DCR Office of Dam Safety to ensure that the inspections of all dams are current.	**Completed.** All dam inspections are current.	No

DRAFT

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Develop a joint Fire Wise Program in cooperation with DCR and the Towns of Dracut and Tyngsborough.	**Completed**. Mutual aid agreement and DCR are part of the program. Agreements with Tyngsborough was made for the bridge that passes through both Lowell and Tyngsborough.	No
Work with DCR Bureau of Fire Control to complete mapping of the state forest for public safety purposes.	**Completed.** DCR Bureau of Fire Control completed the mapping.	No
Participate in the Community Rating System (CRS) or undertake activities to increase the grade level of the community's current CRS participation	**In progress.** Recertification of flood control was done in 2019 but the City does not participate in CRS	Yes
Revise subdivision regulations, erosion control regulations, and Board of Health regulations to improve floodplain management.	**Not done yet.**	Yes
Upgrade all shelter facilities to meet Red Cross standards; includes plumbing upgrades, air conditioning, and generators	**Completed.** Senior center and all the new schools meet the standards	No
Repair erosion/flood control walls and levees to ensure structural integrity.	**In progress.** Repairs are done every year (example: vegetation removal, floodwalls repair, filling up animal burrows in the dikes). Most of the repairs are limited to two canal bridges.	Yes
Repair Canal Walls throughout system	**Not done yet.** Lower locks on canal walls were studied; Ownership of walls can be unknown at times.	Yes
Clean debris from canals and control structures. Clean out idle overflow canals.	**Not Applicable.** Central river power system does the cleaning, City DPW helps with disposing the debris.	Yes

DRAFT

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Study regional consolidation of 911 dispatch services by establishing an RECC	**Not applicable.** City is not part of RECC.	No
Enlarge undersized culverts to alleviate flooding at key locations.	**On hold.** Culverts are failing along Claypit Brook, there are sinkholes. Some culverts need to be replaced by bridges. Hydraulic study needed.	Yes
Replace obsolete snow-plow equipment with modern, more reliable snow removal apparatus. Add two snow throwing apparatus for two new multi-purpose trucks.	**On hold.** Equipment are old; trucks are from 2010. At least one vehicle needs to be replaced each year.	Yes
Purchase a regional snow melting apparatus	**Not done yet.** This will be beneficial for the City.	Yes
Increase public awareness of the dangers of extreme temperatures and outline locations where vulnerable populations (elderly, homeless and those with health issues) can have access to air conditioning or shelter from the cold.	**In progress.** There are facilities for vulnerable populations (misting stations, heating and cooling centers, pools), but public outreach needs to be more efficient.	Yes
Distribute educational information to residents and businesses on protecting life and property from severe winter storm events	**In progress.** Public education office and emergency management offices take care of that through Social Media, Newspapers, City website	Yes
Conduct outreach program to provide information on flood hazards and methods of protecting property located in the floodplain. Will use multi-lingual brochures, website, and social media	**In progress**. The City recently partnered with FEMA and did classes with business owners and Non-profit organizations about flood protection and emergency management in general.	Yes
Add secondary water supply for the City through tie-in with the Billerica system on the Concord River.	**Not applicable.** The primary source of water is Merrimack River which is big. The City has sufficient supply of water.	No

DRAFT

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Add portable water supply units for emergencies.	**Not done yet.** Water trucks are available through private companies. City does not own a portable water supply unit.	Yes
Construct pump station at West Street CSO station to protect Lakeview Avenue from flooding.	**Completed in 2019**	No
Modify the effluent pump system at the Greater Lowell Wastewater Treatment Plant to prevent the river from backing up into the plant and flooding the unit processes.	**Not done yet.** Not a critical project for the City, because this has happened only once since the flooding in 2006.	Yes
Install "Duck Bill" backflow prevention valves on CSO and stormwater outlets to prevent river backflow from inundating pump stations, gravity division stations and local roadways. Locations in need include Tilden, West, Sparks and Rosemont Streets.	**On hold.** The City plans to replace "Duck Bill" with gauges.	No
Construct berms/levees along the western bank of Beaver Brook to flood proof the Walker Street and Tilden Street CSO stations and the Rosemont Street sewer. pump station	**In progress**. One side of the Beaver Brook has a certified levee system. This will be a long-term capital planning project	Yes
Ensure that administrators of schools, businesses, medical facilities, and municipal buildings have a shelter plan in the event of a tornado warning	**Completed.** Shelter plan is in place. Notification of watch is sent out to public through code red and social media.	No
Install a backflow prevention valve on the Alma Street outfall pipe to prevent floodwater from the Merrimack River and Beaver Brook from backing up into the neighborhood. This project includes a structure to house the valve.	**Completed**	No

DRAFT

Mitigation Measure	2020 Status Update (Completed, In Progress, On Hold, Not Applicable, Not done yet)	Include in 2020 Plan?
Inspect public buildings to evaluate the capacity to withstand snow loads and prevent roof collapse. Develop plans to clear roofs of excessive snow accumulations to prevent collapse.	**In progress.** Done on a need basis. Properties that are compromised after a heavy snow are inspected. Properties that have flat roof or have a lot of occupants get priorities. They make sure that the mechanicals are not compromised (exhaust system for example); evaluation is done after each event.	Yes
Identify locations for snow storage farms for utilization in severe winters with heavy snowfall	**In progress.**	Yes
Evaluate public buildings and critical facilities for the potential to withstand high winds	**In progress.** Done on a need basis. After major event city inspectors go out and assess the storm damage or potential damages.	Yes
Assess bridges and roadways to ascertain their capability to support fire apparatus and develop alternative routing plans where deficiencies are noted	**Not done yet.** MassDOT inspects the bridges. Some bridges are closed because of inspection; alternate routes in place. More bridges need to be fixed.	Yes
Develop an inventory of public buildings that do not currently meet seismic standards	**Not done yet.** Because earthquakes are extremely rare in the area, this was not given a priority.	Yes
Provide information to homeowners on how to protect their property from brush fire or wildfire during times of drought.	**Not done yet.**	Yes

DRAFT

7.0 HAZARD MITIGATION AND CLIMATE ADAPTATION STRATEGY

7.1 Identification of Hazard Mitigation and Climate Adaptation Strategies

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

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

Stakeholders were engaged through Core Team meetings, the CRB Workshop, and the public input session. The full list of action items from the CRB Workshop are available in Appendix C. Hazard mitigation strategies often provide protection against more than one natural or climatic hazard.

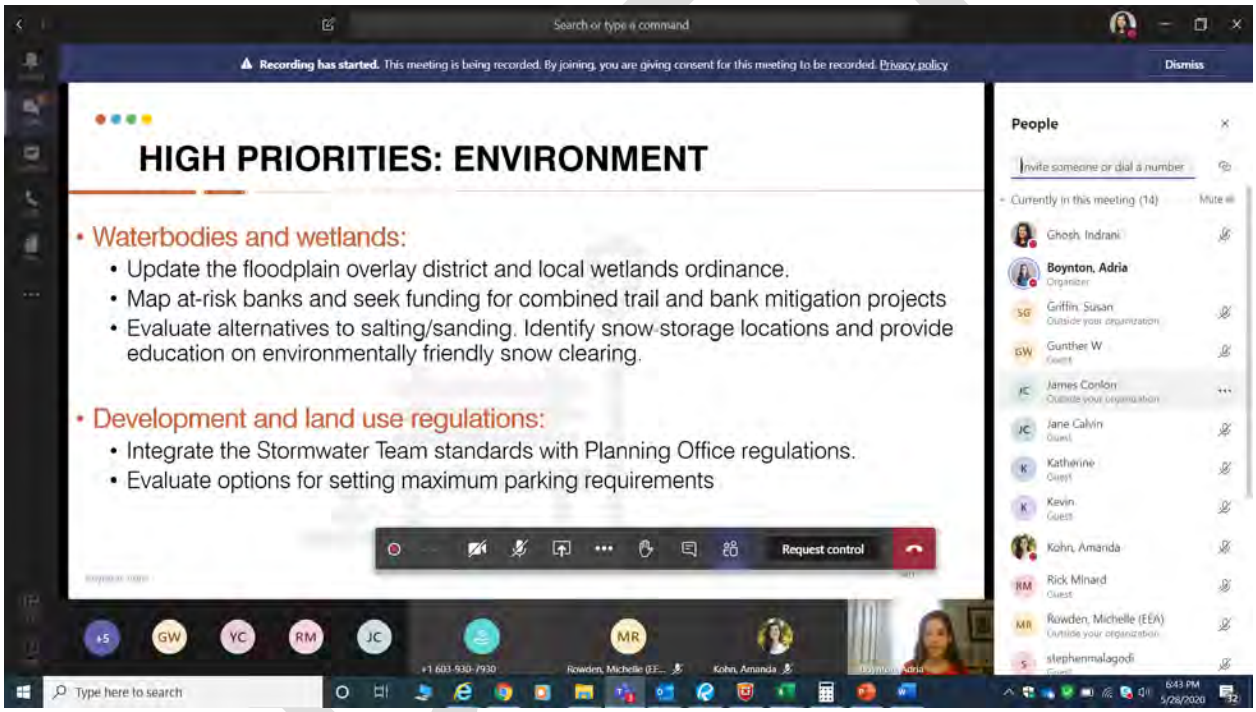


Figure 7-1. Environmental high priority action items were presented during Lowell's virtual Public Listening Session webinar

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

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

Specific Action - A description of a hazard mitigation or climate adaption measure with details, such a specific location, strategy, or technique to be used to work towards fulfilling the general objective.

Implementation Responsibility – Most hazard mitigation and climate adaptation measures will require a multi-department approach where several City departments share responsibility. This determination is at the discretion of the governing body of the community. The designation of implementation responsibility in the table was assigned based on general knowledge of the responsibilities of each municipal department. Departments names in bold will be the lead. In addition, some action items require extensive involvement with the Commonwealth of Massachusetts departments or private entities. In those cases, the relevant entities have been listed in addition to a municipal department. Section 7.2 specifically addresses regional collaboration.

Time Frame – The time frames represented below are assigned based on the complexity of the measure, the overall priority of the measure, and generally reflect when the mitigation measure is planned to initiate. The identification of time frames is not meant to prevent a community from actively seeking out and taking advantage of funding opportunities as they arise. The time frames are divided into the categories below.

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

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

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

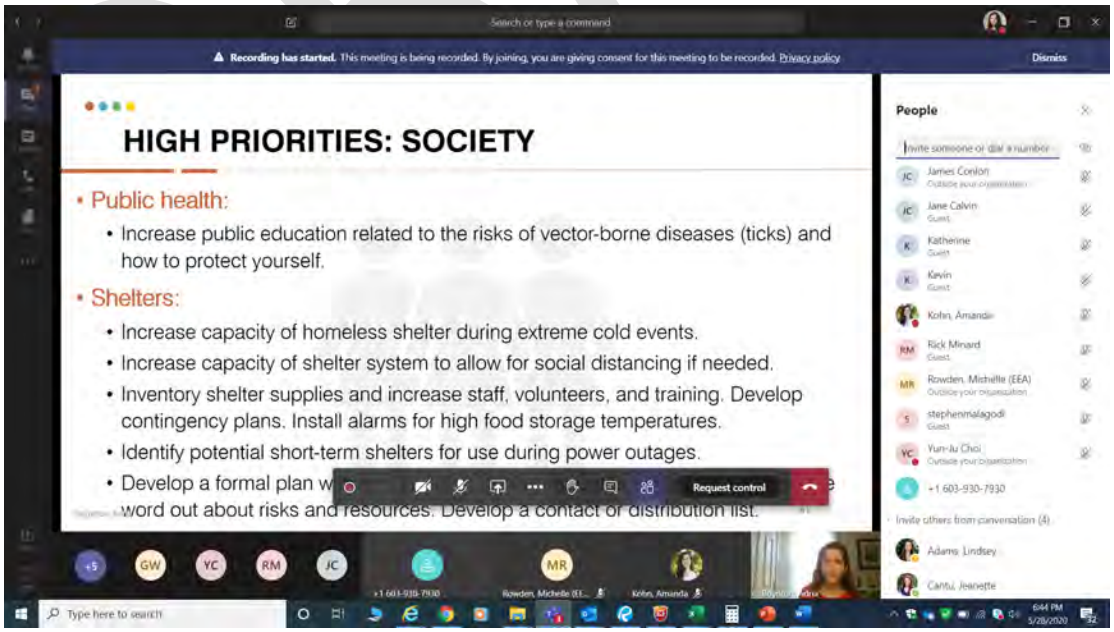


Figure 7-2. Societal high priority action items were presented during Lowell's Virtual Public Listening Session Webinar

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

Residents were asked how Lowell should prioritize climate adaptation and hazard mitigation measures. Most of the residents felt the impact to public safety should be considered followed by funding and time frame (see Appendix D for more details). Figures 7-1, 7-2, 7-3 represent the environmental, societal, and infrastructural high priority action items that were captured during the listening session respectively and the details are provided in Table 7-1.

Figure 7-3. Infrastructural high priority action items were presented during Lowell's Virtual Public Listening Session Webinar

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
Roads, bridges, and public transit	Identify at-risk bridges and develop an emergency plan for each.	• DPW • Emergency Management	1-3	$$	H
	Update snow removal plan and enforce rules for clearing sidewalks. Develop a formal parking ban. Buy new plow equipment.	• DPW • Emergency Management • Planning	5-10	$$- Study $$$$ - Buying equipment	H
	Update tree pruning and maintenance program. Hire a City Arborist and work with the National Grid. Develop a list of appropriate street trees.	• DPW • Conservation Commission	1-3	$$	H
	Develop an emergency tornado response plan for the LRTA Bus system.	• DPW • Emergency Management	3-5	$$	H
Water supply and distribution	Invest in aging infrastructure. Protect the distribution system from the freeze/thaw cycle and proactively secure funding to address breaks. Assess and track "hot spots" with frequent breaks and identify potential solutions.	• DPW	Ongoing	$$$- per year	H
	Floodproof the Water Plant Intake Station	• DPW	3-5	$$$$	H
Stormwater system	Upgrade culverts near Clay Pitt Brook. Assess and map the entire drainage system. Ensure appropriate capacity of catch basins.	• DPW • Conservation Commission	1-3	$$$$$	H

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	Develop a beaver management program	• DPW • Emergency Management	5-10	$$$	H
	Continue to encourage Low Impact Development and assess options for regulatory mechanisms	• Building • Planning • DPW	Ongoing	$	H
Wastewater Infrastructure	Assess floodproofing options for vulnerable pump and combined sewer overflow stations.	• DPW	3-5	$$	H
	Add backflow prevention to combined outfalls	• DPW	5-10	$$$	H
	Integrate new battery storage to the existing solar array and backup generator at the Water Treatment Plant. Consider a similar approach at the Wastewater Plant.	• Energy • DPW	5-10	$$$	H
Canal system and walls	Conduct an inventory and assessment of the walls and identify needed repairs	• DPW	1-3	$$	H
	Increase public education and outreach related to trash removal and encourage residents and visitors to avoid throwing trash in the canals.	• DPW • Planning	1-3	$	H
	Participate in the ongoing Federal Energy Regulatory Commission (FERC) study and re-licensing process and review their materials.	• DPW	1-3	$	H

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	Manage trees along the canals through increased coordination with DCR	• Conservation Commission	1-3	$	H
Dams and gate houses	Model and assess the impact of the 500-year flood on the gate houses and develop and overall response plan	• DPW	1-3	$$	H
	Identify and address vulnerabilities of the earthen dam near Beaver Brook Bridge	• DPW	1-3	$$	H
	Coordinate with dam operators and the hydropower entity on flood mitigation	• DPW • Utility	1-3	$$	H
Waterbodies and wetlands	Update the floodplain overlay district and local wetlands ordinance.	• Planning • Conservation Commission	5-10	$$	H
	Map at-risk banks and seek funding for combined trail and bank mitigation projects	• Planning • Conservation Commission	1-3	$$	H
	Evaluate alternatives to salting/sanding. Identify snow storage locations and provide education on environmentally friendly snow clearing	• DPW • Emergency management	3-5	$$	H
Development and land use regulations	Integrate the Stormwater Team standards with Planning Office regulations	• DPW • Planning	3-5	$$	H
	Evaluate options for setting maximum parking requirements	• Police • DPW	3-5	$	H
Public health	Increase public education related to the risks of vector-borne diseases (ticks) and how to protect yourself.	• Health Department	Ongoing	$	H

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
Shelters	Increase capacity of homeless shelter during extreme cold events	• Emergency Management	3-5	$$$	H
	Increase capacity of shelter system to allow for social distancing if needed.	• Health Department • Emergency Management	3-5	$$$	H
	Inventory shelter supplies and increase staff, volunteers, and training. Develop contingency plans. Install alarms for high food storage temperatures.	• Health Department • Emergency Management	1-3 - inventory 5-10 – plan development and implementation	$$$$	H
	Identify potential short-term shelters for use during power outages.	• Emergency Management	1-3	$	H
	Develop a formal plan with the City, LTC, local organizations, and others to get the word out about risks and resources. Develop a contact or distribution list.	• Emergency Management	3-5	$$	H
Residents at risk of isolation	Work with local partners to share information and get the word out	• Emergency Management	Ongoing/ 1-3	$	H
	Translate announcements into multiple languages. Use accessible visuals.	• Emergency Management	Ongoing/ 1-3	$	H
	Partner with schools to share information with parents. Share information through a range of means, including digital, TV, and messaging signs.	• Emergency Management	Ongoing/ 1-3	$	H

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	Develop a database of at-risk residents with emergency service providers and the senior center. Conduct wellness checks.	• Emergency Management	Ongoing/ 1-3	$	H
Residents with challenges to prepare or adapt	Evaluate safe areas for informal housing (outside of flood-prone areas). Assess best practices.	• Planning • Building	1-3	$	H
	Work with social services and local organizations to provide support to residents experiencing homelessness.	• Health Department • Planning	3-5	$$	H
Municipal and emergency services	Update the existing Emergency Management Plan.	• Emergency Management • Police • Fire	5-10	$$$	H
	Review available City resources and capacity, including emergency generators.	• Emergency Management • Police • Fire	1-3	$	H
Housing	Identify grants for climate-resilient housing, including floodproofing, fire resilience, and energy efficiency for denser and older housing.	• Planning • Building • Fire • Energy • Building	3-5	$$	H
	Provide short-term tenant support if an extreme event prevents residents from working and puts them at risk of eviction	• Building • Planning	3-5	$$	H
Local businesses	Develop and share a toolkit for improving your business' resilience. Provide short-term support for local businesses, including	• Planning	Ongoing	$$$	H

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	mobile generators and refrigerated trucks during extended power outages.				
	Assess ability of local businesses to assist with crisis response, including sewing masks or assisting with food production for food banks.	• Planning	1-3	$	H-M
State forest and park trees	Identify City standard tree pruning and removal within ROW, and working around trees within ROW during construction	• Conservation Commission	Ongoing	$	H-M
Street trees and citywide tree canopy	Develop better tree pit development, etc. to encourage growth in harsh urban conditions.	• Conservation Commission	3-5	$$	H-M
	Evaluate options to minimize impact of salt from winter weather on trees	• Conservation Commission	1-3	$	H-M
	Inventory of city tree canopy in GIS - evaluate changes over time.	• Conservation Commission	3-5	$$	H-M
	Hire a City Arborist, potentially shared regionally, or train existing staff to be certified as an arborist.	•Conservation Commission	1-3	$	H-M
	Create a replacement plan for lost trees along with funding source. Strengthen tree replacement requirements.	•Conservation Commission	3-5	$	H-M
	Evaluate city tree ordinance and whether to include private trees in some capacity,	• Conservation Commission • Planning	5-10	$$	H-M

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	especially for new development (e.g., replace 1:1 or pay into a tree fund).				
	Work with the National Grid's arborist to assist with removal of hazard trees that threaten power lines and can also assist with a list of appropriate street trees.	• Conservation Commission	1-3	$	H-M
	Tree selection types, underground root barriers, stronger root paths away from infrastructure, newer sidewalk details that can accommodate some level of roots, and pruning. Stricter adherence/enforcement of our existing ordinance.	• Conservation Commission • Planning • DPW	5-10	$$$$	H-M
	Manage trees along the canal ways through increased coordination with DCR (increase DCR's capacity?)	• Conservation Commission	Ongoing	$	H-M
	Identify a list of preferred street tree and other tree species for new developments.	• Conservation Commission	1-3	$	H-M
	Public education on benefits of trees	• Conservation Commission	1-3	$	H-M
Energy Resilience and Communications	Increase insulation of multi-family housing.	• Building	3-5	$$$$	M
	Need for warming stations	• Emergency Management • Planning • Health	5-10	$$$$	M
	Renewable microgrid to support existing backup	• DPW • Utility	10+	$$$$	M

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
	Need for cooling stations	• Emergency Management • Health • Planning	5-10	$$$$	M
	Expand outreach to vulnerable populations. Increase use of CodeRED. Continue use of social media, partner with local organizations with existing communications to their members (leverage existing networks). Assess alternative methods for residents without landlines or access to internet.	• Emergency Management • Planning • Police • Fire	1-3	$$	M
Public Buildings	Assess relative threat of public buildings to climate impacts. Plan for the needs (energy to operate, floodproofing, relocate building and services)	• Building	5-10	$$	M
	Salt shed - roof needs repair	• Building	1-3	$$	M
Non-profit community	Volunteer, community, and training programs and planting days for street trees.	• Planning • Conservation Commission	Ongoing	$	M
	Coordinate with parks and recreation, Lowell Parks and Conservation Trust.	• Planning • Conservation Commission	Ongoing	$	M
	Scale model of Lowell Parks and Conservation trust, which plants a new tree for every homeowner.	• Planning • Conservation Commission	Ongoing	$	M
	Create public art related to climate risks.	• Planning • Conservation Commission	Ongoing	$	M

DRAFT

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

General Objective	Specific Actions	Implementation Responsibility	Time Frame (years)	Cost	Priority
Parks and public spaces	Evaluate waterside park infrastructure for flood-resistance. Evaluate parks along roadways and waterways to increase LID stormwater management to alleviate flooding.	• Open Space and Recreation • Planning • Emergency Management	3-5	$	M
	Incorporate educational component.	• Open Space and Recreation • Emergency Management	1-3	$	M
	Assess opportunities for South Common to be modified for flood storage.	• DPW • Emergency Management	1-3	$	M
	Identify snow storage locations that avoid damaging parks.	• DPW • Emergency Management •	1-3	$	M
	Develop maintenance plan amongst various stakeholders	• Emergency Management • Open Space and Recreation	1-3	$	M
	Add splash pads, shade trees, etc. to cope with extreme heat events.	• Open Space and Recreation	Ongoing	$$	M
	Focus tree planting in environmental justice neighborhoods/public spaces where tree canopy is most scarce.	• Open Space and Recreation	3-5	$$	M
	Investigate whether Lowell can participate in Greening the Gateway cities program (DCR grant program)	• Open Space and Recreation • Energy	1-3	$	M

DRAFT

7.2 Regional Partnerships

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

7.3 Potential Funding Sources

There is a great variety of funding available for Massachusetts municipalities, both through the state and federal governments. A full list of funding opportunities can be found on the Community Grant Finder webpage. The Community Grant finder provides a streamlined interface where municipalities can easily learn about grant opportunities. Specific funding options related to action items developed by Lowell are listed below.

Table 7-2: Funding Opportunities for Resiliency Projects

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

DRAFT

Table 7-2: Funding Opportunities for Resiliency Projects

Category	Grant	Description	Limitations & Stipulations
Energy	Green Communities Designation and Grant Program	Provides a road map along with financial and technical support to municipalities that pledge to cut municipal energy and meet other criteria	None
Environment	Community Forest Grant Program	Funding to establish community forests	None
Environment	Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value	None
Environment	604b Grant Program	Water quality assessment and management planning	None
Environment	Land Use Planning Grants	Support effort to plan, regulate, and act to conserve and develop land consistent with the Massachusetts' Sustainable Development Principles	None
Environment	LAND Grant Program	Helps cities acquire land for conservation and passive recreation	Reimbursement rate: 52-70%
Environment	Federal Land & Water Conservation Fund	Funding for the acquisition, development, and renovation of parks, trails, and conservation areas.	Municipality must have an OSRP
Environment	MassTrails Program	Trail protection, construction, and stewardship projects	None
Environment	Municipal Vulnerability Preparedness (MVP) Program	Provides support implement climate change resiliency priority projects	None
Environment	Natural Resource Damages Program	Funding for restoration projects. Funding comes from settlements, so it is does not follow a set schedule.	None
Environment	MS4 Grant Program	Meeting the requirements of the 2016 MS4 permit and reduce stormwater pollution through partnerships	Two or more municipalities subject to the 2016 Small MS4 General Permit (must apply together)
Public Safety	Emergency Management	Reimbursable grant program to assist local emergency management departments to	Reimbursable

DRAFT

Table 7-2: Funding Opportunities for Resiliency Projects

Category	Grant	Description	Limitations & Stipulations
	Performance Grant (EMPG)	build and maintain an all-hazards emergency preparedness system	
Public Safety	Public Assistance Program	The state reimburses governments and other applicants for disaster related costs	75% reimbursable
Public Safety	Senior SAFE	Supports fire and life safety education for seniors	None
Public Safety	Student Awareness of Fire Education (S.A.F.E.)	Grants for local fire departments to teach fire and life safety to schools	None
Public Works and Transportation	Chapter 90 Program	Reimbursable grants on approved projects	None
Public Works and Transportation	Community Transit Grant Program	Funding to meet the transportation and mobility needs of seniors and people with disabilities	Depends on project type
Public Works and Transportation	Complete Streets Funding Program	Technical assistance and construction funding	Eligible communities must pass a Complete Streets Policy and develop a Prioritization Plan
Public Works and Transportation	Municipal Small Bridge Program	Funding for small bridge replacement, preservation, and rehab projects	Bridges with spans between 10' and 20'

DRAFT

8.0 PLAN ADOPTION AND MAINTENANCE

8.1 Plan Adoption

The City of Lowell 2020 HMP-MVP Plan was adopted by the City Council on *[ADD DATE]*. See Appendix D for documentation. The plan was approved by FEMA on [*ADD DATE*] for a five-year period that will expire on [*ADD DATE*].

8.2 Plan Implementation

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

8.3 Plan Maintenance

8.3.1 Tracking Progress and Updates

FEMA's initial approval of this plan is valid for five years. During that time, the City will need to continue to track progress, document hazards, and identify future mitigation efforts. The Core Team, coordinated by APPOINTEE, will meet annually or on an as-needed basis, whichever is most frequent, to monitor plan implementation. The Core Team will be amended as needed. The coordinator of Core Team, APPOINTEE, will also prepare and distribute a survey every two years. The survey will be made available to all Core Team members and any other interested local stakeholders. The survey will assist in determining any necessary changes or revisions to the plan that may be needed. In addition, it will help provide information on progress and accomplishments for implementation and any new hazards or problem areas that have been identified since the plan drafting. The information collected through the survey will be used to formulate a report and/or addendum to the plan. The survey may be collectively filled out at a Core Team meeting.

8.3.1 Continuing Public Participation

The adopted plan will be posted on the City's website. The posting of the plan on the City's web site will provide a mechanism for citizen feedback, such as an e-mail address for interested parties to send comments. The City will encourage local participation whenever possible during the next five-year planning and implementation cycle. The Core Team will incorporate engagement into the implementation of the priority action items. All updates to the plan, including implementation progress, will be placed on the City's website. All public meetings related to the HMP-MVP Plan will be publicly noticed in accordance with City and State open meeting laws.

8.3.2 Integration of the Plans with Other Planning Initiatives

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

DRAFT

Department of Public Works
Conservation Commission
Open Space and Recreation
Emergency Management
Planning Department
Police Department
Fire Department
Health Department
Building Department

Appropriate sections of the HMP-MVP Plan will be integrated into other plans, policies and documents as those are updated and renewed, including the writing of, or updates to, the City's Master Plan, Open Space Plan, Comprehensive Emergency Management Plan, and Capital Investment Program. Coordination with the Northern Middlesex Council of Governments, local organizations, businesses, watershed groups, and state agencies will be required for successful implementation and continued updating.

8.4 Process of Updating

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

DRAFT

9.0 LIST OF REFERENCES

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

Blake, Eric S.; Landsea, Christopher W.; and Gibney, Ethan J. 2011. *The Deadliest, Costliest, and Most Intense United States Tropical Cyclones from 1851 to 2010*. NOAA Technical Memorandum NWS NHC-6. National Weather Service, National Hurricane Center. https://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf.

Cardinali, M, P. Reichenback, R. Guzzetti, F. Ardizzone, G. Antonini, M. Galli, M. Cacciano, M. Castellani, P. Salvati. 2002. A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy. European Geophysical Society. Natural Hazards and Earth System Sciences. 2: 57-72. https://www.nat-hazards-earth-syst-sci.net/2/57/2002/nhess-2-57-2002.pdf.

City of Lowell. Complete Streets Policy. 2016. https://www.lowellma.gov/DocumentCenter/View/2477/Lowell-Complete-Streets-Policy?bidId=

City of Lowell. "Sustainable Lowell 2025", Spring 2013.

City of Lowell. "Open Space and Recreation Plan 2019-2023". 2018

City of Lowell. Part 6 Management of Stormwater. Article X, Chapter 272. 2018. https://ecode360.com/34304419

City of Lowell. Article |General Regulations. Snow and Ice. 2008. https://ecode360.com/8184933

City of Lowell and National Grid. Strategic Energy Management Partnership. 2019

City of Lowell. Wetlands Protection Ordinance; Chapter 280. 2012. https://ecode360.com/8823434

City of Lowell. Zoning Book. Chapter 290. 2018 (latest amendments). https://www.lowellma.gov/DocumentCenter/View/1007/Zoning-Code-PDF?bidId=

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

Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and National Weather Service. "Storm Data Preparation." Operations and Services Performance, NWSPF 10-16., July 9, 2018a. nws.noaa.gov/directives/sym/pd01016005curr.pdf.

EPA, United States Environmental Protection Agency SDWIS. https://enviro.epa.gov.

Federal Emergency Management Agency (FEMA). 2020a. Hazard Mitigation Planning. https://www.fema.gov/hazard-mitigation-planning

Federal Emergency Management Agency (FEMA). 2020b.Grants. http://www.fema.gov/grants.

DRAFT

Federal Emergency Management Agency (FEMA). 2019a "Hazard Mitigation Grant Program." https://www.fema.gov/hazard-mitigation-grant-program.

Federal Emergency Management Agency (FEMA). 2019b. "Flood Zones," https://www.fema.gov/flood-zones.

Federal Emergency Management Agency (FEMA). 2019c. "NFIP Flood Insurance Manual Appendix F: Community Rating System," fema.gov/media-library-data/1559830308363-e690ed2aea6606fb81826904e4a7bd7f/app-f_crs_508_apr2019.pdf.

Federal Emergency Management Agency (FEMA). 2019d. "Disasters: Total Number of Declared Disasters," Accessed April 2020. fema.gov/disasters?field_dv2_state_territory_tribal_value_selective=MA&field_dv2_incident_type_tid=All&field_dv2_declaration_type_value=All&field_dv2_incident_begin_value%5Bvalue%5D%5Bmonth%5D=&field_dv2_incident_begin_value%5Bvalue%5D%5Byear%5D=&field_dv2_incident_end_value%5Bvalue%5D%5Bmonth%5D=&field_dv2_incident_end_value%5Bvalue%5D%5Byear%5D=.

Federal Emergency Management Agency (FEMA). 2019e. "Definitions: Repetitive Loss Structure.". fema.gov/national-flood-insurance-program/definitions.

Federal Emergency Management Agency (FEMA). 2019f "The National Flood Insurance Program." fema.gov/national-flood-insurance-program.

Federal Emergency Management Agency (FEMA). 2013. "Local Mitigation Planning Handbook". https://www.fema.gov/media-library/assets/documents/31598?id=7209.

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

General Laws of Massachusetts. Section 3A of Chapter 23A: "Economic development incentive program; establishment; definitions for Secs. 3A to 3G. Gateway municipality'". https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter23A/Section3A

General Laws of Massachusetts. Section 40 of Chapter 131: "Section 40: Removal, fill, dredging or altering of land bordering waters". https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter23A/Section3A

Kocin, P. J., and L. W. Uccellini, 2004: A snowfall impact scale derived from Northeast storm snowfall distributions. Bull. Amer. Meteor. Soc., 85, 177–194.

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

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

Massachusetts Department of Conservation and Recreation (DCR). 2020b. "Emergency Action Plans." Office of Dam Safety. mass.gov/service-details/emergency-action-plans.

DRAFT

Massachusetts Department of Conservation and Recreation (DCR).2020a "Community Information System: Repetitive Loss for the City of Lowell," Data as of September 2019.

Massachusetts Department of Conservation and Recreation (DCR). "Inventory of Dams." 2020. https://docs.digital.mass.gov/dataset/massgis-data-dams

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

Massachusetts Department of Conservation and Recreation (DCR). 2019. Recent Drought History. https://www.mass.gov/doc/drought-status-map-september-2019/download

Massachusetts Department of Conservation and Recreation (DCR). 2017b. Recent Drought History. https://www.mass.gov/files/documents/2017/09/08/drought-status-history.pdf

Massachusetts Department of Environmental Protection. 310 CMR 10.00: Wetlands Protection Act Regulations. 2017. https://www.mass.gov/regulations/310-CMR-1000-wetlands-protection-act-regulations

Massachusetts Department of Public Health (DPH), 2019. Populations Potentially Vulnerable to Heat-Related Impacts. Bureau of Environmental Health. Retrievable from https://nescaum-dataservices-assets.s3.amazonaws.com/MA-statewide-vuln-pop-map.JPG

Massachusetts Division of Fisheries and Wildlife. 2012. BioMap2 Conserving the Biodiversity of Massachusetts in a Changing World. http://maps.massgis.state.ma.us/dfg/biomap/pdf/town_core/Lowell.pdf

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

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

Massachusetts Executive Office of Energy and Environmental Affairs (MA EOEEA) and Executive Office of Public Safety and Security (EOPSS). 2018. Massachusetts State Hazard Mitigation and Climate Adaptation Plan.

Massachusetts Executive Office of Energy and Environmental Affairs (EEA) and the Massachusetts Emergency Management Agency (MEMA). 2019. Massachusetts Drought Management Plan. https://www.mass.gov/doc/massachusetts-drought-management-plan/download.

Massachusetts Fire and EMS Mobilization Plan. 2018. https://www.mass.gov/doc/statewide-fire-mobilization-plan/download

Massachusetts Executive Office of Energy and Environmental Affairs (EEA) and the Massachusetts Emergency Management Agency (MEMA). 2019. Massachusetts Drought Management Plan. https://www.mass.gov/doc/massachusetts-drought-management-plan/download

DRAFT

Mass GIS. 2020. Standardized Assessor's Parcel Data. https://docs.digital.mass.gov/dataset/massgis-data-standardized-assessors-parcels.

MA State Building Code. Ninth Edition: 780. 2018. https://www.mass.gov/handbook/ninth-edition-of-the-ma-state-building-code-780

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

National Oceanic Atmospheric Administration (NOAA). 2019a National Oceanic Atmospheric Administration (NOAA).2019a. "Storm Events Database: Worcester County." National Centers for Environmental Information. https://www.ncdc.noaa.gov/stormevents/.

National Oceanic and Atmospheric Administration (NOAA). 2018. National Weather Service Forecast Office: Boston, MA. "Seasonal Climate Report." https://w2.weather.gov/climate/index.php?wfo=box

National Oceanic and Atmospheric Administration. 2015. Atlas 14: Precipitation-Frequency Atlas of the United Sates. Volume 10 Version 2.0: Northeastern States.

National Oceanic and Atmospheric Administration (NOAA) and National Weather Service. 2019. "Heavy Snow." Glossary. https://w1.weather.gov/glossary/index.php?word=heavy+snow.

National Oceanic and Atmospheric Administration (NOAA).n.d. Heat Index. https://www.weather.gov/bgm/heat

National Oceanic and Atmospheric Administration (NOAA).n.d. " Wind Chill Safety." https://www.weather.gov/bou/windchill

Northern Middlesex Council of Governments (NMCOG); "Hazard Mitigation Plan for the Northern Middlesex Region 2015 Update"

Northeast Region Ethnography Program. National Park Service. "Ethnicity in Lowell". 2011. https://www.aacu.org/sites/default/files/files/CLDE/Ethnicity%20in%20Lowell.pdf

Oliver: MassGIS Online Mapping Tool for Environmental justice community. http://maps.massgis.state.ma.us/map_ol/ej.php

Slope Stability Map of Massachusetts focusing on Lowell. The Massachusetts Geological Survey. 2013. https://mgs.geo.umass.edu/biblio/slope-stability-map-massachusetts

US Census Bureau QuickFacts U.S Department of Commerce "QuickFacts: City of Lowell; Middlesex County, Massachusetts," https://www.census.gov/quickfacts/fact/table/lowellcitymassachusetts,US/PST045219

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

DRAFT

United States Geological Survey (USGS). 2019. "Landslides 101." https://www.usgs.gov/natural-hazards/landslide-hazards/science/landslides-101?qt-science_center_objects=0#qt-science_center_objects.

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

United States Weather Bureau. 1961. Technical Paper No. 40 (TP-40): Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. https://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf.

DRAFT

Appendix A

Core Team Materials

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Core Team Meeting
March 19, 2020 | 2:00-3:00PM
Skype Meeting

Introductions	5 minutes
Project Overview	5 minutes
Core Team Role	5 minutes
Climate Change in Lowell	10 minutes
Community Resilience Building Workshop Materials	15 minutes
Data Sources	5 minutes
Workshop Participants	10 minutes
Wrap Up and Next Steps	5 minutes

Weston & Sampson

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project
March 19, 2020 | 2:00-3:00PM

Name	Present- Mark with X
Katherine Moses	X
Kara Keefe Mullin	
Alex Magee	X
Diane Tradd	
Craig Thomas	X
Christine Clancy	X
Mark Young	
John Gleason	
Daniel Larocque	
Maryann Ballotta	X
Jeff Winward	
George Rose	
Paul LaChance	
Michelle Rowden	X

CITY OF LOWELL

Core Team Meeting

March 19, 2020

Weston & Sampson

1

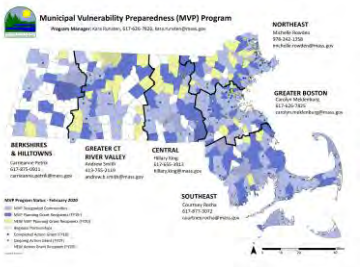
WELCOME CORE TEAM

Alex Magee	George Rose	Mark Young
Christine Clancy	Jeff Winward	Maryann Ballotta
Craig Thomas	John Gleason	Paul LaChance
Daniel Larocque	Kara Keefe Mullin	
Diane Tradd	Katherine Moses	

Weston & Sampson

2

MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM (MVP)



Weston & Sampson

3

MVP PROVIDES OPPORTUNITIES

- Improved resilience and preparedness of natural and climate-driven hazards
- Collaboration with stakeholders about climate change, natural hazards and impacts
- Increased education, planning, and implementation of priority actions
- Funding for resilience actions as well as efforts that are not exclusively resilience-based (i.e. improved parks, infrastructure)

Weston & Sampson

4

MVP COMPONENTS

PHASE 1 - PLANNING

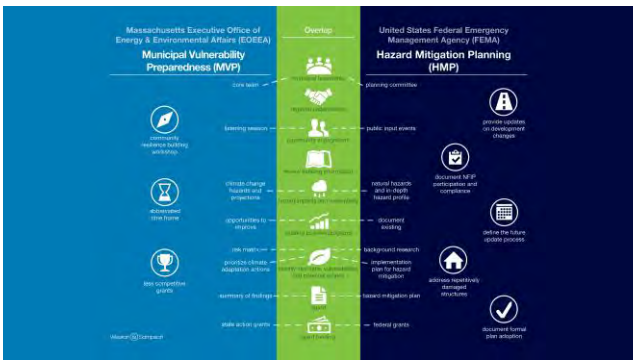
- Receive Planning Grant
- Prioritize Action Items
- Complete MVP Program
- Submit Final Report for Approval
- Become Certified

PHASE 2 - ACTION

- Select an Action Item from Planning Phase
- Apply for Action Grant Funding
- Up to $2 million for planning, design, permitting, construction
- 25% grant match in cash or in-kind
- $10-15 million available

Weston & Sampson

5



6

SCOPE OF WORK

1. Review Plans
2. Convene the Core Team → Thanks for coming!
3. Critical Facilities List → Seeking input
4. Hazards Map
5. Community Resilience Building Workshop → March/April, discuss options for virtual formats
6. Finalize Priorities
7. Public Listening Session → March, discuss options for virtual formats
8. Report → Due June 2020

Weston & Sampson

7

SCHEDULE

Finish at least one listening session prior to April to be eligible for Action Grant

Core Team Kickoff	Listening Session	CRB Workshop	Action Grant	HMP-MVP Plan
Early Mar 2020	March 2020	March/ April '20	Apr 2020	Jun 2020

Weston & Sampson

8

ELIGIBLE MVP ACTION GRANT PROJECTS

- Detailed Vulnerability and Risk Assessment
- Public Education and Communication
- Local Bylaws, Ordinances, Plans, and Other Management Measures
- Redesigns and Retrofits
- Energy Resilience Strategies
- Chemical Safety
- Nature-Based Storm-Damage Protection, Drought Prevention, Water Quality, and Water Infiltration Techniques
- Nature-Based, Infrastructure and Technology Solutions to Reduce Vulnerability to Extreme Heat and Poor Air Quality
- Nature-Based Solutions to Reduce Vulnerability to other Climate Change Impacts
- Acquisition of Land to Achieve a Resiliency Objective
- Ecological Restoration and Habitat Management to Increase Resiliency

Weston & Sampson

9

CORE TEAM

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

TODAY'S OBJECTIVES
- Review Process
- Set Goals
- Prepare for Stakeholder Workshop

11

11

CLIMATE DATA

- Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018)
- Massachusetts Climate Change Projections (NECSC, 2018 on resilientma.org)
- Massachusetts Climate Change Adaptation Report (MA EEA, 2011)

APPLICABLE PLANS

- Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update
- Sustainable Lowell 2025
- Open Space and Recreation Plan 2019-2023
- 2016 Greater Lowell Community Health Needs Assessment
- Master Plan Public Opinion & Existing Conditions Data (March 2012)
- Public Opinion Report: Master Plan Update/Sustainability Plan (December 2011)
- City of Lowell Master Plan Update: Existing Conditions Report (December 2011)

Weston & Sampson

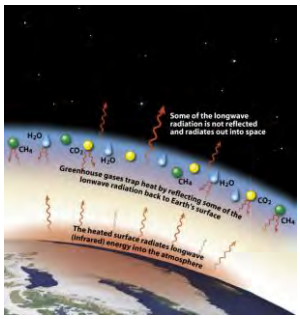
12

12

GREENHOUSE GASES (GHG)

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

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



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

Weston & Sampson

13

13

MASSACHUSETTS GHG GOALS

Global Warming Solutions Act (GWSA) of 2008

25% reduction in GHG emissions by 2020

80% reduction in GHG emissions by 2050

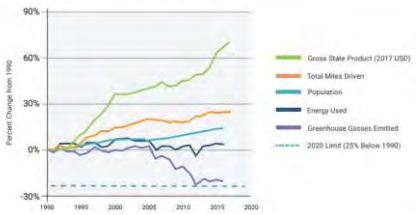
1990 is the baseline year

Weston & Sampson Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report," 10. 14

14

MASSACHUSETTS GHG GOALS

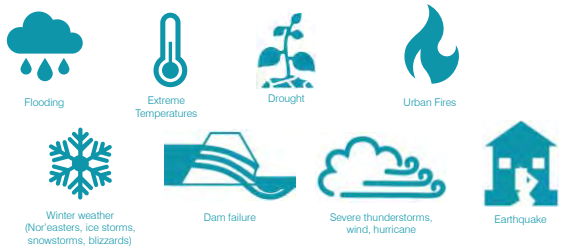
FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



Weston & Sampson Source: Commonwealth of Massachusetts. 2019. "Global Warming Solutions Act 10-year Progress Report," 10. 15

15

CLIMATE HAZARDS IN LOWELL



Weston & Sampson 16

16

EXTREME TEMPERATURES

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

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

Source: ResilientMA.org. "Rising Temperatures," 2017 17

17

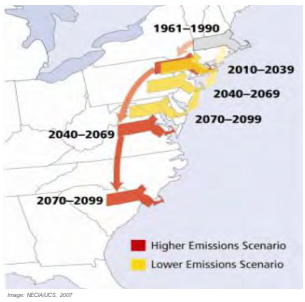


Image: NECAUCE, 2007 18

18

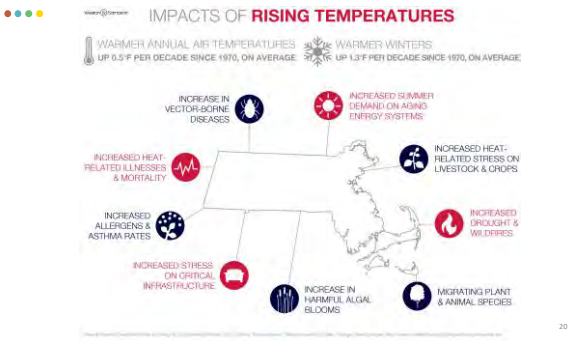
EXTREME TEMPERATURES

2005 OBSERVED ANNUAL AVERAGE	MID-CENTURY PROJECTED ANNUAL AVERAGE	END-OF-CENTURY PROJECTED ANNUAL AVERAGE
6	24	35
DAYS WITH TEMPERATURES ABOVE 90°F		
145	114	101
DAYS WITH TEMPERATURES BELOW 32°F		

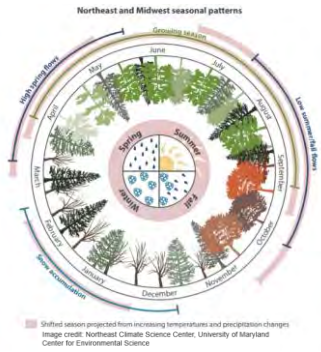
Image: City of Lowell Twitter

19

19



20



The most recent notable drought event was in 2016.[1]

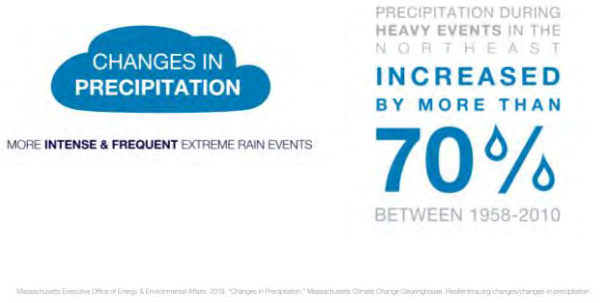
The occurrence of droughts lasting 1 to 3 months could go up by as much as 75% over existing conditions by the end of the century, under the high emissions scenario.[1]

What was the drought response in 2016?

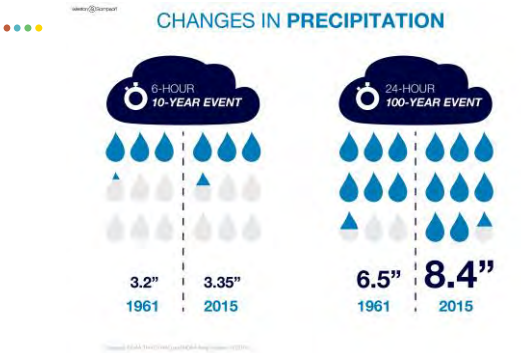
1. Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 17.

21

21



22



23

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by midcentury

13%

Increase in extreme precipitation events by 2100

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 19.

24

24

FLOOD MAPS

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

Updated in 2014 for Lowell

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

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 19.

25

25

STORMWATER FLOODING

Areas with:

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

City of Lowell Stormwater Management Webpage

26

26

LOCAL FLOODING NEAR WATERBODIES

- Northern banks of the Merrimack River near the Water Treatment Plant
- Land around Black Brook and the Trull Brook tributary between Phoenix Ave and Clark Road
- Areas in the 100-year floodplain along major waterways:
  - Concord River
  - Marginal Brook
  - River Meadow Brook
  - Beaver Brook
  - Clay Pit Brook
- Marsh along Wentworth Avenue
- The mouth of Black Brook
- The mouth of Marginal Brook

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

27

27

LOCAL FLOODING ALONG STREETS

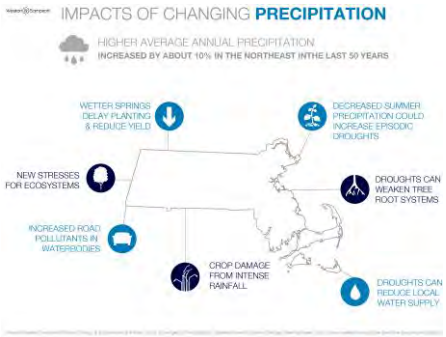
- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

A rainstorm in the summer of 2003 filled the Gorham and Moore Street intersection with up to 4' of water

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

28

28



29

29

HAZARD POTENTIAL OF DAMS

Name	Ownership	Hazard Class
Northern Canal-Great Wall	DCR - Dept. of Conservation & Recreation	Low Hazard
Guard Locks	**DCR - Dept. of Conservation & Recreation**	**High Hazard**
Lower Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard
Swamp Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard
Pawtucket Dam	Boott Hydropower, Inc. c/o Enel North America, Inc.	Low Hazard
Lowell Reservoir Dam	**City of Lowell, Lowell Regional Water Utility**	**High Hazard**
Middlesex Dam	City of Lowell, Lowell Regional Water Utility	N/A
Wamesit Power Company Dam	Centennial Island Hydroelectric Company, A Mass. Lim. Part.	Low Hazard

Weston & Sampson *Office of Dam Safety, 2019*

30

30

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

Increased coastal flooding

Permanently inundated low-lying coastal areas

Increased shoreline erosion

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

(Source: Northeast Climate Adaption Science Center)

31

31

WINTER STORMS

- The blizzard of 2013 left nearly 400,000 Massachusetts residents without power.[1]
- "Heavy blizzards are among the most costly and disruptive weather events for Massachusetts communities."[2]
- Snowpack likely to decrease annually, but snowfall will occur with heavy intensity
- In the winter of 1995, snowfall in Lowell reached 126.5"[3]
- Extended power outages, cost of snow removal, repairing damages, and loss of business can have a severe economic impact.
- The elderly and infirmed are populations of particular concern during these events.[2]

1. Resilient MA Climate Change Clearinghouse for the Commonwealth, "Extreme Weather," 2017
2. "Massachusetts State Hazard Mitigation and Adaptation Plan," 2018, P4-226
3. 2015 Regional HMP

Graphic: City of Lowell Twitter

32

City of Lowell Twitter

33

HURRICANES AND NOR'EASTERS

Upward trend in North Atlantic hurricane activity since 1970

2012: Hurricane Sandy
2017: Hurricane Jose
2018: Hurricane Florence
2019: Hurricane Dorian

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

Jan 3-4, 2018: Winter Storm Grayson
March 2, 2018: Winter Storm Riley
March 8, 2018: Winter Storm Quinn
March 13, 2018: Winter Storm Skylar

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)/Northeast Midwest

34

WIND-RELATED HAZARDS

- Anticipating a future increase in the intensity of severe wind events
- Electric utilities in the Downtown Historic District are underground, helping to prevent power outages in this area

What has been the impacts of these storms?

35

36

URBAN FIRE

CAUSES

- Human error and carelessness
- Density of development
- Leading causes of residential building fires in Lowell is cooking, followed by smoking
- Much of the housing stock are old, multi-family, wood buildings
- Many older structures lack sprinkler systems

DATA

- 522 fires were reported during 2013
- 7 residents perished in an apartment fire in 2014
- 80% of building fires in Lowell occur in residential properties (mostly apartments)

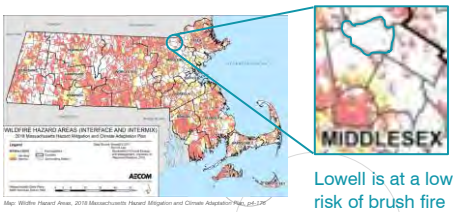
NEIGHBORHOODS MOST AT RISK OF FIRE

- The Acre
- South Lowell
- Centralville

2015 Regional HMP

37

AS AN FYI: **BRUSH FIRE**



Map: Wildfire Hazard Areas, 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, pg 129

Lowell is at a low risk of brush fire

38

38

EXISTING HAZARD MITIGATION IN LOWELL

- Participating in NFIP Insurance Program
- Floodplain zoning overlay district ordinance
- City Wetlands ordinance
- Program to reduce combined sewer overflows
- Street tree program
- Ongoing flood protection system improvement program
- Brush thin and fuel reduction program for State Forest
- Open Space plan
- Master Plan
- Green Community Designation
- Enforcement of State Building Code
- Plan to notify residents in event of disaster

Weston & Sampson 2015 Regional HMP

39

39

OTHER ONGOING PROJECTS OR PRIORITIES?

40

40

WORKSHOP OUTLINE

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

- BREAK -

INDIVIDUAL TABLES:
- Identify Community Features

- LUNCH -

INDIVIDUAL TABLES:
- Identify and Prioritize Actions

- BREAK -

LARGE GROUP DISCUSSION:
- Determine Overall Priority Actions

Photo: City Facebook

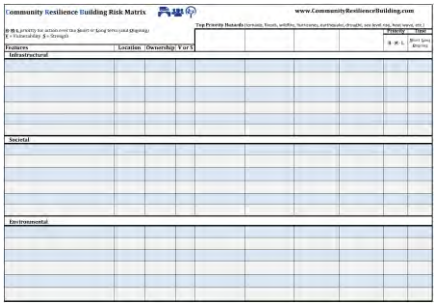
41

RISK MATRIX

Photo: City Facebook

42

RISK MATRIX



43

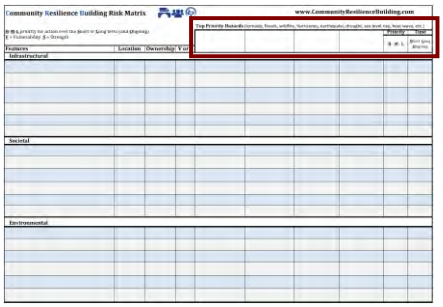
43

IDENTIFY HAZARDS

Photo: City Facebook

44

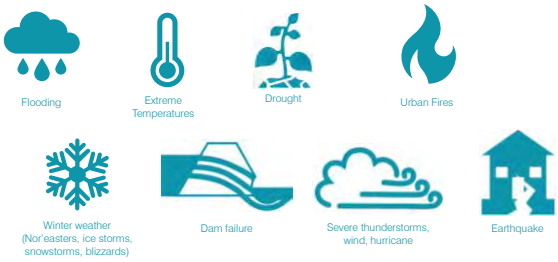
RISK MATRIX: HAZARDS



45

CLIMATE HAZARDS IN LOWELL

CHOOSE FOUR



Weston & Sampson

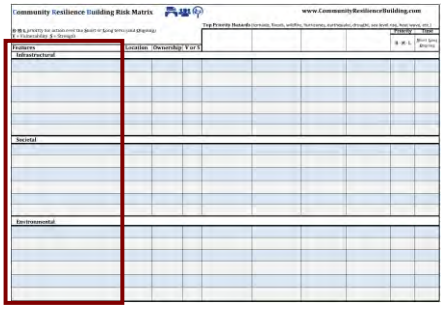
46

IDENTIFY FEATURES

Photo: City Facebook

47

RISK MATRIX: FEATURES



48

RISK MATRIX: FEATURES

FEATURES	LOCATION	OWNERSHIP	VULNERABILITY OR STRENGTH
Infrastructural	Town wide	State	Vulnerability
Societal	Multi- vs. Single-neighborhood	Town	Strength
Environmental	Specific location	Private	Both
		Shared	

49

INFRASTRUCTURAL FEATURES

Public Transportation

Photo: Weston & Sampson

Emergency Services

Photo: City of Lowell Facebook

Wastewater Treatment and Collection

Dams

MA Office of Travel and Tourism, 2014

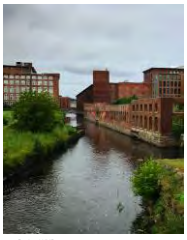
Roadways

Photo: Weston & Sampson

Water Supply

50

INFRASTRUCTURAL FEATURES



- There are 300+ stormwater outfalls in Lowell
- 50% of Lowell's sewer pipes are part of a combined sewer and stormwater system
- Approximately 50% of the combined system is over 100 years old
- The Lowell Regional Wastewater Utility (LRWU) receives wastewater from Lowell, Chelmsford, Dracut, and Tewksbury
- There are 9 combined sewer overflow structures that regulate flow to the LRWU, and discharge excess stormwater to the Merrimack River and its tributaries
- 100% of Lowell is served by municipal drinking water supply, drawn from the Merrimack River and treated by the City's water treatment plant
- The water system pumps an average of 15 million gallons per day

2015 Regional HMP
Photo: Weston & Sampson

51

SOCIETAL FEATURES

Population	Lowell	Massachusetts
2018	111,670 residents	6,902,149
2010	106,528 residents	6,547,790
Age		
Under 18 years	21.8%	19.8%
65+ years	10.6%	16.5%
Economics		
Median household income, 2014-2018	$51,987	$77,378
Persons in poverty	20.7%	10.0%
Additional Information		
Bachelor's degree or higher:	23.0%	42.9%
With a disability	9.0%	7.9%
Language other than English spoken at home	43.5%	23.6%

Source: U.S. Census Bureau, "Quick Facts: Lowell City, Massachusetts"

52

SOCIETAL FEATURES

- There are 428 public safety personnel in Lowell.
- Lowell is home to the second largest Cambodian refugee population in the U.S.
- The Lowell Office of Cultural Affairs and Special Events plans yearly community events, including:
  - 4th of July Celebration
  - Monster Bash
  - City of Lights Parade & Celebration
  - Winterfest
  - St. Patrick's Day Dinner

1. 2015 Regional HMP
2. Cambodian Mutual Assistance Association of Greater Lowell, Inc.

Photo: Weston & Sampson

53

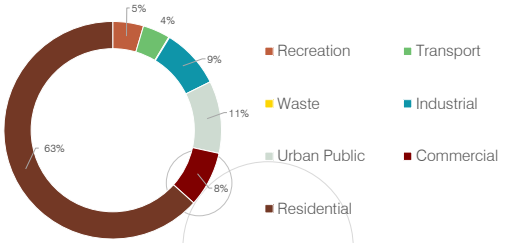
ENVIRONMENTAL FEATURES

City of Lowell Open Space and Recreation Plan 2019-2023
Photo: Weston & Sampson

- 14.27 square miles
  - 13.38 square miles of land area
  - 0.89 square miles of surface water
- Major watersheds and waterways include the Merrimack and Concord Rivers
- Lowell-Tyngsborough State Forest includes 457 acres of land in Lowell
- River Meadow Brook crosses Westford, Chelmsford, and Lowell
- Beaver Brook crosses New Hampshire, Dracut, and Lowell

54

LAND USE



Weston & Sampson *Sustainable Lowell 2025*

55

ADAPTATION STRATEGIES

Photo: City Facebook

56

THANK YOU

Weston & Sampson

57

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Core Team Meeting
March 19, 2020 | 2:00-3:00PM
Skype Meeting

Meeting Notes

- Overview of MVP and HMP program
- Overview of Core Team role
- Overview of historic climate change and future projections in Massachusetts and in Lowell
- The Clay Pit Brook area has experienced significant flooding, including in 2006 and 2007
- Winter storms can be difficult to keep up with. A hot topic item is where to put the snow.
- Floodplain areas are a concern.
- During a snow emergency, the City doesn't allow parking
- Code Red notification system: residents have to opt in. More information about signing up is available on the website.
    - Emergency notifications are an environmental justice issue, we will need to tailor outreach methodologies to better reach vulnerable residents
- Discussion of virtual formats:
    - Survey may be too much for a larger group
    - For a webinar, it would be helpful to pre-populate hazards, features, and ideas using input from a survey or from the Core Team
    - Michelle recommends doing a mini test run of a webinar by testing the process of getting input from the Core Team
- Introduction of stakeholder list
- Discussion of top hazards:
    - Flooding
    - Winter weather
    - Extreme temperatures
    - Wind, microbursts
    - Dam failure
- The senior center has been used as a cooling station.
- Introduction of critical facilities list
- Introduction of draft hazard mitigation and climate adaptation goals
- The project scope includes enhanced outreach to environmental justice communities. What are the virtual engagement options?
    - Post-production or real-time captioning and translation for Skype meetings and webinars
    - Local Access TV
        - Katherine will follow up with contact information
    - Advertising in the community newspaper and other channels
    - Working with local leaders and organizations to spread the word

Weston & Sampson

Appendix B

Additional Hazard Data

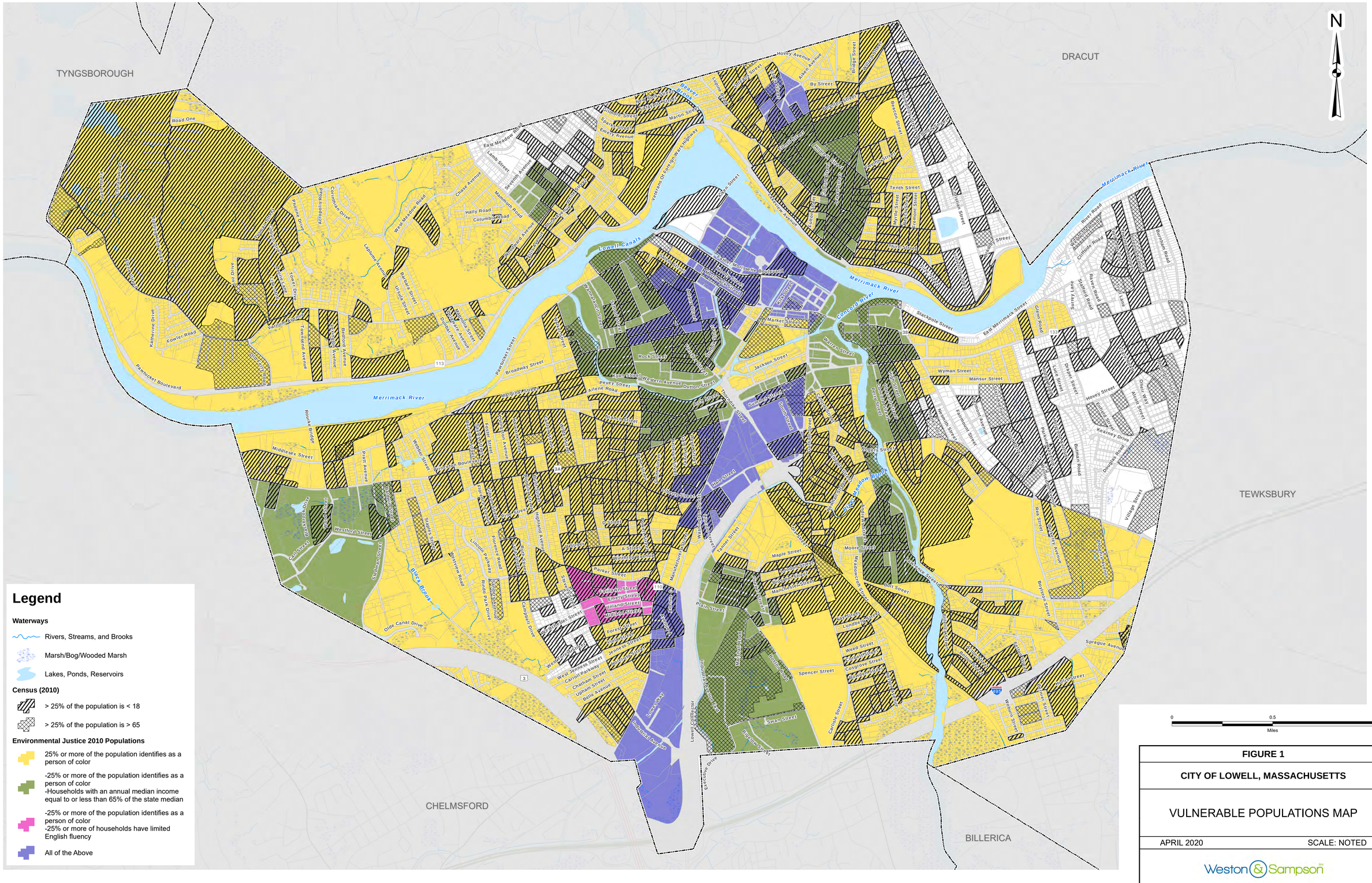


FIGURE 1

CITY OF LOWELL, MASSACHUSETTS

VULNERABLE POPULATIONS MAP

APRIL 2020 SCALE: NOTED

Weston & Sampson

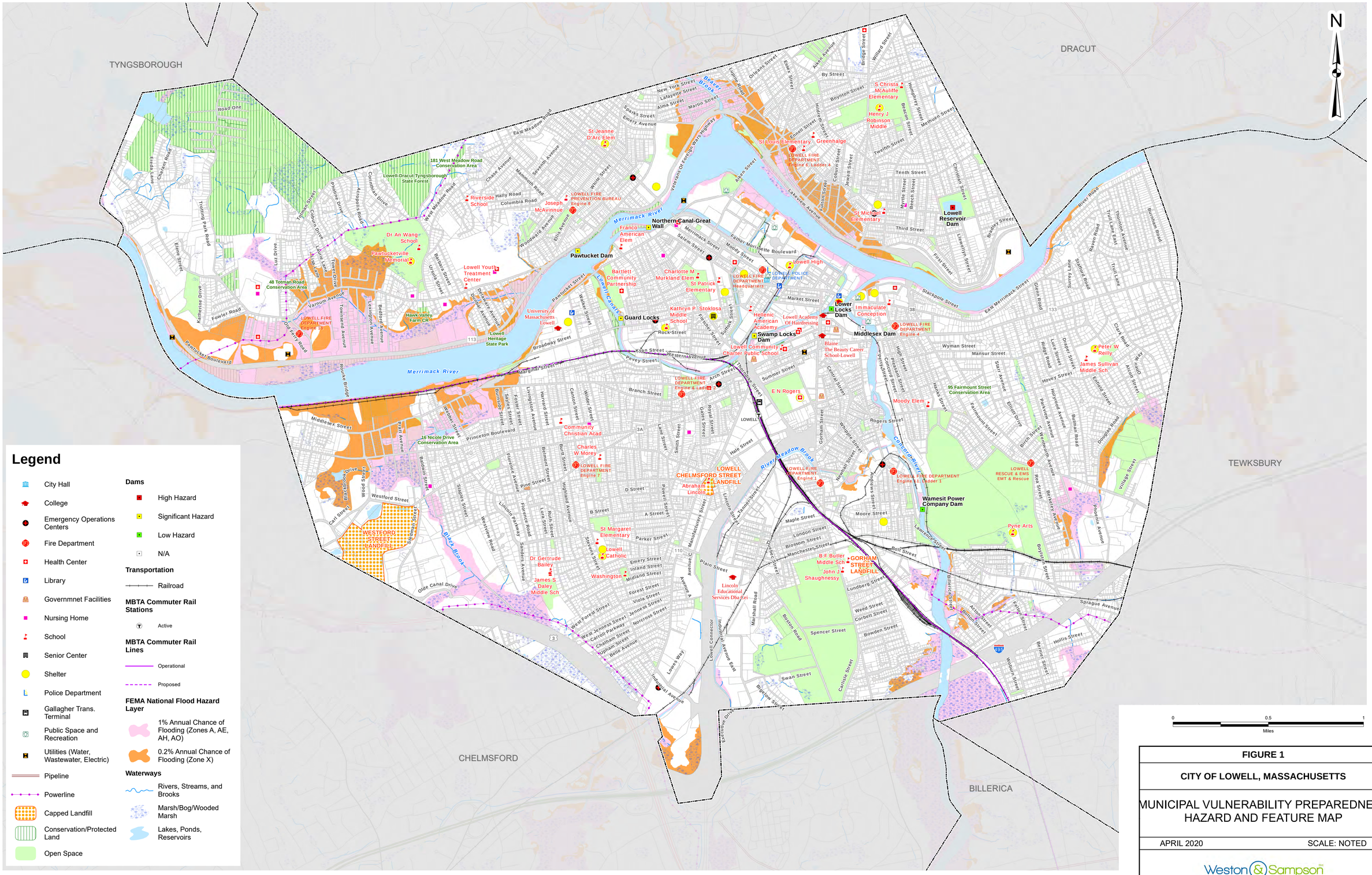


FIGURE 1

CITY OF LOWELL, MASSACHUSETTS

MUNICIPAL VULNERABILITY PREPAREDNESS HAZARD AND FEATURE MAP

APRIL 2020 | SCALE: NOTED

Weston & Sampson

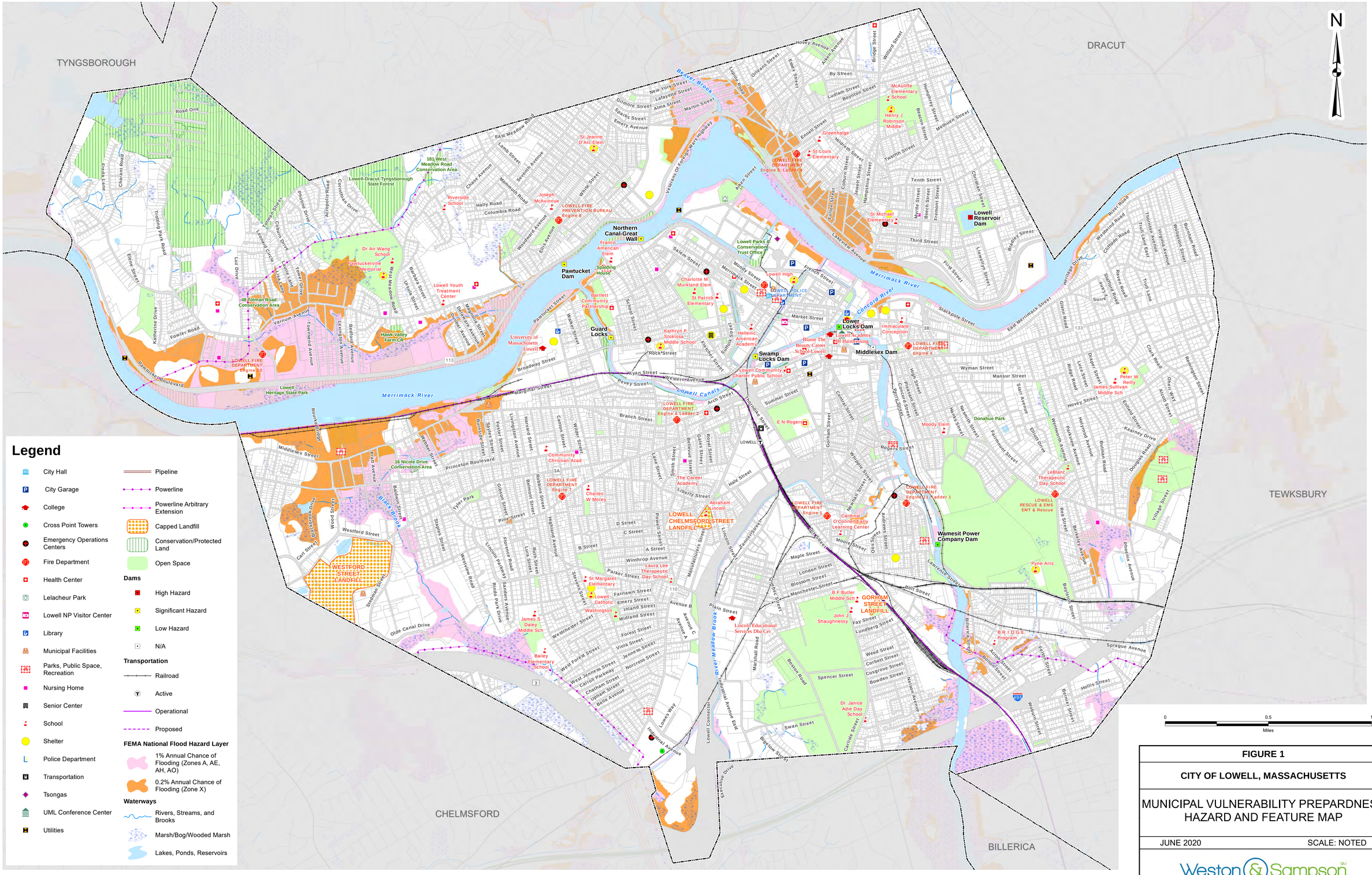


FIGURE 1

CITY OF LOWELL, MASSACHUSETTS

MUNICIPAL VULNERABILITY PREPARDNESS HAZARD AND FEATURE MAP

JUNE 2020 | SCALE: NOTED

Weston & Sampson

Hazus: Hurricane Global Risk Report

Region Name: Lowell_04152020

Hurricane Scenario: Probabilistic 100-year Return Period

Print Date: Friday, April 17, 2020

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

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

Table of Contents

Section	Page #
General Description of the Region	3
Building Inventory	4
General Building Stock	
Essential Facility Inventory	
Hurricane Scenario Parameters	5
Building Damage	6
General Building Stock	
Essential Facilities Damage	
Induced Hurricane Damage	8
Debris Generation	
Social Impact	8
Shelter Requirements	
Economic Loss	9
Building Losses	
Appendix A: County Listing for the Region	10
Appendix B: Regional Population and Building Value Data	11

General Description of the Region

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

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

- Massachusetts

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

The geographical size of the region is 14.53 square miles and contains 25 census tracts. There are over 38 thousand households in the region and a total population of 106,519 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 12,011 million dollars (2014 dollars). Approximately 89% of the buildings (and 76% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 24,205 buildings in the region which have an aggregate total replacement value of 12,011 million (2014 dollars). Table 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

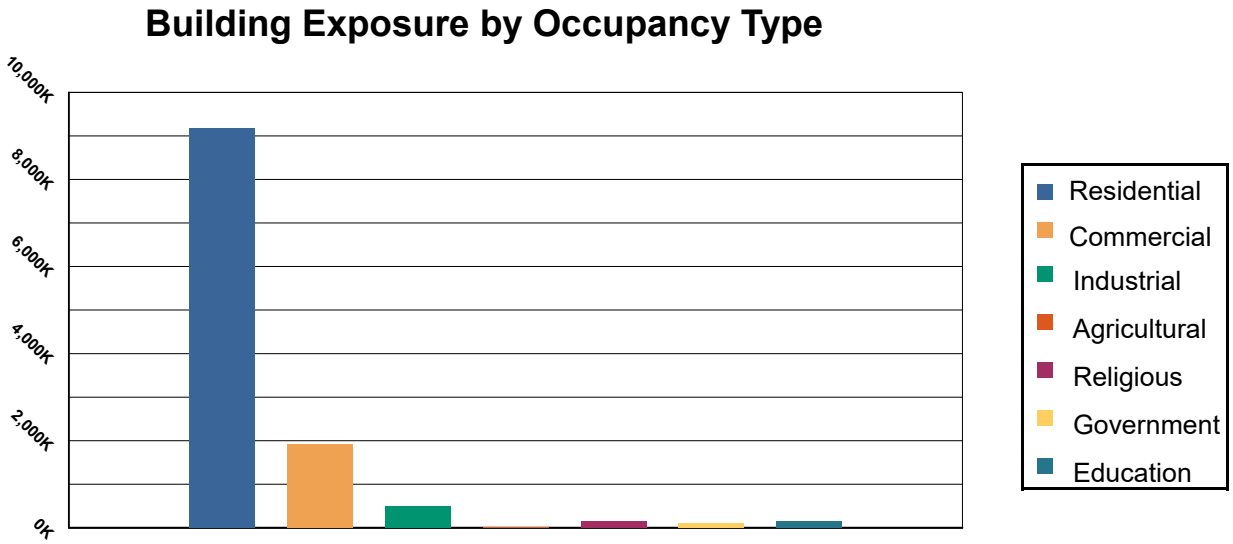


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	9,183,622	76.46 %
Commercial	1,912,298	15.92%
Industrial	502,268	4.18%
Agricultural	17,935	0.15%
Religious	150,374	1.25%
Government	104,960	0.87%
Education	139,669	1.16%
Total	**12,011,126**	**100.00%**

Essential Facility Inventory

For essential facilities, there are 2 hospitals in the region with a total bed capacity of 381 beds. There are 39 schools, 1 fire stations, 3 police stations and 1 emergency operation facilities.

Hurricane Scenario

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

Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 50 buildings will be at least moderately damaged. This is over 0% of the total number of buildings in the region. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

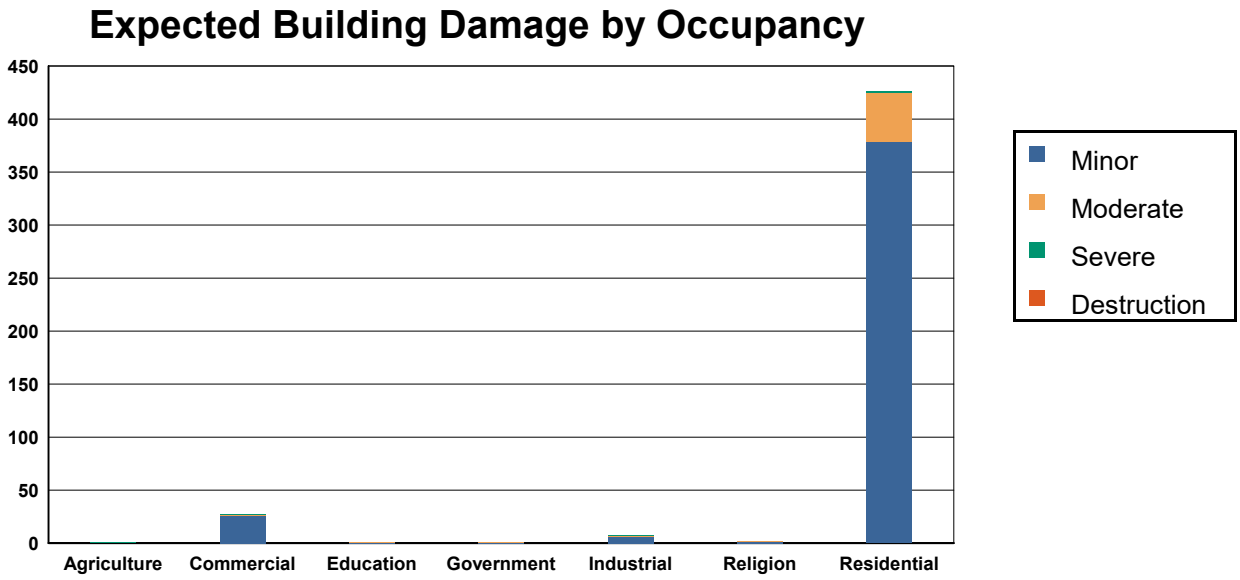


Table 2: Expected Building Damage by Occupancy : 100 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	53.06	98.27	0.83	1.53	0.08	0.15	0.02	0.04	0.00	0.00
Commercial	1,751.83	98.47	25.57	1.44	1.57	0.09	0.04	0.00	0.00	0.00
Education	77.83	98.52	1.15	1.45	0.02	0.03	0.00	0.00	0.00	0.00
Government	67.94	98.47	1.04	1.51	0.02	0.03	0.00	0.00	0.00	0.00
Industrial	434.06	98.43	6.64	1.51	0.25	0.06	0.05	0.01	0.00	0.00
Religion	146.97	98.63	1.98	1.33	0.06	0.04	0.00	0.00	0.00	0.00
Residential	21,207.50	98.03	378.68	1.75	46.05	0.21	1.78	0.01	0.00	0.00
Total	**23,739.19**		**415.87**		**48.05**		**1.89**		**0.00**	

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

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	237	98.00	5	1.96	0	0.04	0	0.00	0	0.00
Masonry	2,407	96.17	75	3.00	20	0.81	1	0.02	0	0.00
MH	27	99.91	0	0.07	0	0.02	0	0.00	0	0.01
Steel	1,116	98.38	18	1.55	1	0.07	0	0.00	0	0.00
Wood	18,681	98.54	263	1.39	12	0.06	1	0.01	0	0.00

Essential Facility Damage

Before the hurricane, the region had 381 hospital beds available for use. On the day of the hurricane, the model estimates that 381 hospital beds (only 100.00%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, 100.00% of the beds will be in service. By 30 days, 100.00% will be operational.

Thematic Map of Essential Facilities with greater than 50% moderate

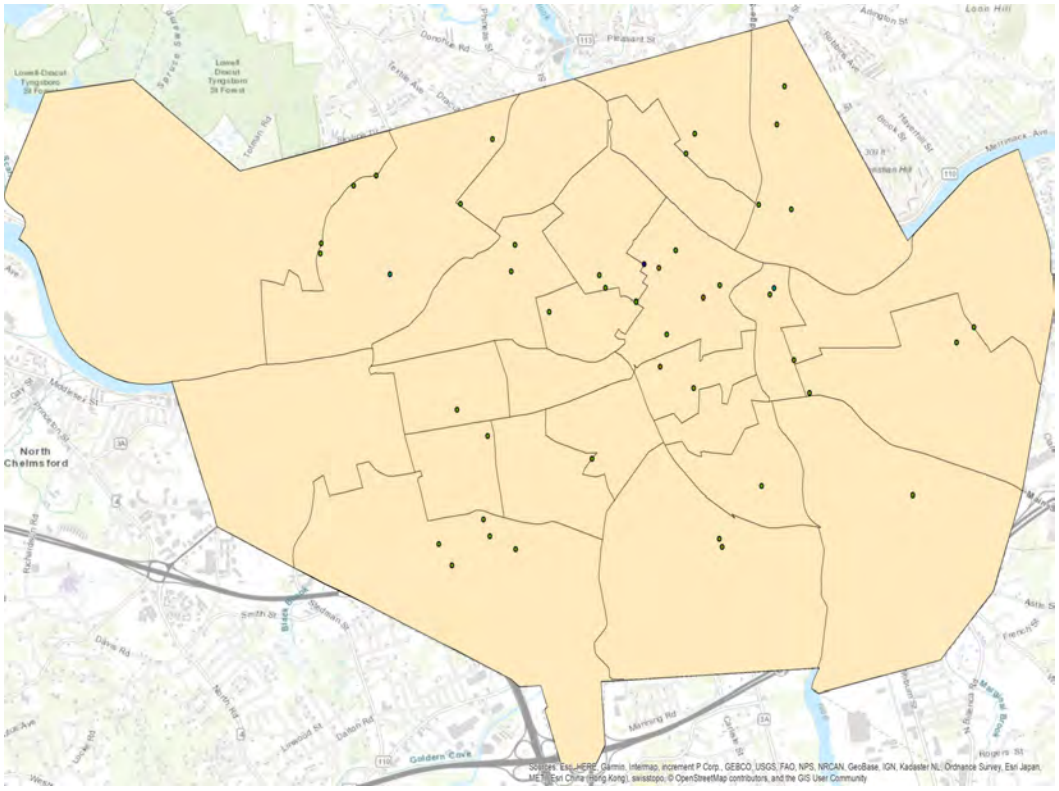
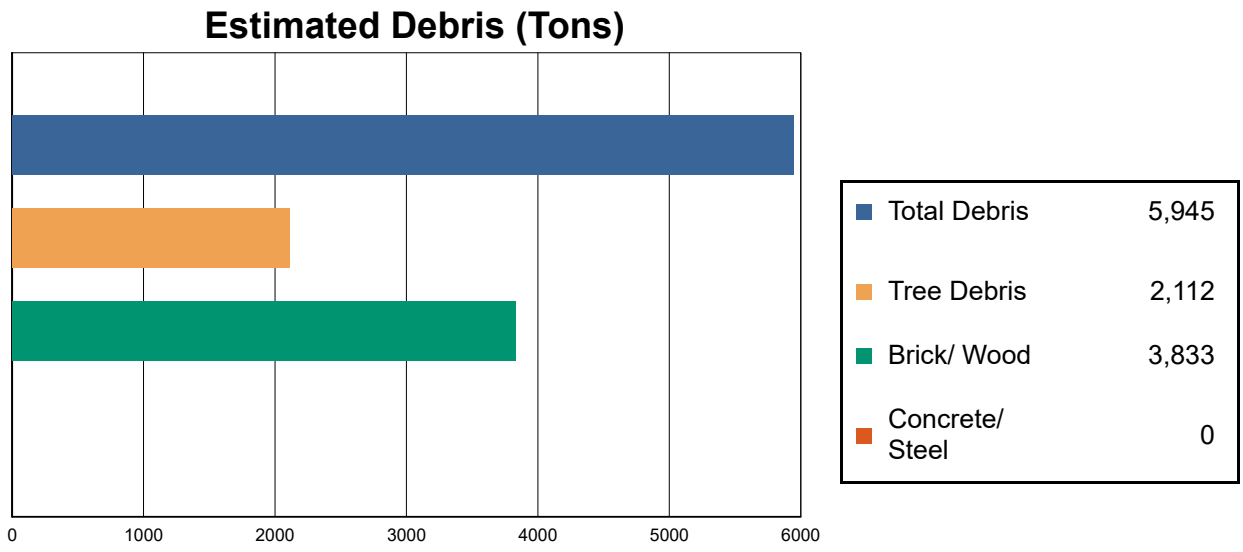


Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**Probability of at Least Moderate Damage > 50%**	**Probability of Complete Damage > 50%**	**Expected Loss of Use < 1 day**
EOCs	1	0	0	1
Fire Stations	1	0	0	1
Hospitals	2	0	0	2
Police Stations	3	0	0	3
Schools	39	0	0	39

Induced Hurricane Damage

Debris Generation

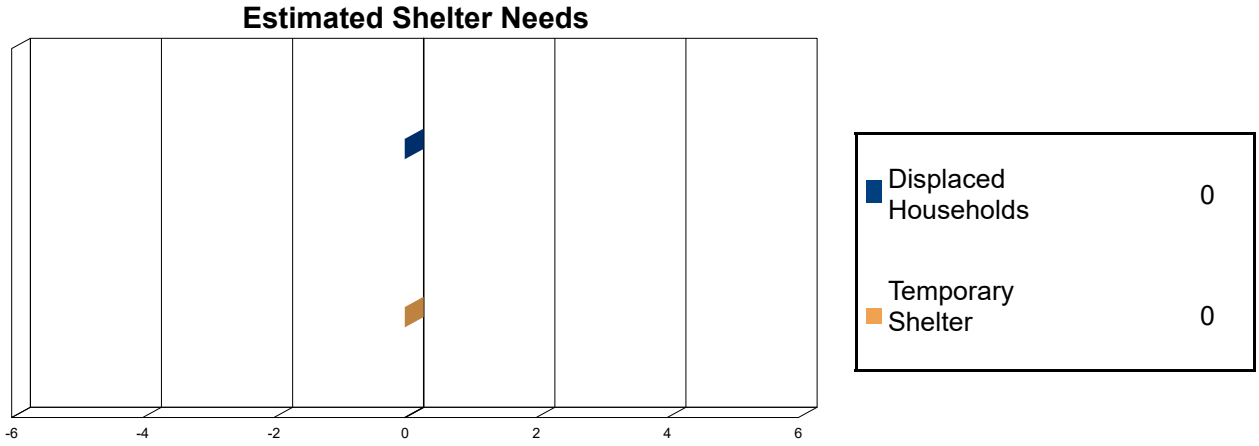


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling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

The model estimates that a total of 5,945 tons of debris will be generated. Of the total amount, 465 tons (8%) is Other Tree Debris. Of the remaining 5,480 tons, Brick/Wood comprises 70% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 153 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 1,647 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 0 households to be displaced due to the hurricane. Of these, 0 people (out of a total population of 106,519) will seek temporary shelter in public shelters.

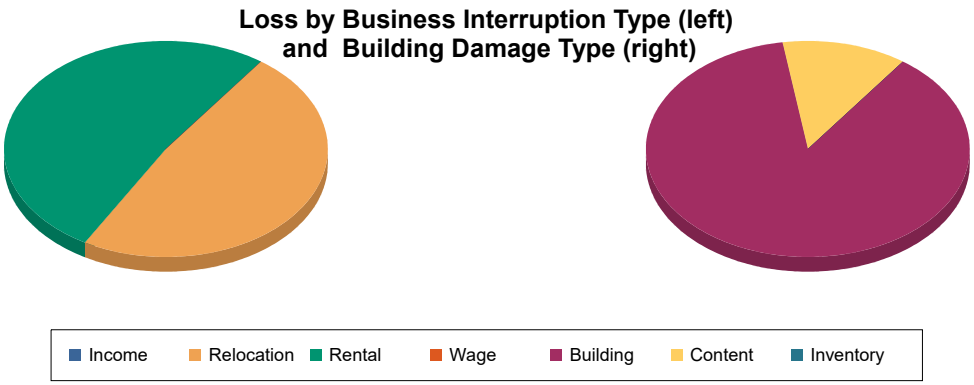
Economic Loss

The total economic loss estimated for the hurricane is 36.7 million dollars, which represents 0.31 % of the total replacement value of the region's buildings.

Building-Related Losses

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

The total property damage losses were 37 million dollars. 5% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 96% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.



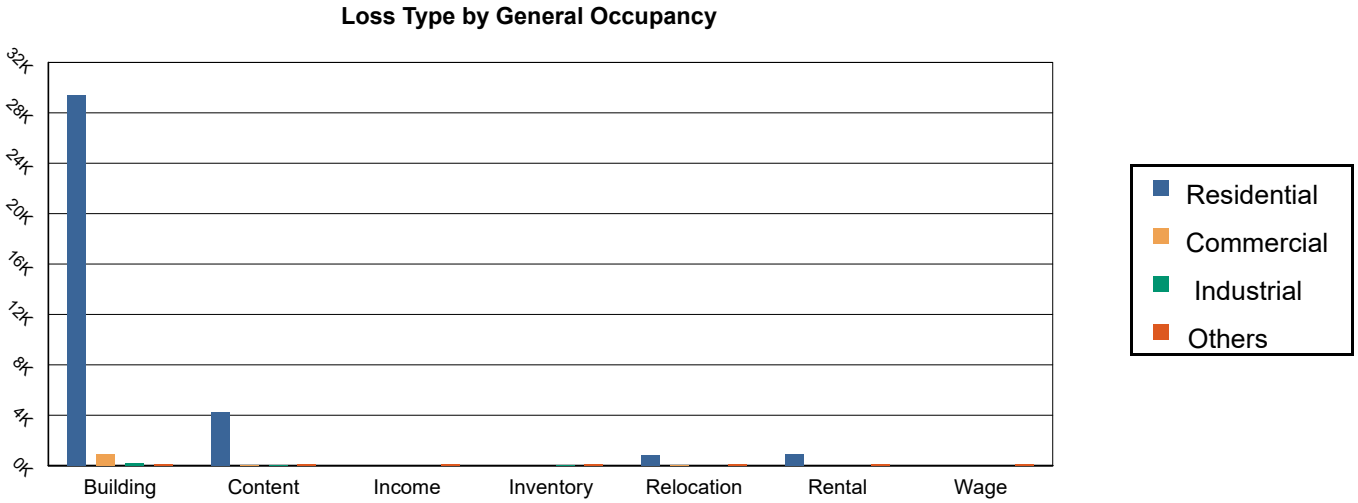


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	29,392.83	884.60	185.93	153.45	30,616.81
	Content	4,278.87	29.36	31.66	1.52	4,341.41
	Inventory	0.00	0.46	5.31	0.13	5.91
	Subtotal	**33,671.70**	**914.43**	**222.90**	**155.11**	**34,964.13**
Business Interruption Loss						
	Income	0.00	0.85	0.00	0.00	0.85
	Relocation	834.75	12.59	0.86	0.89	849.08
	Rental	903.99	0.38	0.00	0.00	904.36
	Wage	0.00	0.30	0.00	0.00	0.30
	Subtotal	**1,738.73**	**14.11**	**0.86**	**0.89**	**1,754.59**

Total

Total	**35,410.43**	**928.54**	**223.76**	**155.99**	**36,718.73**

Appendix A: County Listing for the Region

Massachusetts
- Middlesex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Middlesex	106,519	9,183,622	2,827,504	12,011,126
Total	**106,519**	**9,183,622**	**2,827,504**	**12,011,126**
Study Region Total	**106,519**	**9,183,622**	**2,827,504**	**12,011,126**

Hazus: Hurricane Global Risk Report

Region Name: Lowell_04152020

Hurricane Scenario: Probabilistic 500-year Return Period

Print Date: Friday, April 17, 2020

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

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

Table of Contents

Section	Page #
General Description of the Region	3
Building Inventory	4
General Building Stock	
Essential Facility Inventory	
Hurricane Scenario Parameters	5
Building Damage	6
General Building Stock	
Essential Facilities Damage	
Induced Hurricane Damage	8
Debris Generation	
Social Impact	8
Shelter Requirements	
Economic Loss	9
Building Losses	
Appendix A: County Listing for the Region	10
Appendix B: Regional Population and Building Value Data	11

General Description of the Region

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

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

- Massachusetts

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

The geographical size of the region is 14.53 square miles and contains 25 census tracts. There are over 38 thousand households in the region and a total population of 106,519 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 12,011 million dollars (2014 dollars). Approximately 89% of the buildings (and 76% of the building value) are associated with residential housing.

Building Inventory

General Building Stock

Hazus estimates that there are 24,205 buildings in the region which have an aggregate total replacement value of 12,011 million (2014 dollars). Table 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

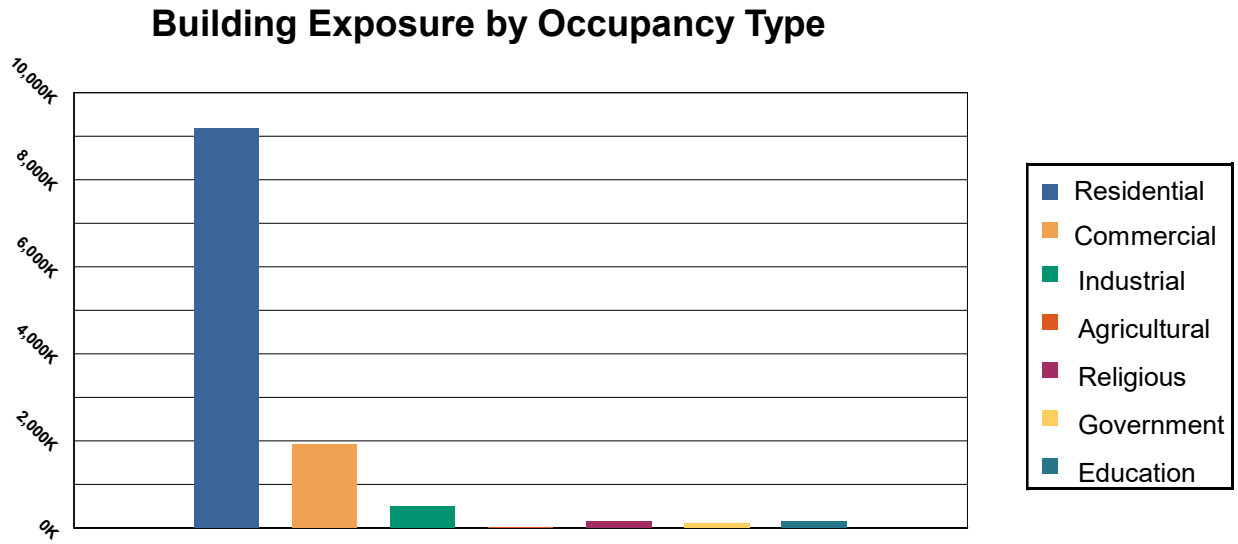


Table 1: Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Tot
Residential	9,183,622	76.46 %
Commercial	1,912,298	15.92%
Industrial	502,268	4.18%
Agricultural	17,935	0.15%
Religious	150,374	1.25%
Government	104,960	0.87%
Education	139,669	1.16%
Total	**12,011,126**	**100.00%**

Essential Facility Inventory

For essential facilities, there are 2 hospitals in the region with a total bed capacity of 381 beds. There are 39 schools, 1 fire stations, 3 police stations and 1 emergency operation facilities.

Hurricane Scenario

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

Scenario Name:	Probabilistic
Type:	Probabilistic

Building Damage

General Building Stock Damage

Hazus estimates that about 568 buildings will be at least moderately damaged. This is over 2% of the total number of buildings in the region. There are an estimated 5 buildings that will be completely destroyed. The definition of the 'damage states' is provided in the Hazus Hurricane technical manual. Table 2 below summarizes the expected damage by general occupancy for the buildings in the region. Table 3 summarizes the expected damage by general building type.

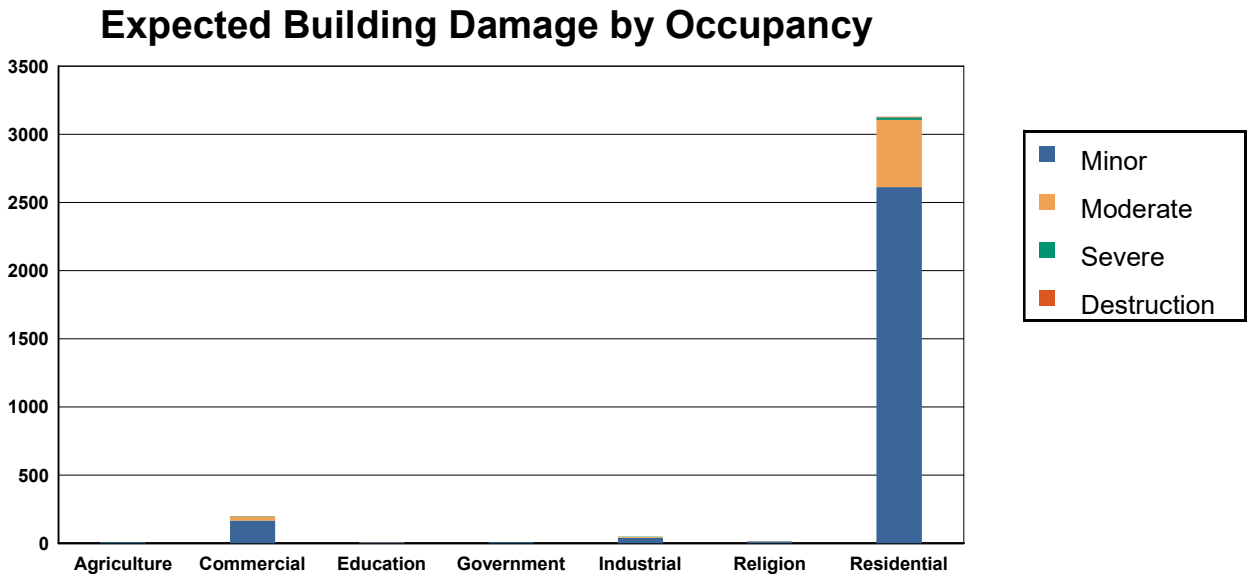


Table 2: Expected Building Damage by Occupancy : 500 - year Event

	None		Minor		Moderate		Severe		Destruction	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	46.38	85.89	5.67	10.50	1.31	2.43	0.59	1.09	0.05	0.10
Commercial	1,579.26	88.77	164.84	9.27	31.99	1.80	2.90	0.16	0.00	0.00
Education	70.88	89.72	6.98	8.83	1.10	1.39	0.04	0.05	0.00	0.00
Government	61.62	89.30	6.26	9.08	1.08	1.56	0.04	0.06	0.00	0.00
Industrial	392.59	89.02	38.79	8.80	8.02	1.82	1.51	0.34	0.10	0.02
Religion	132.81	89.14	14.26	9.57	1.84	1.23	0.08	0.05	0.00	0.00
Residential	18,504.62	85.53	2,612.35	12.08	492.84	2.28	19.50	0.09	4.69	0.02
Total	**20,788.16**		**2,849.15**		**538.18**		**24.67**		**4.84**	

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

Building Type	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	209	86.25	27	11.18	6	2.52	0	0.04	0	0.00
Masonry	2,042	81.59	290	11.57	165	6.58	6	0.25	0	0.01
MH	25	94.20	1	3.58	0	1.52	0	0.03	0	0.66
Steel	1,009	89.00	100	8.84	22	1.97	2	0.19	0	0.00
Wood	16,443	86.74	2,284	12.05	212	1.12	14	0.07	5	0.02

Essential Facility Damage

Before the hurricane, the region had 381 hospital beds available for use. On the day of the hurricane, the model estimates that 381 hospital beds (only 100.00%) are available for use by patients already in the hospital and those injured by the hurricane. After one week, 100.00% of the beds will be in service. By 30 days, 100.00% will be operational.

Thematic Map of Essential Facilities with greater than 50% moderate

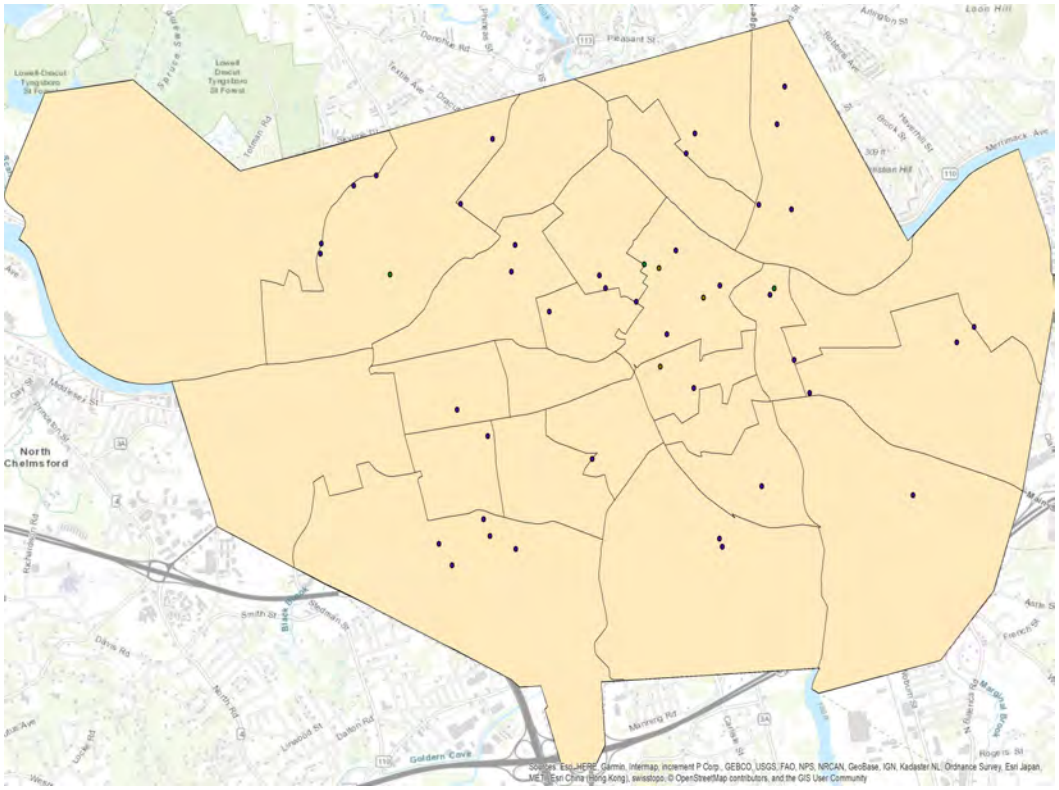
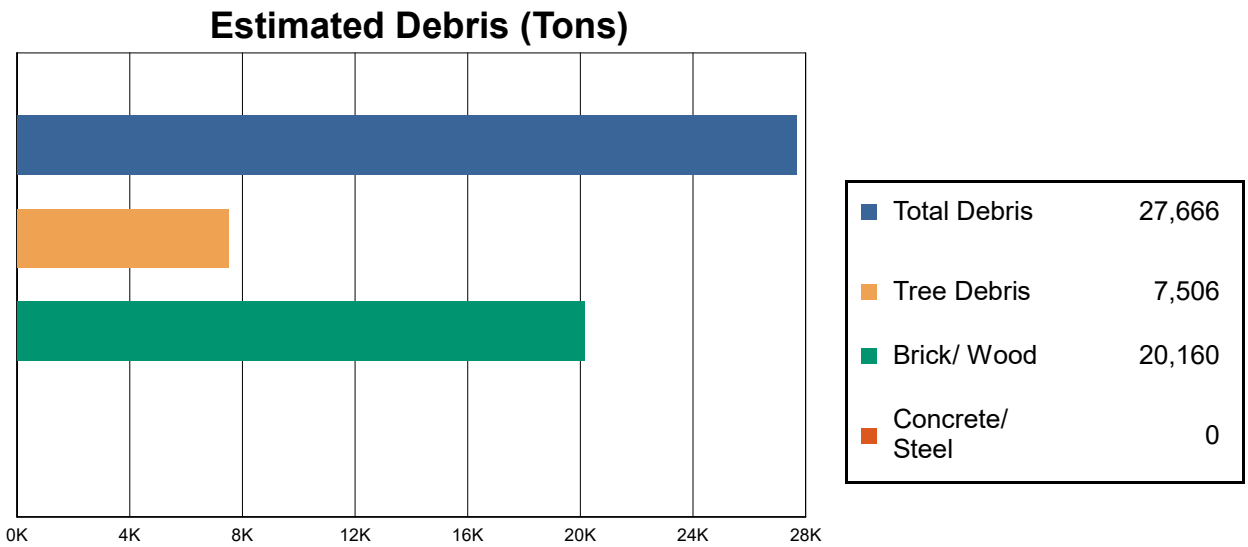


Table 4: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**Probability of at Least Moderate Damage > 50%**	**Probability of Complete Damage > 50%**	**Expected Loss of Use < 1 day**
EOCs	1	0	0	1
Fire Stations	1	0	0	1
Hospitals	2	0	0	2
Police Stations	3	0	0	3
Schools	39	0	0	38

Induced Hurricane Damage

Debris Generation

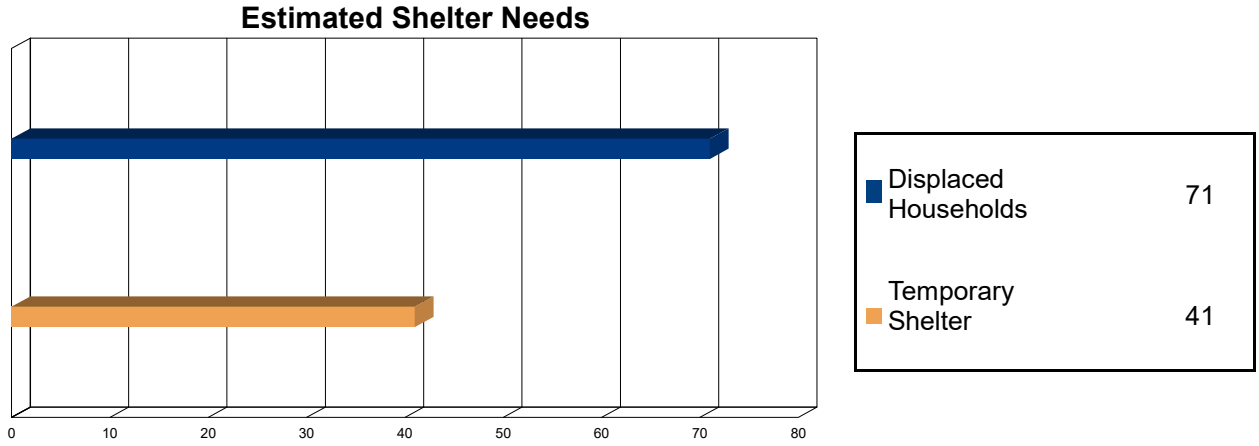


Hazus estimates the amount of debris that will be generated by the hurricane. The model breaks the debris into four general categories: a) Brick/Wood, b) Reinforced Concrete/Steel, c) Eligible Tree Debris, and d) Other Tree Debris. This distinction is made because of the different types of material handling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

The model estimates that a total of 27,666 tons of debris will be generated. Of the total amount, 1,817 tons (7%) is Other Tree Debris. Of the remaining 25,849 tons, Brick/Wood comprises 78% of the total, Reinforced Concrete/Steel comprises of 0% of the total, with the remainder being Eligible Tree Debris. If the building debris tonnage is converted to an estimated number of truckloads, it will require 806 truckloads (@25 tons/truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 5,689 tons of Eligible Tree Debris are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

Social Impact

Shelter Requirement



Hazus estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 71 households to be displaced due to the hurricane. Of these, 41 people (out of a total population of 106,519) will seek temporary shelter in public shelters.

Economic Loss

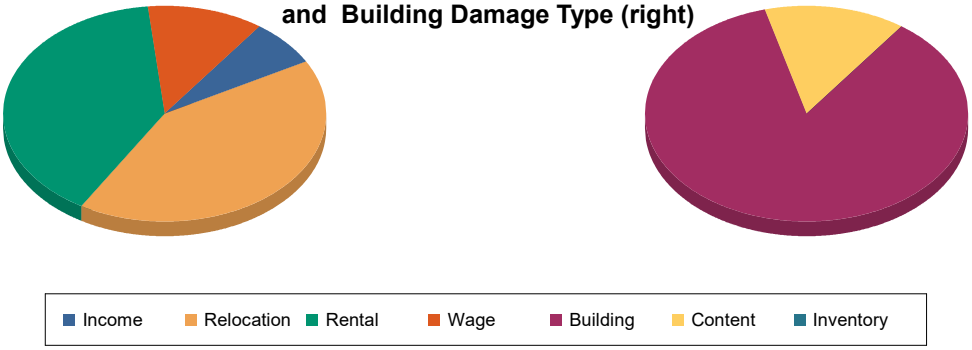
The total economic loss estimated for the hurricane is 187.7 million dollars, which represents 1.56 % of the total replacement value of the region's buildings.

Building-Related Losses

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

The total property damage losses were 188 million dollars. 9% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 90% of the total loss. Table 5 below provides a summary of the losses associated with the building damage.

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



Loss Type by General Occupancy

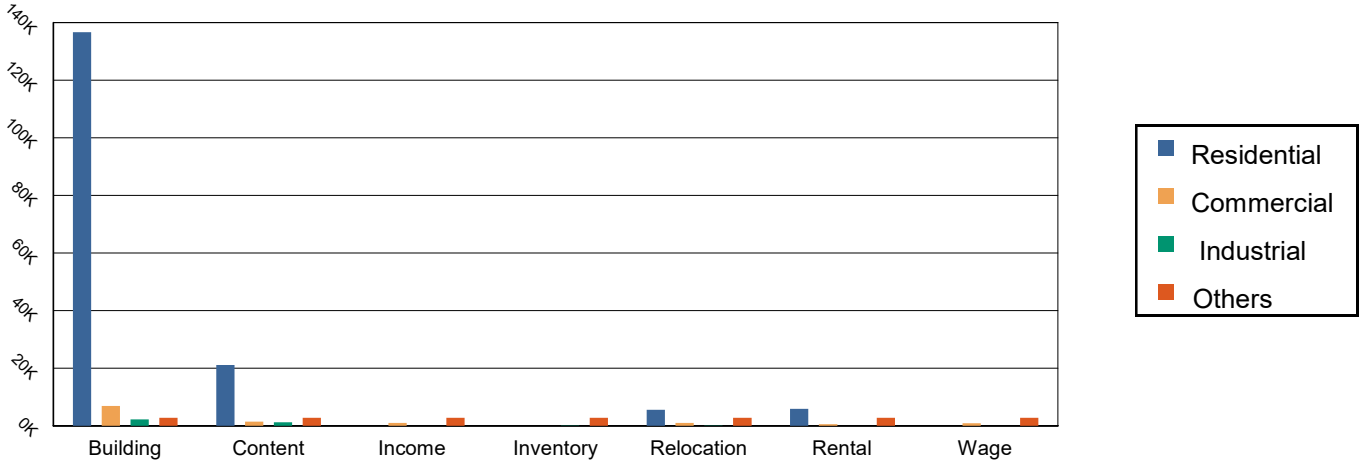


Table 5: Building-Related Economic Loss Estimates

(Thousands of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	136,594.78	6,899.84	2,237.23	1,272.38	147,004.24
	Content	21,081.73	1,433.68	1,285.95	253.96	24,055.31
	Inventory	0.00	20.19	180.19	4.65	205.03
	Subtotal	**157,676.51**	**8,353.71**	**3,703.37**	**1,530.99**	**171,264.59**
Business Interruption Loss						
	Income	0.00	978.57	23.93	133.45	1,135.95
	Relocation	5,608.73	969.87	104.16	182.43	6,865.19
	Rental	5,907.97	566.75	19.54	22.83	6,517.09
	Wage	0.00	953.92	39.44	918.76	1,912.11
	Subtotal	**11,516.70**	**3,469.09**	**187.07**	**1,257.46**	**16,430.33**

Total

Total	**169,193.21**	**11,822.81**	**3,890.44**	**2,788.45**	**187,694.91**

Appendix A: County Listing for the Region

Massachusetts
- Middlesex

Appendix B: Regional Population and Building Value Data

		Building Value (thousands of dollars)		
	Population	Residential	Non-Residential	Total
Massachusetts				
Middlesex	106,519	9,183,622	2,827,504	12,011,126
Total	**106,519**	**9,183,622**	**2,827,504**	**12,011,126**
Study Region Total	**106,519**	**9,183,622**	**2,827,504**	**12,011,126**

Hazus: Earthquake Global Risk Report

Region Name Lowell_04152020

Earthquake Scenario: Lowell Magnitude 5.0 Earthquake

Print Date: April 15, 2020

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

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

Table of Contents

Section	Page #
General Description of the Region	3
Building and Lifeline Inventory	4
Building Inventory	
Critical Facility Inventory	
Transportation and Utility Lifeline Inventory	
Earthquake Scenario Parameters	7
Direct Earthquake Damage	8
Buildings Damage	
Essential Facilities Damage	
Transportation and Utility Lifeline Damage	
Induced Earthquake Damage	14
Fire Following Earthquake	
Debris Generation	
Social Impact	15
Shelter Requirements	
Casualties	
Economic Loss	17
Building Related Losses	
Transportation and Utility Lifeline Losses	

Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

General Description of the Region

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

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

Massachusetts

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

The geographical size of the region is 14.52 square miles and contains 25 census tracts. There are over 38 thousand households in the region which has a total population of 106,519 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 12,011 (millions of dollars). Approximately 89.00 % of the buildings (and 76.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,104 and 1,002 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 12,011 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 79% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

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

For essential facilities, there are 2 hospitals in the region with a total bed capacity of 381 beds. There are 39 schools, 1 fire stations, 3 police stations and 1 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 17 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

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

The total value of the lifeline inventory is over 3,106.00 (millions of dollars). This inventory includes over 88.86 miles of highways, 74 bridges, 997.92 miles of pipes.

Table 1: Transportation System Lifeline Inventory

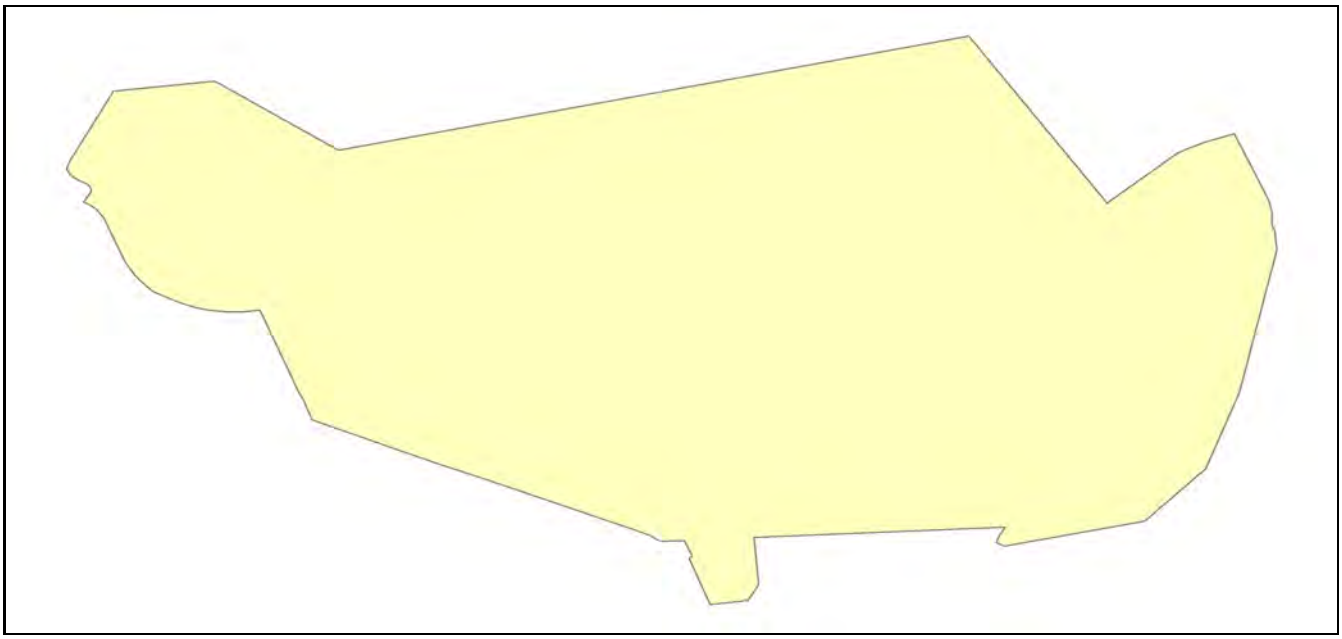
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	74	1070.6973
	Segments	111	981.3499
	Tunnels	0	0.0000
		Subtotal	**2052.0472**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	32	31.3847
	Tunnels	0	0.0000
		Subtotal	**31.3847**
Light Rail	Bridges	0	0.0000
	Facilities	1	2.6630
	Segments	2	13.7751
	Tunnels	0	0.0000
		Subtotal	**16.4381**
Bus	Facilities	4	5.0576
		Subtotal	**5.0576**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**2,104.90**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	16.0623
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**16.0623**
Waste Water	Distribution Lines	NA	9.6374
	Facilities	1	77.2560
	Pipelines	0	0.0000
		Subtotal	**86.8934**
Natural Gas	Distribution Lines	NA	6.4249
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**6.4249**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	7	893.2000
		Subtotal	**893.2000**
Communication	Facilities	3	0.3480
		Subtotal	**0.3480**
		Total	**1,002.90**

Earthquake Scenario

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



Scenario Name	Lowell Magnitude 5.0 Earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.31
Latitude of Epicenter	42.64
Earthquake Magnitude	5.00
Depth (km)	10.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 5,791 buildings will be at least moderately damaged. This is over 24.00 % of the buildings in the region. There are an estimated 366 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

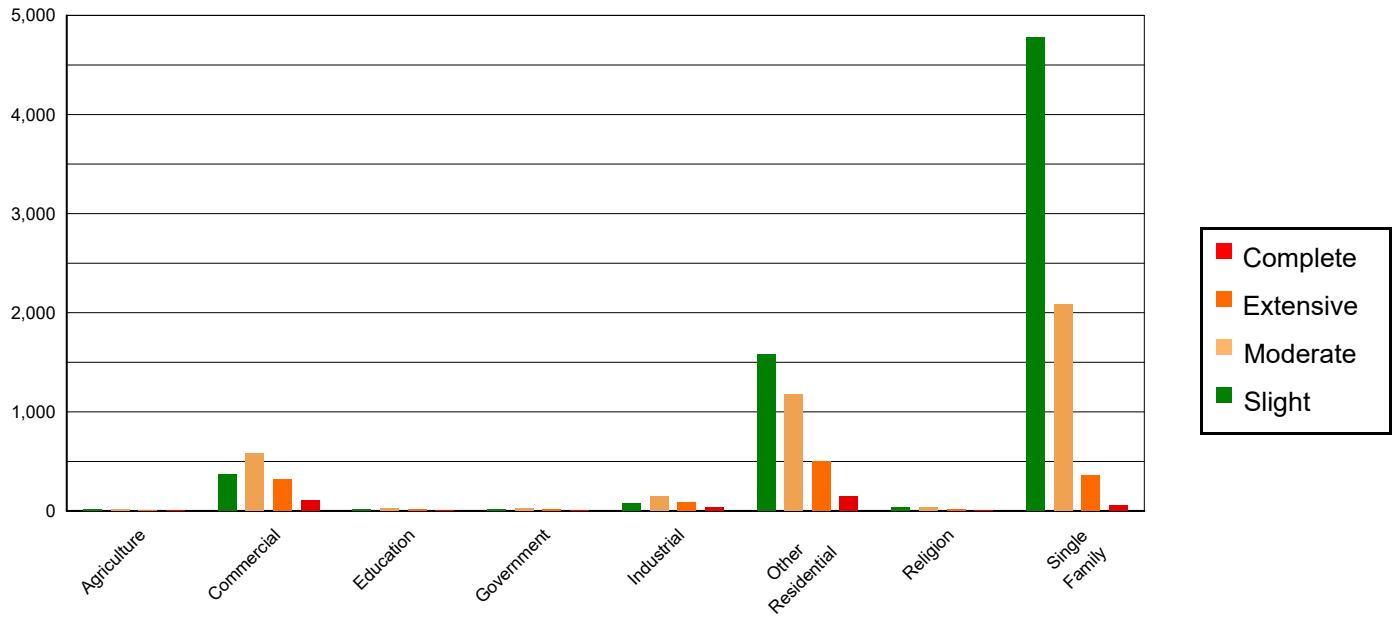


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	11.80	0.10	13.09	0.19	18.00	0.44	8.31	0.62	2.80	0.77
Commercial	393.46	3.42	370.50	5.38	580.32	14.17	323.90	24.35	110.83	30.28
Education	18.44	0.16	15.86	0.23	25.75	0.63	14.22	1.07	4.73	1.29
Government	14.50	0.13	12.76	0.19	23.01	0.56	13.97	1.05	4.76	1.30
Industrial	92.25	0.80	81.57	1.18	146.24	3.57	90.12	6.77	30.83	8.42
Other Residential	2570.35	22.31	1583.38	22.97	1178.83	28.79	504.37	37.92	148.06	40.45
Religion	52.67	0.46	35.23	0.51	35.64	0.87	19.17	1.44	6.30	1.72
Single Family	8367.45	72.63	4780.51	69.35	2087.24	50.97	356.08	26.77	57.72	15.77
Total	**11,521**		**6,893**		**4,095**		**1,330**		**366**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	10297.97	89.38	5911.49	85.76	2535.56	61.92	352.97	26.54	27.64	7.55
Steel	253.18	2.20	213.93	3.10	461.45	11.27	291.95	21.95	103.84	28.37
Concrete	70.65	0.61	64.51	0.94	151.12	3.69	100.59	7.56	30.13	8.23
Precast	15.13	0.13	11.06	0.16	28.33	0.69	28.29	2.13	8.70	2.38
RM	230.75	2.00	107.08	1.55	216.85	5.30	168.78	12.69	29.51	8.06
URM	647.36	5.62	576.84	8.37	685.48	16.74	376.44	28.30	163.42	44.65
MH	5.89	0.05	7.99	0.12	16.23	0.40	11.11	0.84	2.78	0.76
Total	**11,521**		**6,893**		**4,095**		**1,330**		**366**	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 381 hospital beds available for use. On the day of the earthquake, the model estimates that only 89 hospital beds (23.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 45.00% of the beds will be back in service. By 30 days, 74.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	2	2	0	0
Schools	39	39	0	0
EOCs	1	1	0	0
PoliceStations	3	2	0	1
FireStations	1	1	0	0

Transportation Lifeline Damage

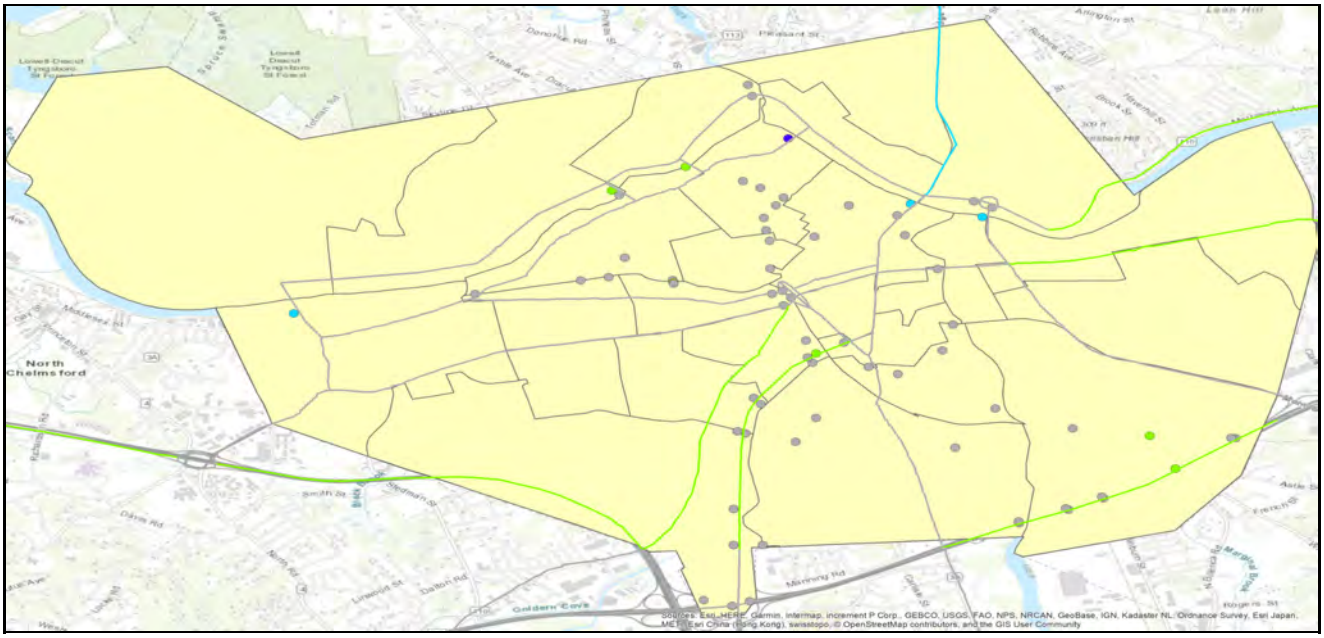


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	111	0	0	111	111
	Bridges	74	20	0	57	74
	Tunnels	0	0	0	0	0
Railways	Segments	32	0	0	27	27
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	2	0	0	2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Bus	Facilities	4	2	0	4	4
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

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

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

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	1	1	0	0	1
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	7	7	0	0	7
Communication	3	3	0	0	3

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

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	499	131	33
Waste Water	299	66	16
Natural Gas	200	22	6
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	38,470	113	0	0	0	0
Electric Power		32,335	21,465	8,972	1,610	38

Induced Earthquake Damage

Fire Following Earthquake

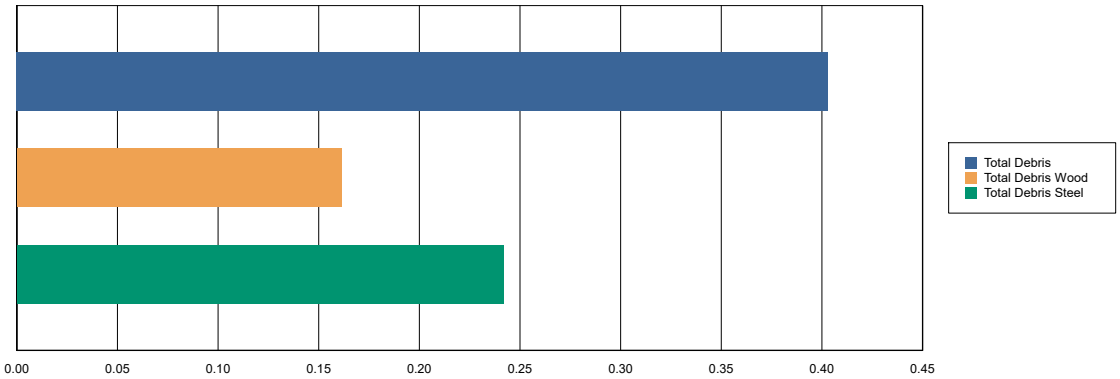
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 3 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 1 people and burn about 0 (millions of dollars) of building value.

Debris Generation

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

The model estimates that a total of 403,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 40.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 16,120 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



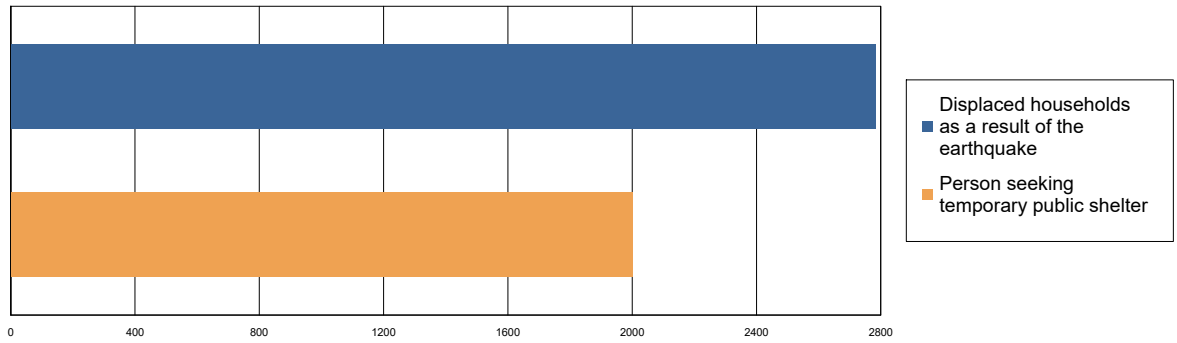
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
0.16	0.24	0.40	16,120 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 2,783 households to be displaced due to the earthquake. Of these, 2,000 people (out of a total population of 106,519) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
2,783	2,000

Casualties

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

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

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

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

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	6.65	1.64	0.23	0.44
	Commuting	0.03	0.04	0.07	0.01
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	11.23	2.81	0.39	0.77
	Other-Residential	293.61	72.36	10.58	20.83
	Single Family	52.31	8.94	0.92	1.79
	Total	**364**	**86**	**12**	**24**
2 PM	Commercial	386.09	95.33	13.20	25.69
	Commuting	0.29	0.35	0.63	0.12
	Educational	154.80	39.51	5.88	11.42
	Hotels	0.00	0.00	0.00	0.00
	Industrial	82.97	20.82	2.94	5.70
	Other-Residential	64.51	16.15	2.43	4.59
	Single Family	10.72	1.90	0.21	0.39
	Total	**699**	**174**	**25**	**48**
5 PM	Commercial	275.33	68.24	9.56	18.33
	Commuting	6.03	7.39	13.27	2.53
	Educational	22.76	5.81	0.86	1.68
	Hotels	0.00	0.00	0.00	0.00
	Industrial	51.86	13.01	1.84	3.56
	Other-Residential	116.42	29.11	4.37	8.26
	Single Family	20.55	3.64	0.40	0.74
	Total	**493**	**127**	**30**	**35**

Economic Loss

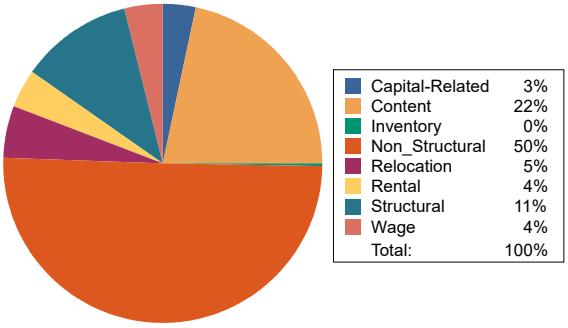
The total economic loss estimated for the earthquake is 2,282.48 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

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

The total building-related losses were 1,855.63 (millions of dollars); 16 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 57 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

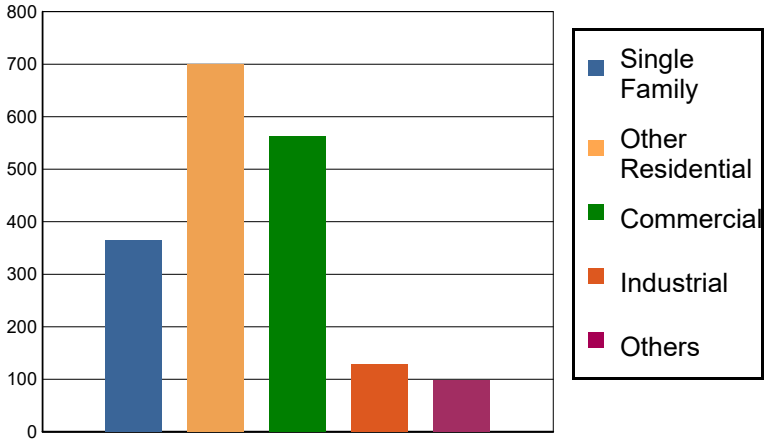


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	13.5034	53.1864	2.4186	4.2365	73.3449
	Capital-Related	0.0000	5.7199	51.5633	1.4584	0.5741	59.3157
	Rental	4.7223	37.7758	28.1526	0.9181	1.7035	73.2723
	Relocation	16.9147	24.3493	41.5488	4.0841	10.9041	97.8010
	Subtotal	**21.6370**	**81.3484**	**174.4511**	**8.8792**	**17.4182**	**303.7339**
Capital Stock Losses							
	Structural	34.5591	74.7901	68.4453	16.7076	13.8678	208.3699
	Non_Structural	208.5269	416.2223	207.6357	56.7544	42.7549	931.8942
	Content	100.3865	128.1718	110.6919	40.6093	24.0624	403.9219
	Inventory	0.0000	0.0000	1.6227	5.9666	0.1171	7.7064
	Subtotal	**343.4725**	**619.1842**	**388.3956**	**120.0379**	**80.8022**	**1551.8924**
	Total	**365.11**	**700.53**	**562.85**	**128.92**	**98.22**	**1855.63**

Transportation and Utility Lifeline Losses

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

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

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	981.3499	0.0000	0.00
	Bridges	1070.6973	90.2458	8.43
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**2052.0472**	**90.2458**	
Railways	Segments	31.3847	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**31.3847**	**0.0000**	
Light Rail	Segments	13.7751	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	2.6630	0.1809	6.79
	Subtotal	**16.4381**	**0.1809**	
Bus	Facilities	5.0576	1.1357	22.46
	Subtotal	**5.0576**	**1.1357**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**2,104.93**	**91.56**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	16.0623	0.5877	3.66
	Subtotal	**16.0623**	**0.5877**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	77.2560	25.9364	33.57
	Distribution Line	9.6374	0.2952	3.06
	Subtotal	**86.8934**	**26.2316**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	6.4249	0.1011	1.57
	Subtotal	**6.4249**	**0.1011**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	893.2000	308.2567	34.51
	Subtotal	**893.2000**	**308.2567**	
Communication	Facilities	0.3480	0.1153	33.13
	Subtotal	**0.3480**	**0.1153**	
	Total	**1,002.93**	**335.29**	

Appendix A: County Listing for the Region

Middlesex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Middlesex	106,519	9,183	2,827	12,011
Total Region		**106,519**	**9,183**	**2,827**	**12,011**

Hazus: Earthquake Global Risk Report

Region Name Lowell_04152020

Earthquake Scenario: Lowell Megnitude 7.0 Earthquake

Print Date: April 16, 2020

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

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

Table of Contents

Section	Page #
General Description of the Region	3
Building and Lifeline Inventory	4
Building Inventory	
Critical Facility Inventory	
Transportation and Utility Lifeline Inventory	
Earthquake Scenario Parameters	7
Direct Earthquake Damage	8
Buildings Damage	
Essential Facilities Damage	
Transportation and Utility Lifeline Damage	
Induced Earthquake Damage	14
Fire Following Earthquake	
Debris Generation	
Social Impact	15
Shelter Requirements	
Casualties	
Economic Loss	17
Building Related Losses	
Transportation and Utility Lifeline Losses	

Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

General Description of the Region

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

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

Massachusetts

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

The geographical size of the region is 14.52 square miles and contains 25 census tracts. There are over 38 thousand households in the region which has a total population of 106,519 people (2010 Census Bureau data). The distribution of population by Total Region and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 12,011 (millions of dollars). Approximately 89.00 % of the buildings (and 76.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,104 and 1,002 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 12,011 (millions of dollars) . Appendix B provides a general distribution of the building value by Total Region and County.

In terms of building construction types found in the region, wood frame construction makes up 79% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

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

For essential facilities, there are 2 hospitals in the region with a total bed capacity of 381 beds. There are 39 schools, 1 fire stations, 3 police stations and 1 emergency operation facilities. With respect to high potential loss facilities (HPL), there are no dams identified within the inventory. The inventory also includes 17 hazardous material sites, no military installations and no nuclear power plants.

Transportation and Utility Lifeline Inventory

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

The total value of the lifeline inventory is over 3,106.00 (millions of dollars). This inventory includes over 88.86 miles of highways, 74 bridges, 997.92 miles of pipes.

Table 1: Transportation System Lifeline Inventory

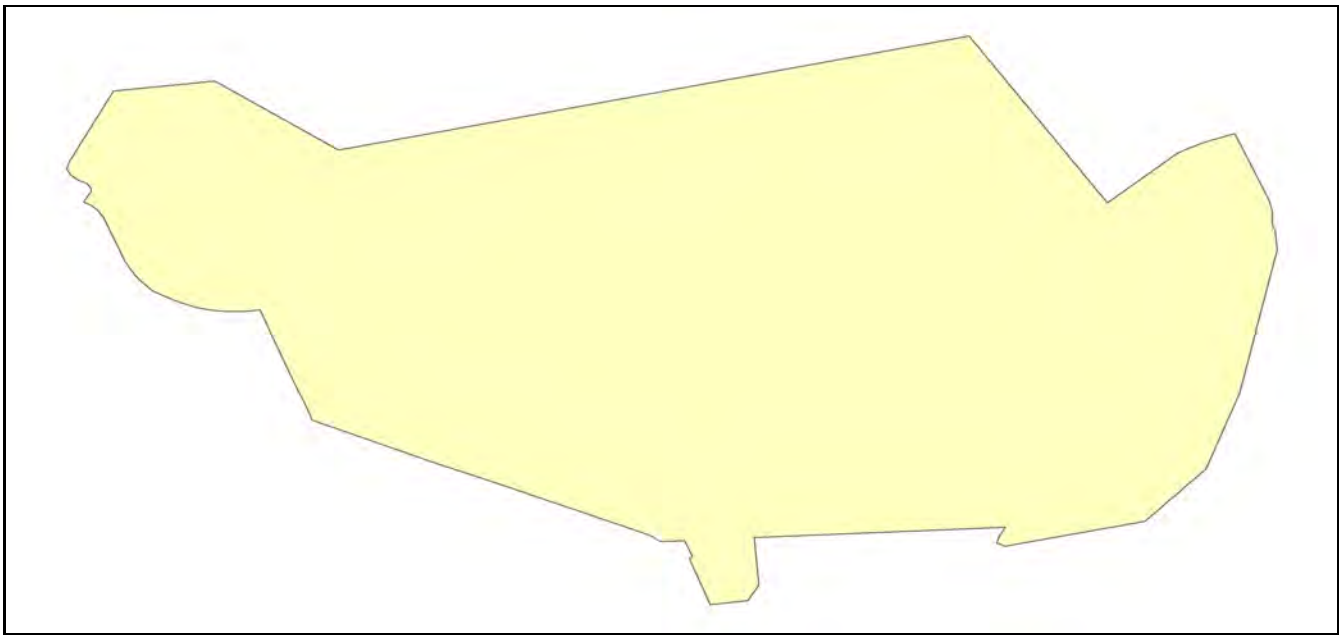
System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	74	1070.6973
	Segments	111	981.3499
	Tunnels	0	0.0000
		Subtotal	**2052.0472**
Railways	Bridges	0	0.0000
	Facilities	0	0.0000
	Segments	32	31.3847
	Tunnels	0	0.0000
		Subtotal	**31.3847**
Light Rail	Bridges	0	0.0000
	Facilities	1	2.6630
	Segments	2	13.7751
	Tunnels	0	0.0000
		Subtotal	**16.4381**
Bus	Facilities	4	5.0576
		Subtotal	**5.0576**
Ferry	Facilities	0	0.0000
		Subtotal	**0.0000**
Port	Facilities	0	0.0000
		Subtotal	**0.0000**
Airport	Facilities	0	0.0000
	Runways	0	0.0000
		Subtotal	**0.0000**
		Total	**2,104.90**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	16.0623
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**16.0623**
Waste Water	Distribution Lines	NA	9.6374
	Facilities	1	77.2560
	Pipelines	0	0.0000
		Subtotal	**86.8934**
Natural Gas	Distribution Lines	NA	6.4249
	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**6.4249**
Oil Systems	Facilities	0	0.0000
	Pipelines	0	0.0000
		Subtotal	**0.0000**
Electrical Power	Facilities	7	893.2000
		Subtotal	**893.2000**
Communication	Facilities	3	0.3480
		Subtotal	**0.3480**
		Total	**1,002.90**

Earthquake Scenario

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



Scenario Name	Lowell Megnitude 7.0 Earthquake
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-71.31
Latitude of Epicenter	42.64
Earthquake Magnitude	7.00
Depth (km)	12.00
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	Central & East US (CEUS 2008)

Direct Earthquake Damage

Building Damage

Hazus estimates that about 23,280 buildings will be at least moderately damaged. This is over 96.00 % of the buildings in the region. There are an estimated 12,256 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Damage Categories by General Occupancy Type

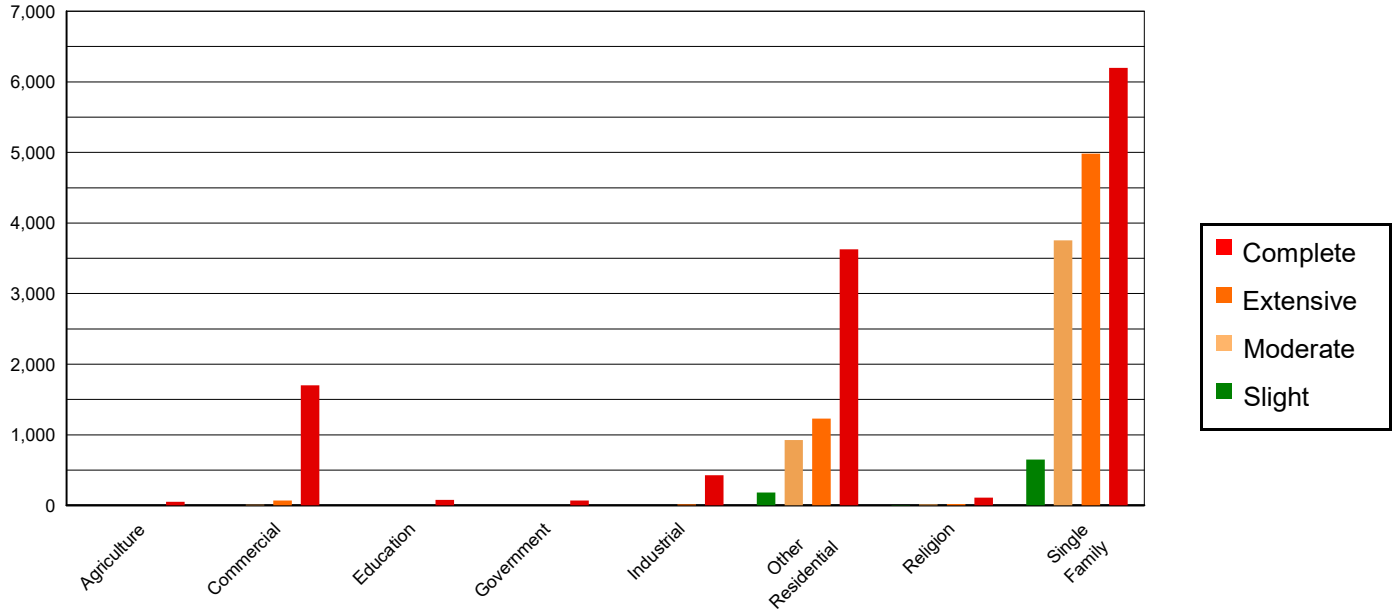


Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0.00	0.00	0.02	0.00	0.30	0.01	3.00	0.05	50.68	0.41
Commercial	0.12	0.13	0.56	0.07	8.43	0.18	69.60	1.10	1700.30	13.87
Education	0.00	0.01	0.02	0.00	0.30	0.01	2.54	0.04	76.13	0.62
Government	0.01	0.01	0.01	0.00	0.21	0.00	1.91	0.03	66.86	0.55
Industrial	0.02	0.03	0.09	0.01	1.29	0.03	11.99	0.19	427.61	3.49
Other Residential	23.30	25.32	180.49	21.68	925.01	19.67	1228.36	19.44	3627.83	29.60
Religion	0.51	0.56	3.28	0.39	14.71	0.31	19.62	0.31	110.87	0.90
Single Family	68.06	73.95	647.90	77.84	3753.41	79.80	4983.32	78.85	6196.31	50.55
Total	**92**		**832**		**4,704**		**6,320**		**12,257**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	91.69	99.63	830.32	99.75	4679.91	99.49	6189.59	97.93	7334.12	59.84
Steel	0.07	0.07	0.08	0.01	1.33	0.03	25.03	0.40	1297.85	10.59
Concrete	0.01	0.01	0.06	0.01	0.57	0.01	5.60	0.09	410.76	3.35
Precast	0.00	0.00	0.02	0.00	0.21	0.00	0.77	0.01	90.51	0.74
RM	0.18	0.19	0.26	0.03	4.04	0.09	12.91	0.20	735.57	6.00
URM	0.09	0.10	1.63	0.20	17.49	0.37	85.29	1.35	2345.05	19.13
MH	0.00	0.00	0.01	0.00	0.12	0.00	1.15	0.02	42.72	0.35
Total	**92**		**832**		**4,704**		**6,320**		**12,257**	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 381 hospital beds available for use. On the day of the earthquake, the model estimates that only 0 hospital beds (0.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 0.00% of the beds will be back in service. By 30 days, 1.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	2	2	2	0
Schools	39	39	38	0
EOCs	1	1	1	0
PoliceStations	3	3	2	0
FireStations	1	1	1	0

Transportation Lifeline Damage

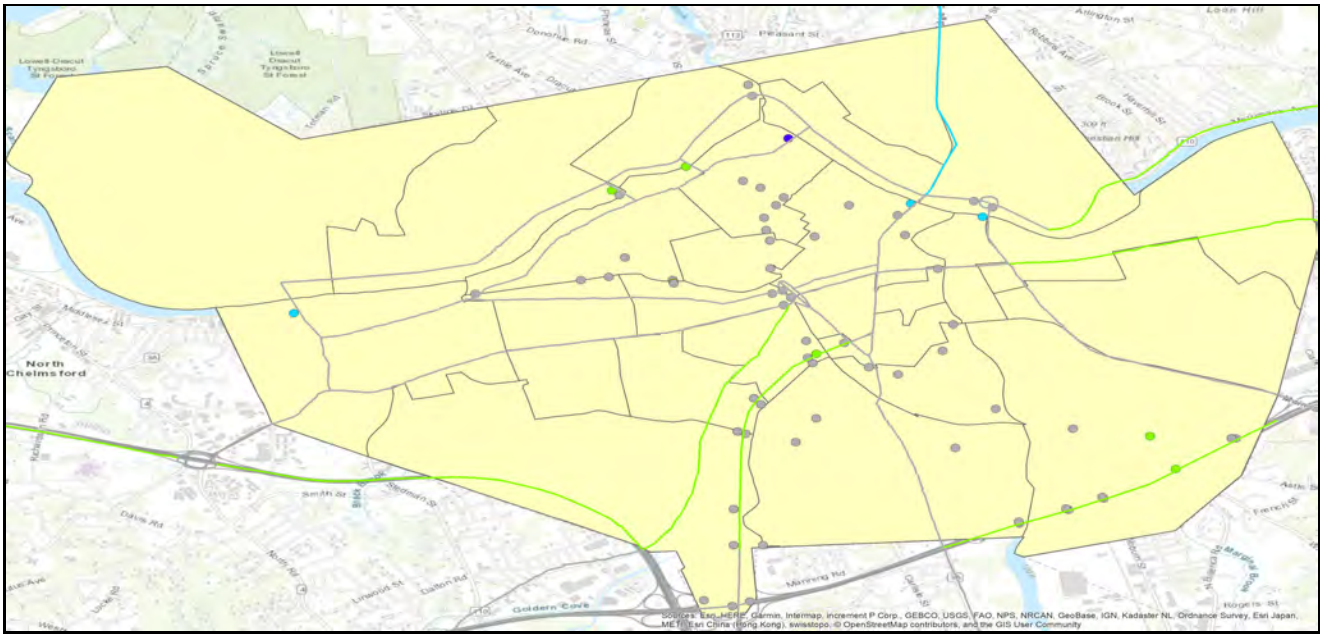


Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	111	0	0	111	111
	Bridges	74	69	67	5	5
	Tunnels	0	0	0	0	0
Railways	Segments	32	0	0	27	27
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	2	0	0	2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	1	0	0	0
Bus	Facilities	4	4	2	2	2
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Table 6 provides damage estimates for the transportation system.

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

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

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	1	1	1	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	7	7	7	0	0
Communication	3	3	3	0	0

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

System	Total Pipelines Length (miles)	Number of Leaks	Number of Breaks
Potable Water	499	4094	1024
Waste Water	299	2057	514
Natural Gas	200	705	176
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	38,470	38,408	38,395	38,360	35,595	0
Electric Power		37,040	34,814	28,499	11,943	38

Induced Earthquake Damage

Fire Following Earthquake

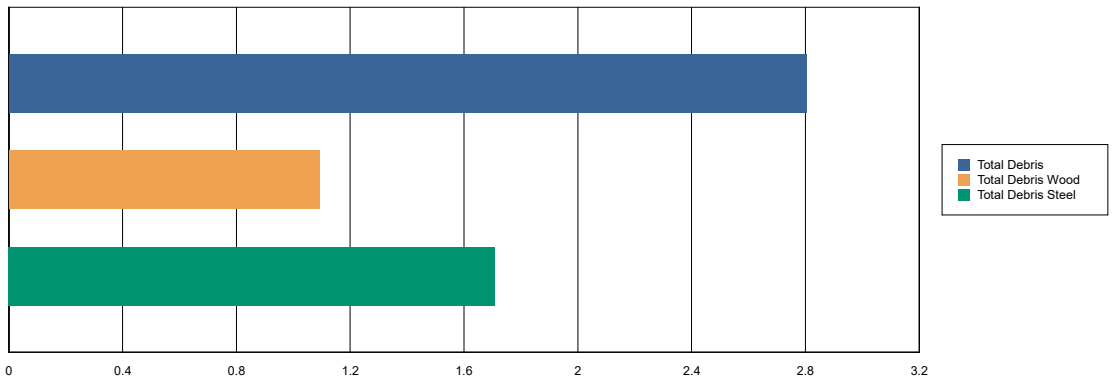
Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 9 ignitions that will burn about 0.34 sq. mi 2.31 % of the region's total area.) The model also estimates that the fires will displace about 4,851 people and burn about 486 (millions of dollars) of building value.

Debris Generation

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

The model estimates that a total of 2,802,000 tons of debris will be generated. Of the total amount, Brick/Wood comprises 39.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 112,080 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Earthquake Debris (millions of tons)



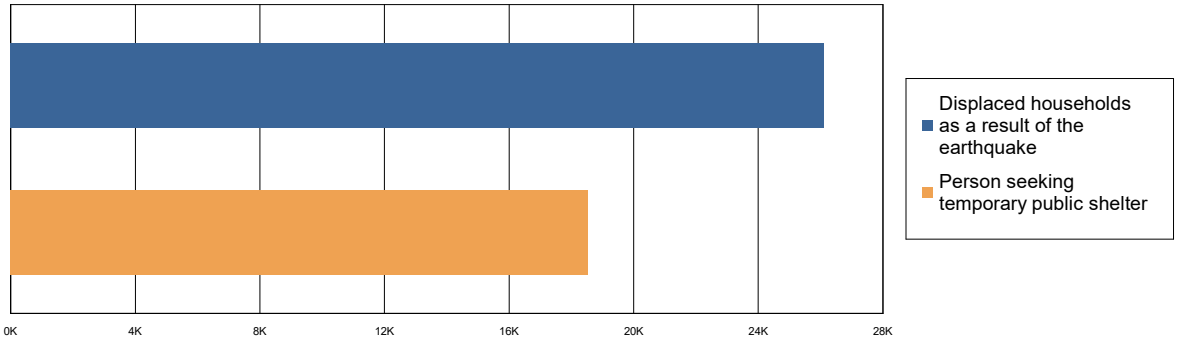
Brick/ Wood	Reinforced Concrete/Steel	Total Debris	Truck Load
1.09	1.71	2.80	112,080 (@25 tons/truck)

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 26,110 households to be displaced due to the earthquake. Of these, 18,542 people (out of a total population of 106,519) will seek temporary shelter in public shelters.

Displaced Households/ Persons Seeking Short Term Public Shelter



Displaced households as a result of the earthquake	Persons seeking temporary public shelter
26,110	18,542

Casualties

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

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

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

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

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	67.97	21.68	3.43	6.76
	Commuting	0.37	0.61	0.89	0.18
	Educational	0.00	0.00	0.00	0.00
	Hotels	0.00	0.00	0.00	0.00
	Industrial	104.59	34.01	5.54	10.93
	Other-Residential	3612.49	1130.00	172.74	337.71
	Single Family	1318.87	332.12	27.81	49.13
	Total	**5,104**	**1,518**	**210**	**405**
2 PM	Commercial	3954.15	1261.48	200.63	392.43
	Commuting	3.32	5.48	7.97	1.61
	Educational	1592.84	521.95	87.58	170.39
	Hotels	0.00	0.00	0.00	0.00
	Industrial	776.33	252.32	41.35	80.62
	Other-Residential	794.47	250.23	39.70	73.56
	Single Family	275.55	69.74	6.81	10.39
	Total	**7,397**	**2,361**	**384**	**729**
5 PM	Commercial	2833.78	905.08	145.50	279.43
	Commuting	66.28	104.93	157.11	31.44
	Educational	233.87	76.72	12.86	25.13
	Hotels	0.00	0.00	0.00	0.00
	Industrial	485.21	157.70	25.85	50.39
	Other-Residential	1444.06	454.23	71.89	133.10
	Single Family	532.02	134.66	13.14	20.02
	Total	**5,595**	**1,833**	**426**	**540**

Economic Loss

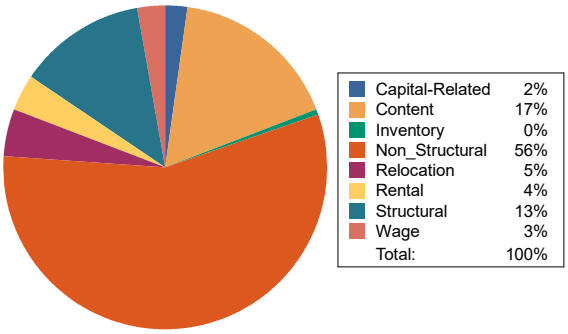
The total economic loss estimated for the earthquake is 13,977.43 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

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

The total building-related losses were 12,512.13 (millions of dollars); 13 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 65 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Earthquake Losses by Loss Type ($ millions)



Earthquake Losses by Occupancy Type ($ millions)

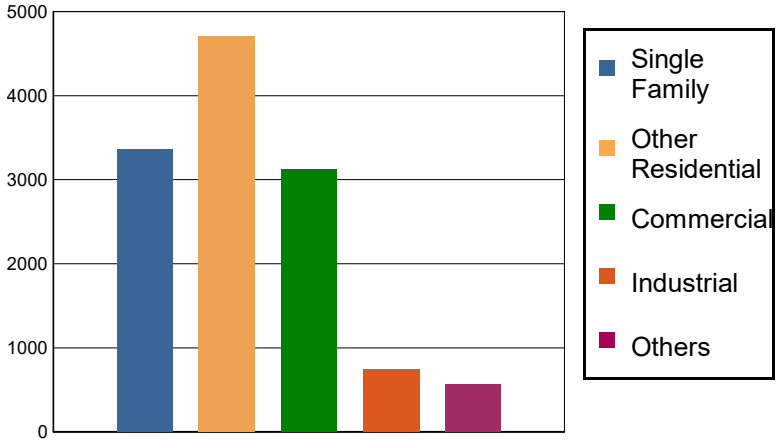


Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.0000	79.2108	230.2261	9.7218	16.6517	335.8104
	Capital-Related	0.0000	33.5515	234.0543	5.8362	2.7698	276.2118
	Rental	71.4898	264.1236	104.9539	3.1121	6.9573	450.6367
	Relocation	235.3609	150.6252	146.5001	11.6033	46.7130	590.8025
	Subtotal	**306.8507**	**527.5111**	**715.7344**	**30.2734**	**73.0918**	**1653.4614**
Capital Stock Losses							
	Structural	579.6522	527.5340	355.6567	77.5852	75.4156	1,615.8437
	Non_Structural	2019.7685	3006.9208	1386.4389	368.5889	286.1514	7,067.8685
	Content	456.7891	645.4418	654.1929	236.1738	137.2459	2,129.8435
	Inventory	0.0000	0.0000	9.4839	34.9008	0.7257	45.1104
	Subtotal	**3056.2098**	**4179.8966**	**2405.7724**	**717.2487**	**499.5386**	**10858.6661**
	Total	**3363.06**	**4707.41**	**3121.51**	**747.52**	**572.63**	**12512.13**

Transportation and Utility Lifeline Losses

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

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

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	981.3499	0.0000	0.00
	Bridges	1070.6973	626.0560	58.47
	Tunnels	0.0000	0.0000	0.00
	Subtotal	**2052.0472**	**626.0560**	
Railways	Segments	31.3847	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**31.3847**	**0.0000**	
Light Rail	Segments	13.7751	0.0000	0.00
	Bridges	0.0000	0.0000	0.00
	Tunnels	0.0000	0.0000	0.00
	Facilities	2.6630	1.7853	67.04
	Subtotal	**16.4381**	**1.7853**	
Bus	Facilities	5.0576	3.3373	65.99
	Subtotal	**5.0576**	**3.3373**	
Ferry	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Port	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Airport	Facilities	0.0000	0.0000	0.00
	Runways	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
	Total	**2,104.93**	**631.18**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	16.0623	18.4244	114.71
	Subtotal	**16.0623**	**18.4244**	
Waste Water	Pipelines	0.0000	0.0000	0.00
	Facilities	77.2560	64.1360	83.02
	Distribution Line	9.6374	9.2551	96.03
	Subtotal	**86.8934**	**73.3911**	
Natural Gas	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Distribution Line	6.4249	3.1707	49.35
	Subtotal	**6.4249**	**3.1707**	
Oil Systems	Pipelines	0.0000	0.0000	0.00
	Facilities	0.0000	0.0000	0.00
	Subtotal	**0.0000**	**0.0000**	
Electrical Power	Facilities	893.2000	738.8519	82.72
	Subtotal	**893.2000**	**738.8519**	
Communication	Facilities	0.3480	0.2881	82.79
	Subtotal	**0.3480**	**0.2881**	
	Total	**1,002.93**	**834.13**	

Appendix A: County Listing for the Region

Middlesex,MA

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Massachusetts					
	Middlesex	106,519	9,183	2,827	12,011
Total Region		**106,519**	**9,183**	**2,827**	**12,011**

Appendix C

Workshop Materials

City of Lowell Community Resilience Building (CRB) Workshop Invitation Letter

Hello,

The City of Lowell was recently awarded a grant from the Commonwealth's Municipal Vulnerability Preparedness Program to identify priority action items that will improve our community's resilience to climate change and to update our Hazard Mitigation Plan.

As a leader in our community, we hope you or a designee can join the City at an important, invitation-only, virtual workshop. The workshop will include three live webinars discussing climate risks and adaptation related to the following categories:

- **Infrastructure Assets**: Monday, April 27th from 2:00-3:30
- **Natural Resources and Land Use:** Wednesday, April 29th from 10:00-11:30
- **Community Health and the Economy:** Thursday, April 30th from 2:00-3:30

You are welcome to join each webinar, although, you may opt to only attend one. The workshop format was based on the Community Resilience Building Guidebook developed by the Nature Conservancy, which has been successfully used in over 200 communities. The workshop's objectives are to:

- Identify natural hazards that present the greatest threat to the community.
- Evaluate strengths and vulnerabilities of our community, infrastructure assets, and natural resources.
- Develop and prioritize actions that reduce the impact of hazards and increase resilience.

By participating in this effort, Lowell will be designated as an MVP Community and will be eligible for future grants that promote resilience. We are conducting virtual public engagement to receive broader input on the planning process.

Please RSVP for the webinar(s) by Monday, April 27th by responding to a forthcoming Eventbrite invitation.

We will follow up with more information regarding meeting materials and logistics for joining the webinar. Thank you for your consideration and participation!

Office of the City Manager
City Hall • 375 Merrimack Street • Lowell, MA 01852
P: 978.674.4400 • F: 978.970.4007
www.LowellMA.gov

Eileen M. Donoghue
City Manager

Kara Keefe Mullin
Assistant City Manager

FOR IMMEDIATE RELEASE

May 22, 2020

City of Lowell Seeks Public Input for Municipal Vulnerability Preparedness and Hazard Mitigation Plan

The City of Lowell has embarked on a planning process to identify projects to reduce the potential impacts from natural hazards like severe storms, flooding, and extreme heat. The City will also consider the likelihood of experiencing more severe natural hazards more frequently due to projected climate change. The planning process will broadly focus on three topic areas: infrastructure assets, societal and economic resilience, and environmental resources.

The City of Lowell's resilience is evident through the community's response to the current public health concerns and historic responses to weather-related events. The Municipal Vulnerability Preparedness (MVP) and Hazard Mitigation Plan (HMP) Project aims to document historic successes and challenges in order to better develop solutions for tomorrow. The City is seeking input from the public in this process. Feedback from the community is vital to ensure the planning process is comprehensive and relevant to its constituents.

Given the current COVID-19 crisis, in person public meetings will not be possible. However, the City is making available resources to connect as a community online. The latest information will be available on a dedicated project webpage. Posts will also be found on the City's social media platforms. The City plans to release videos, surveys, and more in the coming days to hear about experiences, concerns, ideas, and solutions for the challenges associated with natural hazards and climate change. Please note, materials will be available in English, Khmer, Portuguese, and Spanish.

The MVP-HMP project is funded through a $77,550 grant award from the Commonwealth's Municipal Vulnerability Preparedness (MVP) Planning Grant program, which provides technical and financial support for cities and towns to plan for climate change and implement the results. As part of the process, the City of Lowell will also fulfill the Federal Emergency Management Agency's (FEMA) requirements to update the City's Hazard Mitigation Plan (HMP) from 2015. The HMP update will maintain the City's eligibility for FEMA grant funding.

If you would like to receive updates on this project, please forward your contact information to Adria Boynton, Resiliency Specialist at Weston & Sampson (boyntona@wseinc.com).

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Virtual Community Resilience Building (CRB) Workshop Webinar
April 27, 2020 | 2:00-3:30PM
Microsoft Teams Meeting

Welcome and Introductions	5 minutes
MVP Program Overview	10 minutes
Overview of Hazards and Climate Change Data	15 minutes
Risk Matrix	15 minutes
Action Items	40 minutes
Wrap Up and Next Steps	5 minutes

Weston & Sampson

CITY OF LOWELL

Community Resilience Building (CRB) Workshop Webinar:
Infrastructure Assets

April 27, 2020

Weston & Sampson Photo: Merrimack River, Weston & Sampson

1

WELCOME FROM W&S AND RIVERMOOR ENERGY

ADRIA BOYNTON | STEVE ROY | INDRANI GHOSH | AMANDA KOHN | JOHN FREY | JOHN TOURTELOTTE

Weston & Sampson RIVERMOOR ENERGY Photo: Kinetic Sculpture Festival, W&S

2

WELCOME PARTICIPANTS

Weston & Sampson Photo: Kinetic Sculpture Festival, W&S

3

LOGISTICS

- This webinar is being recorded
- Comment in the chat!
- Materials shared for comment:
  - Risk Matrix
  - Hazard Maps
- Materials shared for reference:
  - Critical facilities list
  - PDF of presentation
  - Agenda

4

WEBINAR OUTLINE

PRESENTATION:

- Overview of the MVP and HMP Programs
- Historic and Future Climate Change Impacts

DISCUSSION:

- Pre-Selected Hazards
- Pre-Selected Features
- Identify and Prioritize Action Items

Photo: City Facebook

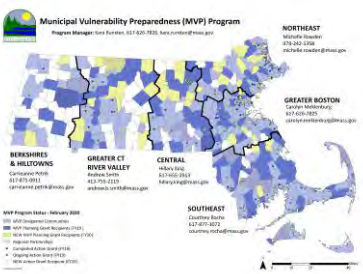
5

MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM (MVP)

Community Resilience Building Process:
82% participation
287 communities

Action Grant Projects:
FY 18: **37**
FY 19: **36**
FY20: **54**

Total Awards:
$33M+ to date



MVP Website: www.mass.gov/mvp
Northeast Regional Coordinator: Michelle Rowden

6

MVP Program Goals

7

MVP Process

1. **MVP Planning Grant**
   - Define climate hazards
   - Identify community vulnerabilities and strengths
   - Develop and prioritize adaptation actions
   - Receive MVP designation

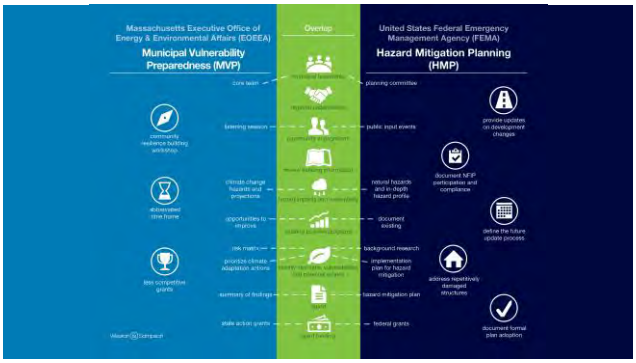
   ** We're also updating Lowell's Hazard Mitigation Plan!*

2. **MVP Action Grant**
   1. Implement priority adaptation actions identified during the planning process

8

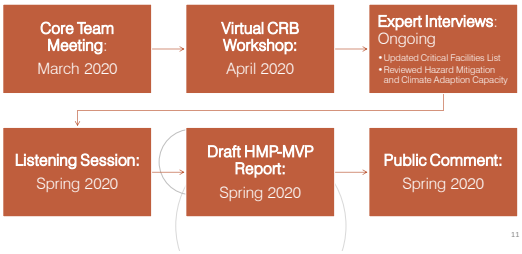
What Can the MVP Action Grant Fund?

9



10

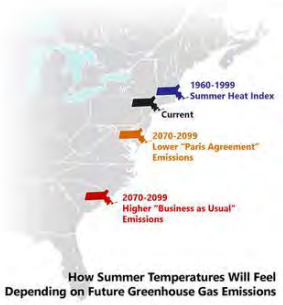
SCHEDULE



11

Any questions
on the MVP or HMP Programs?

12



Mass Audubon, Union of Concerned Scientists (2016)

13

13

EXTREME TEMPERATURES

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

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

Source: ResilientMA.org, "Rising Temperatures," 2017

14

14

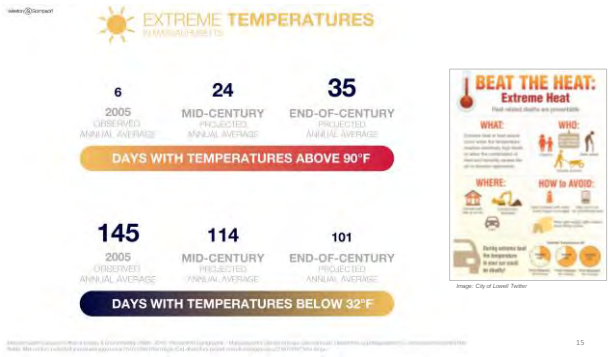
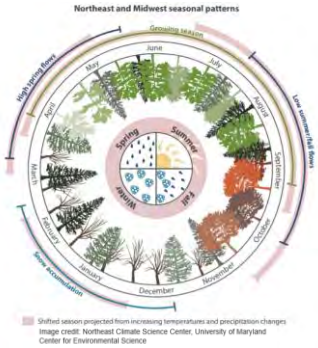


Image: City of Lowell Twitter

15

15



The most recent notable drought event was in
2016.[1]

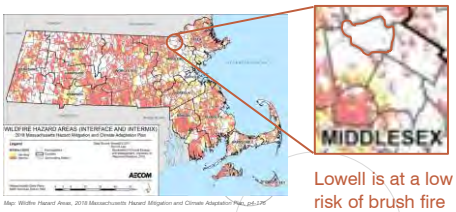
The occurrence of droughts
lasting 1 to 3 months
could go up by as much as
75% over existing conditions
by the end of the century,
under the high emissions scenario.

1. Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 17.

16

16

AS AN FYI: **BRUSH FIRE**



Map: Wildfire Hazard Areas, 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, pg. 178

Lowell is at a low risk of brush fire

17

17

URBAN FIRE

CAUSES

- Human error and carelessness
- Density of development
- Leading causes of residential building fires in Lowell is cooking, followed by smoking
- Much of the housing stock are old, multi-family, wood buildings
- Many older structures lack sprinkler systems

DATA

- **522 fires** were reported during 2013
- **7 residents** perished in an apartment fire in 2014
- **80% of building fires** in Lowell occur in residential properties (mostly apartments)

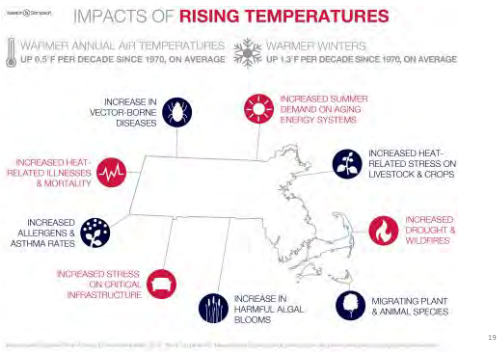
NEIGHBORHOODS MOST AT RISK OF FIRE

- The Acre
- South Lowell
- Centralville

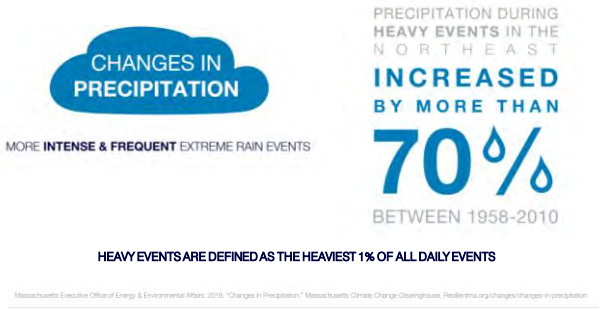
Sources: 2015 Regional HMP

18

18



19



20

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by midcentury

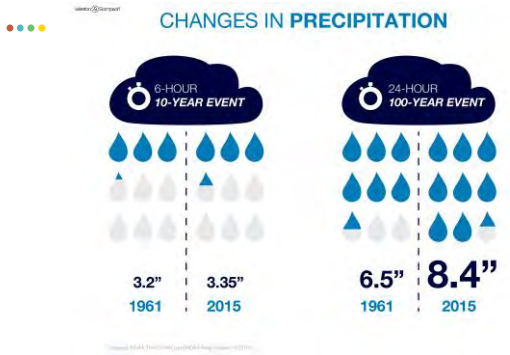
13%

Increase in extreme precipitation events by 2100

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report." 19.

21

21



22

STORMWATER FLOODING

Areas with:

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

City of Lowell Stormwater Management Webpage

23

23

LOCAL FLOODING NEAR WATERBODIES

- Northern banks of the Merrimack River near the Water Treatment Plant
- Land around Black Brook and the Trull Brook tributary between Phoenix Ave and Clark Road
- Areas in the 100-year floodplain along major waterways:
  - Concord River
  - Marginal Brook
  - River Meadow Brook
  - Beaver Brook
  - Clay Pit Brook (including floods in 2006 and 2007)
- Marsh along Wentworth Avenue
- The mouth of Black Brook
- The mouth of Marginal Brook

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

24

24

LOCAL FLOODING ALONG STREETS

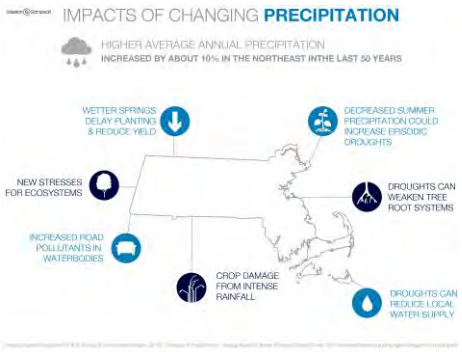
- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

A rainstorm in the summer of 2003 filled the Gorham and Moore Street intersection with up to 4' of water

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

25

25



26

26

WINTER STORMS

- The blizzard of 2013 left nearly 400,000 Massachusetts residents without power.[1]
- "Heavy blizzards are among the most costly and disruptive weather events for Massachusetts communities."[2]
- Snowpack likely to decrease annually, but snowfall will occur with heavy intensity
- In the winter of 1995, snowfall in Lowell reached 126.5"[3]
- Extended power outages, cost of snow removal, repairing damages, and loss of business can have a severe economic impact.
- The elderly and infirmed are populations of particular concern during these events.

1. Resilient MA Climate Change Clearinghouse for the Commonwealth: "Extreme Weather," 2017
2. "Massachusetts State Hazard Mitigation and Adaptation Plan," 2018: P4-226
3. 2015 Regional HMP

Graphic: City of Lowell Twitter

27

27

HURRICANES AND NOR'EASTERS

Upward trend in North Atlantic hurricane activity since 1970

2012: Hurricane Sandy
2017: Hurricane Jose
2018: Hurricane Florence
2019: Hurricane Dorian

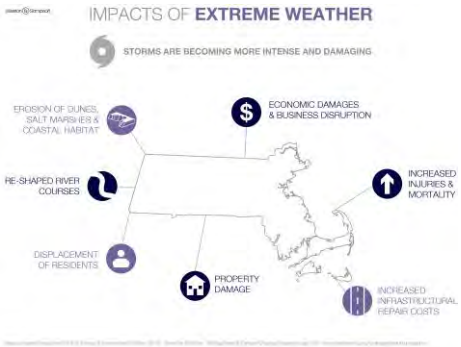
Nor'easters along the Atlantic coast are increasing in frequency and intensity

Jan 3-4, 2018: Winter Storm Grayson
March 2, 2018: Winter Storm Riley
March 8, 2018: Winter Storm Quinn
March 13, 2018: Winter Storm Skylar

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)/Northern Middlesex

28

28



29

29

Any questions about climate hazards?

30

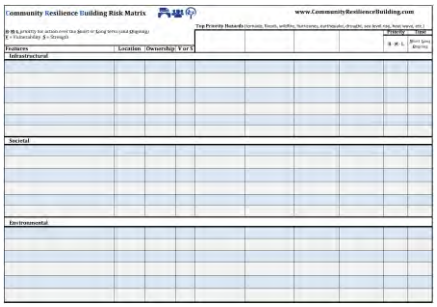
30

RISK MATRIX

Photo: City Facebook

31

RISK MATRIX



Community Resilience Building Risk Matrix

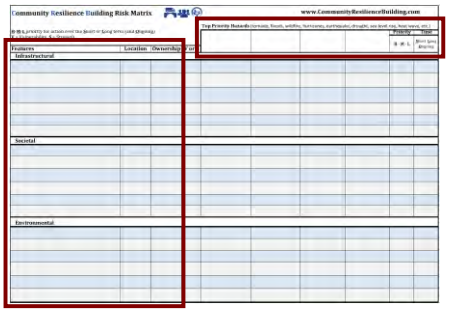
www.CommunityResilienceBuilding.com

Features	Location	Ownership: Y or N	Top Priority Hazards											
													Priority	Time
Infrastructural														
Societal														
Environmental														

32

32

RISK MATRIX: HAZARDS AND FEATURES



Community Resilience Building Risk Matrix

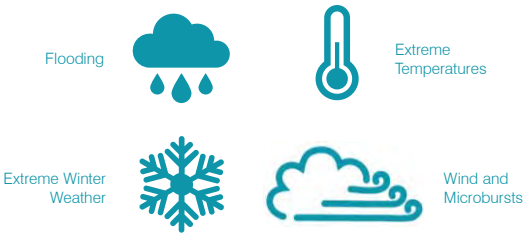
www.CommunityResilienceBuilding.com

Features	Location	Ownership: Y or N	Top Priority Hazards											
													Priority	Time
Infrastructural														
Societal														
Environmental														

33

33

CLIMATE HAZARDS IN LOWELL



Weston & Sampson

34

34

FEATURES IN LOWELL

Photo: City Facebook

35

INFRASTRUCTURAL FEATURES

Public Transportation

Photo: LRTA Bus, Wikimedia Commons

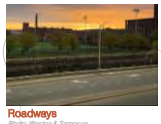
Emergency Services

Photo: City of Lowell Facebook

Wastewater Treatment and Collection

Dams

MA Office of Travel and Tourism, 2014



Roadways

Photo: Weston & Sampson

Water Supply

36

36

INFRASTRUCTURAL FEATURES

2015 Regional HMP
Photo: Weston & Sampson

- There are **300+ stormwater outfalls** in Lowell
- **65% of Lowell's sewer pipes** are part of a combined sewer and stormwater system
- Approximately **60% of the combined system** is over **100 years old**
- The Lowell Regional Wastewater Utility (LRWU) receives wastewater from Lowell, Chelmsford, Dracut, and Tewksbury
- There are **9 combined sewer overflow structures** that regulate flow to the LRWU, and discharge excess stormwater to the Merrimack River and its tributaries
- **100% of Lowell** is served by municipal drinking water supply, drawn from the Merrimack River and treated by the City's water treatment plant
- The water system pumps an average of **11 million gallons** per day

37

HAZARD POTENTIAL OF DAMS

Name	Ownership	Hazard Class
Northern Canal-Great Wall	DCR - Dept. of Conservation & Recreation	Low Hazard
Guard Locks	**DCR - Dept. of Conservation & Recreation**	**High Hazard**
Lower Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard
Swamp Locks Dam	DCR - Dept. of Conservation & Recreation	Low Hazard
Pawtucket Dam	Hull Street Energy	Low Hazard
Lowell Reservoir Dam	**City of Lowell, Lowell Regional Water Utility**	**High Hazard**
Middlesex Dam	City of Lowell, Lowell Regional Water Utility	N/A
Wamesit Power Company Dam	Centennial Island Hydroelectric Company, A Mass. Lim. Part.	Low Hazard

Weston & Sampson *Office of Dam Safety, 2019*

38

ADAPTATION STRATEGIES

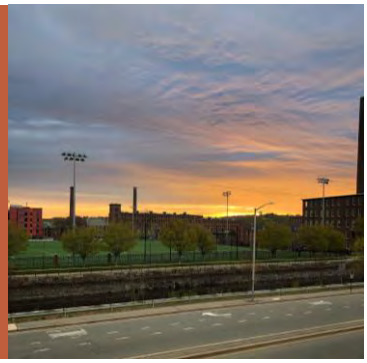


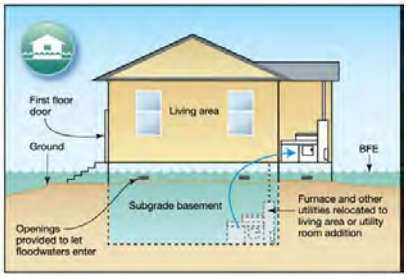
Photo by Weston & Sampson

43

ADAPTATION STRATEGY TYPES

44

WET FLOODPROOFING



45

RAISED BUILDINGS

46

RETROFITTED FLOODPROOF DOORWAYS

47

47

DEPLOYABLE FLOOD BARRIER

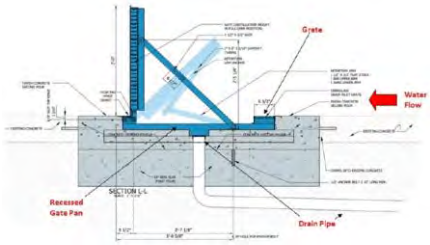
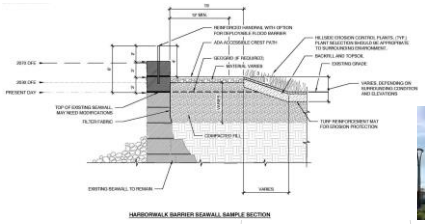


FIGURE 1 | A FloodBreak barrier gate diagram

48

48

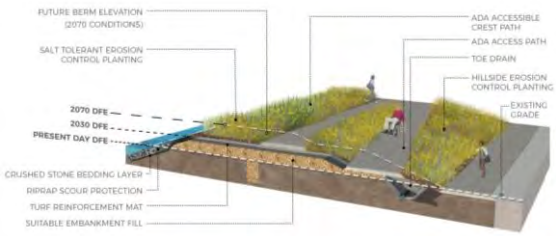
FLOOD WALLS



49

49

VEGETATED BERM



50

50

MULTI-PURPOSE FLOOD STORAGE

51

51

LOW IMPACT DEVELOPMENT (LID)

52

52

Bioretention and Raingardens

53

53

STREET TREES & TREE BOX FILTERS

54

54

STORMWATER DETENTION & RETENTION

55

55

POROUS ASPHALT & PERMEABLE PAVERS

56

56

CULVERT WIDENING TO IMPROVE HABITAT & FLOW

57

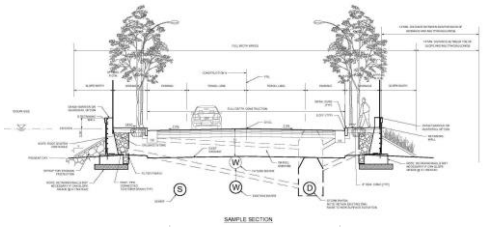
57

CLOUDBURST STREETS

58

58

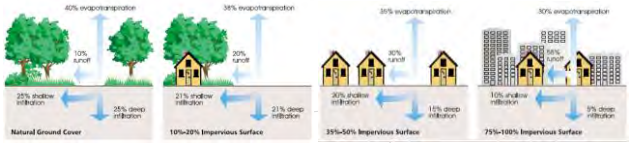
RAISED ROADWAYS



59

59

REDUCE IMPERVIOUS AREAS



60

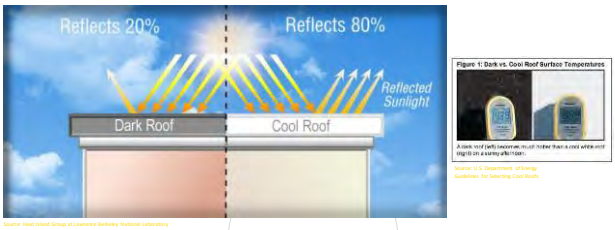
60

GREEN ROOFS

61

61

COOL ROOFS



Source: Heat Island Group at Lawrence Berkeley National Laboratory

Source: U.S. Department of Energy Guidelines for Selecting Cool Roofs

62

62

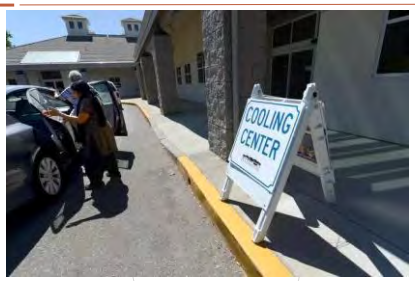
RE-EVALUATE LOCAL REGULATIONS & POLICIES

- Floodplain Overlay District?
- Wetlands Ordinance?
- Stormwater Management Ordinance?
- Zoning Ordinance?

63

63

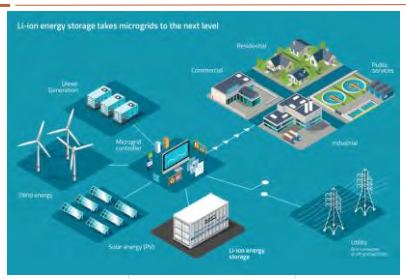
COOLING CENTERS



64

64

RENEWABLE ENERGY/MICRO-GRIDS



65

RIVERMOOR ENERGY

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

April 28, 2020

To: Adria Boynton, Weston & Sampson
Cc: Steve Roy, Weston & Sampson

RE: Rivermoor's Notes from April 27 "Lowell MVP Workshop for Infrastructure"

Infrastructure and Facilities at Risk:

- **Communications infrastructure: phone and cell**
- Christine Clancy (Lowell DPW Commissioner):
  - CodeRED – works, but getting people to sign up is a challenge
  - CodeRED is a one-way app
  - Can create geo-targeting with app
  - Multi-lingual? Christine thinks "yes"
  - Texts can be sent – (also voice calling and/or voice mail?)

- **Dams: Walls and structural support**
  - Question: Could energy-producing dams be used for energy resiliency (as a distributed generating resource)?
  - FERC re-certification of Lowell's dams: Process currently underway
    - Requested copy of draft findings / report / process from Lowell team during call

- **Energy Resiliency:**
  - Katherine Moses: Redundancy needed – more than one type of backup energy generating resource for critical facilities needed

- **Water Infrastructure**
  - Mark Young: Fresh Water System is a strength due to "evergreen" source
  - Note: Merrimack River provides fresh water to approximately 500,000 people in Lowell and surrounding communities. Source, EPA: https://www.epa.gov/merrimackriver/about-merrimack
  - Stormwater and drainage is a risk (per Mark Young)
  - Christine Clancy:
    - Stormwater Culverts are at risk

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

        - There is a lack of mapping on location of stormwater culverts in Lowell
    - Mark Young & Christine: Agree that collection system is a vulnerability for stormwater

- **Canal System:**
    - Christine Clancy: Canal walls are old, age of walls is a concern, structural viability
    - City of Lowell does not own many of the Canals (National Park Service and other owners)
    - Canal Systems are a vulnerability per Christine Clancy
    -
- **Dams & Gate Houses:**
    - Some dams are at risk per Mark Young
    - Celeste Bernardo. Superintendent at Lowell National Historical Park
        - Some of the dams are vulnerable – aged

- **Municipal Buildings:**
    - Consensus among group: Buildings are older & Energy systems (primarily heating) are old (heating systems close to end-of life?)
    - Celeste Bernardo suggests adding non-publicly owned buildings (privately owned, other governmental owned, institutionally owned facilities)
        - Hospital
        - UMass Lowell facilities & infrastructure
        - National Park Service owned facilities and infrastructure

- **Public Housing**
    - Risk in terms of power outages
    - Suggestion from “Rick” to increase insulation to increase thermal efficiency and ability to withstand cold temperatures and hot temperatures

- **Community Outreach:** Important in Lowell

- **Roads and Bridges:**
    - Identify bridges that are at-risk
    - There is a capital maintenance plan for bridges in Lowell (obtain a copy?)

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

- Lowell has strength in winter weather (snow plowing and maintenance are perceived strengths)

- **Tree Canopy in Lowell:** Need for a City Arborist (city does not have this position)

- **Invasive Species:**
  - Hogweed near RR tracks
  - Need for ongoing invasive species management
  - There are also tree pests in Lowell (ash borers, Asian long horned beetles and other)
  - Jane Calvin: Lowell Parks Trust: bio - https://lowelllandtrust.org/staff-member/jane-calvin/
  - Confirms: Emerald ash borer is a problem in Lowell's tree inventory
  - Jane notes that, also, Asian longhorn beetle is a problem

- **Water Supply and Distribution:**
  - Paul Young: Paul notes intake station for flood proofing of pump stations
  - Christine Clancy: Freezing conditions in winter cause water distribution system to be at risk due to freezing water distribution pipes. City needs resources (staff and funding) to protect and repair water distribution water line breaks

- **Stormwater:**
  - Christine Clancy: Culverts by Clay Pit Brook are at risk / inadequate
  - Need better understanding of culvert status and location (back to mapping point above)
  - Assessment of entire drainage system needed? Comment from Steve Roy of Weston & Sampson
  - Christine Clancy: Beavers by Claypit Brook cause dams that are a problem
  - Storm water catch basins – failing, need review?

- **Waste Water and Storm Water Infrastructure:**
  - Mark Young: Risk matrix should include a flooding scenario
  - Vulnerable pump stations, including Rosemont Station

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

- During flooding outfalls, flooding from rivers should not “back-flow” into storm water system
- Need for investment in back flow prevention?

- **Wind and Microburst:**
  - Waste Water Plant – Backup Generator in place
  - Updated fresh water utility generator recently
  - Steve Roy, W& S – Comment: Perhaps an opportunity to increase redundancy and resiliency with solar and storage for these critical facilities

- **Celeste Bernardo: Lowell National Park Service**
  - FERC is going through an analysis of city dams presently (see comments on FERC above)
  - Hydropower units
  - Includes: Planning for 500-year floods and how it will impact these assets (fact check)

Lowell MVP Workshop

04/27/2020

Infrastructure

Attendees

Zoe Dzineku

Alex Magee

Maryann Ballotta

Francesca Cigliano

Christine McCall

Celeste Bernardo

Christine Clancy

Katherine Moses

Rick Minard

Shanon

William Garr

Alison Lamey

Mark Young

Jared Alves

Tom Golden

Jane

****

Margaret McCarthy, WSE

Adria Boynton, WSE

Steve Roy, WSE

John Tourtelotte, Rivermoor Energy

Meeting Notes

What do you like about Lowell?

- People and open spaces
- Restaurants that reflect our immigration story

CLIMATE THREATS

FLOODING, EXTREME TEMPS, EXTREME WINTER WEATHER, WIND & MICROBURSTS

Infrastructure Features Discussion

Celeste – add Dams and gate houses to critical infrastructure

Christine – Code Red requires users to opt in

Katherine – Lowell has some amount of energy resilience but in the future with more extreme events they will need more

Christine- Roads are an issue – need funding, snow clearing from sidewalks is an issue and vulnerability

Mark Young – Drinking water is a strength

Stormwater is very vulnerable – drainage system and culverts need to be mapped. Christine – culverts are an issue

Mark Y. Wastewater is a strength, but they have some age issues with the WW collection system infrastructure.

Christine – Canals are a vulnerability, walls are failing. They are looking at a project at the Lower Locks

Dams are a strength- ACOE recently recertified the dams.

Celeste- the gate houses are a vulnerability

Christine – add municipal building to the infrastructure list – maintenance is needed for all

Katherine suggested the need for micro-grids at public facilities

Rick Minard – need to increase insulation at multi-family public housing

UMass Lowell and Park Service should be better integrated with city resiliency plans

Communications – need to expand outreach to critical populations – Code Red may not work for this population. Need to reach out using social media and other methods

Create a plan to replace aging bridges

Revisit operation plans for winter service for roads

Need for new equipment for road maintenance

Clearing snow from sidewalks is an issue that falls on private owners

A tree management plan is needed

Invasive species is an issue – Giant Hogweed near train tracks. Need a long-term management plan and assessment of invasive species, Emerald Ash Borer, Asian Longhorn Beatle.

Water supply – need to floodproof the influent pump station

Water supply distribution system has issues – freeze-thaw breaks. Need to assess chronic supply line breaks

Stormwater- culverts need replacing, need to assess the drainage system, beaver controls may be necessary

Mark- pumping stations need assessments for resiliency including the Tilton PS and Rosent St? PS

Backflow prevention is needed for CSO controls

Need to update generators at water utility. Could include renewable energy as backup

Need complete inventory of canal walls condition – FERC relicensing of hydropower station is underway

DCR and the Park Service own the gate houses – need coordination to better understand how they work and what happens during a 500 year event

Salt storage shed needs repairs

Meeting Chat

[4/24 3:46 PM] Boynton, Adria joined the meeting.

[Yesterday 12:31 PM] McCarthy, Margaret and 3 others joined the meeting.

[Yesterday 12:31 PM] Boynton, Adria renamed the meeting to .

[Yesterday 1:04 PM] Adams, Lindsey joined the meeting.

[Yesterday 1:33 PM] John Tourtelotte joined the meeting.

[Yesterday 1:43 PM] Boynton, Adria added Forms to the meeting.

[Yesterday 1:43 PM] Forms
Boynton, Adria created a poll
Results are visible to everyone; Names recorded

What do you like most about Lowell?

- ☐ The public spaces
- ☐ The people

- ☐ The community events
- ☐ Other (tell us in the chat!)

[Yesterday 1:55 PM] Rick Minard joined the meeting.

[Yesterday 1:56 PM] Christine McCall joined the meeting.

[Yesterday 1:56 PM] Bernardo, Celeste joined the meeting.

[Yesterday 1:58 PM] Dzineku, Zoe (SEN) joined the meeting.

[Yesterday 1:58 PM] Mark Young joined the meeting.

[Yesterday 1:58 PM] Maryann Ballotta joined the meeting.

[Yesterday 1:59 PM] Maryann Ballotta left the conversation.

[Yesterday 1:59 PM] William Garr joined the meeting.

[Yesterday 2:00 PM] Maryann Ballotta joined the meeting.

[Yesterday 2:00 PM] Allison Lamey joined the meeting.

[Yesterday 2:01 PM] Chris Hayes joined the meeting.

[Yesterday 2:01 PM] Jared Alves joined the meeting.

[Yesterday 2:03 PM] Fran Cigliano joined the meeting.

[Yesterday 2:03 PM] Jane joined the meeting.

[Yesterday 2:16 PM] Roy, Steven
you can type questions into the meeting chat

[Yesterday 2:18 PM] Christine McCall
The people and the open spaces

[Yesterday 2:19 PM] Jared Alves
The restaurants that reflect our immigration story

[Yesterday 2:24 PM] William Garr left the conversation.

[Yesterday 2:31 PM] Chris Hayes
Should we include trails and parks?

[Yesterday 2:31 PM] Jared Alves
Would tree canopy count?

[Yesterday 2:34 PM] Chris Hayes
Communication/fiber optic/internet/phone/cell?

[Yesterday 2:41 PM] Jared Alves
Re Comm: Can submit inquiries/issues using Civic Plus emails on the City's website, but no municipal 311 service (app or phone)

[Yesterday 2:42 PM] Maryann Ballotta
Re: Comm: Residents can also text 911 in emergencies if they aren't able to talk

[Yesterday 2:43 PM] Jared Alves
During snow events, sidewalk clearing is a vulnerability

[Yesterday 2:48 PM] Christine McCall
Lowell has significant development close to wetlands; vulnerability

[Yesterday 2:49 PM] Jared Alves
And development within 100-yr floodplains, e.g., near Clay Pit Brook and Merrimack River

[Yesterday 2:52 PM] Christine McCall
I don't think we have a clear picture of the integrity of the walls throughout the entire system; vulernability

[Yesterday 2:52 PM] Christine McCall
*vulnerability

[Yesterday 2:52 PM] Chris Hayes
Yes

[Yesterday 2:54 PM] Fran Cigliano
Regarding stormwater management, Lowell is generally very impervious and continues to become more impervious with new development. Lack of education on how wetlands benefit water supply/help with stormwater management is a vulnerability

[Yesterday 2:55 PM] Christine McCall
I think including City buildings is important, because I don't think we have flood insurance policies (because we are a municipality).

[Yesterday 2:57 PM] Chris Hayes
Have to go--my colleagues are totally on top of it--will join for next meetings

[Yesterday 2:57 PM] Chris Hayes left the conversation.

[Yesterday 2:58 PM] Boynton, Adria
Thanks for joining us, Chris!

[Yesterday 3:04 PM] Allison Lamey
I have to jump off. Thank you for this discussion. I'm planning to join Thursday's call. See you all then!

[Yesterday 3:04 PM] Allison Lamey left the conversation.

[Yesterday 3:05 PM] Jared Alves left the conversation.

[Yesterday 3:06 PM] Boynton, Adria
Thanks for joining us, Allison! For anyone who has to leave early, feel free to reach out by phone or email with any additional feedback or comments that you'd like to share!

[Yesterday 3:16 PM] Rick Minard
increase insulation of multi-family housing

[Yesterday 3:24 PM] Christine McCall
Not everyone has a landline nor access to internet home. It might be helpful to think through alternative methods.

[Yesterday 3:33 PM] Christine McCall
We have had an outbreak of giant hogweed near rail lines.

[Yesterday 3:37 PM] Maryann Ballotta left the conversation.

[Yesterday 3:42 PM] Fran Cigliano
Continue to encourage low impact development methods (infiltration basins, rain gardens, etc)

[Yesterday 3:42 PM] Christine McCall
Best practices would be helpful. On the permitting side, I know it's not really clear for staff in some situations.

[Yesterday 3:42 PM] Jane
I had to step out for a minute, but have some urban forestry comments

[Yesterday 3:50 PM] Rick Minard left the conversation.

[Yesterday 3:58 PM] Jane left the conversation.

[Yesterday 4:01 PM] Christine McCall
Thank you all for your time today. See you at future meetings!

[Yesterday 4:01 PM] Christine McCall left the conversation.

[Yesterday 4:01 PM] Boynton, Adria
Thanks for joining us today!

[Yesterday 4:04 PM] Fran Cigliano left the conversation.

[Yesterday 4:16 PM] Roy, Steven
thanks you everyone

[Yesterday 4:17 PM] Mark Young left the conversation.

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Virtual Community Resilience Building (CRB) Workshop Webinar
April 29, 2020 | 10:00-11:30AM
Microsoft Teams Meeting

Welcome and Introductions	5 minutes
MVP Program Overview	10 minutes
Overview of Hazards and Climate Change Data	15 minutes
Risk Matrix	15 minutes
Action Items	40 minutes
Wrap Up and Next Steps	5 minutes

Weston & Sampson

CITY OF LOWELL

Community Resilience Building (CRB) Workshop Webinar:

Natural Resources and Land Use

April 29, 2020

Weston & Sampson Photo: Merrimack River, Weston & Sampson

1

WELCOME FROM W&S AND RIVERMOOR ENERGY

ADRIA BOYNTON | STEVE ROY | INDRANI GHOSH | AMANDA KOHN | JOHN FREY | JOHN TOURTELOTTE

Weston & Sampson RIVERMOOR ENERGY Photo: Kinetic Sculpture Festival, W&S

2

WELCOME PARTICIPANTS

Weston & Sampson Photo: Kinetic Sculpture Festival, W&S

3

LOGISTICS

- This webinar is being recorded
- Overview of Microsoft Teams
  - Comment in the chat!
- Materials shared for comment:
  - Risk Matrix
  - Hazard Maps
- Materials shared for reference:
  - Critical facilities list
  - PDF of presentation
  - Agenda

4

WEBINAR OUTLINE

PRESENTATION:

- Overview of the MVP and HMP Programs
- Historic and Future Climate Change Impacts

DISCUSSION:

- Pre-Selected Hazards
- Pre-Selected Features
- Identify and Prioritize Action Items

Photo: City Facebook

5

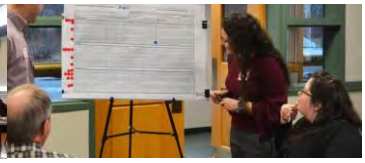
Municipal Vulnerability Preparedness Program

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

6

MVP Core Principles

- Furthering a community identified priority action to address climate change impacts.
- Utilizing best available climate change data for a proactive solution. Data from local-level climate change vulnerability studies may also be used.
- Employing nature-based solutions.
- Involving Environmental Justice Populations in meaningful decision-making, as defined and outlined in the 2017 EEA EJ Policy, and giving special consideration to Climate Vulnerable Populations.
- Achieving broad and multiple community benefits.
- Committing to monitoring project success and maintaining the project into the future.
- Utilizing regional solutions toward regional benefit.
- Pursuing approaches from which other MVP communities and the state can learn.



7

Planning GRANT

$15,000- $100,000 per plan
Some expanded scopes
$1M available

Action GRANT

Open to MVP communities
$25,000- $2M per project,
$5M regional projects
$10M available

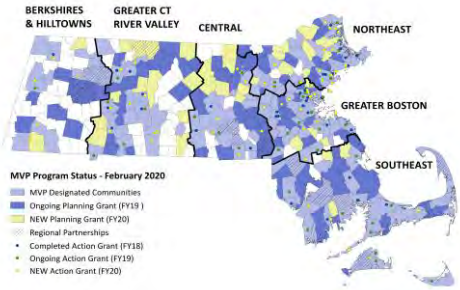
8

Three Years of MVP

MVP Designations
82% of the Commonwealth
287 communities

Action Grant Projects
FY 18: 37
FY 19: 36
FY 20: 54

Total Awards
$33M+ in planning and action grants to date



9

Action Grant Project Types

- Planning, Assessments, and Regulatory Updates
- Nature-based Solutions for Ecological and Public Health
- Resilient Redesigns and Retrofits for Critical Facilities and Infrastructure

10

Climate Data and Projections

11

What are Nature Based Solutions (NBS)?

Projects that **restore**, **protect**, and/or **manage** natural systems and/or mimic natural processes to address hazards like flooding, erosion, drought, and heat islands in ways that are **cost-effective**, **low maintenance**, and **multi-beneficial** for public health, safety, and well-being.

From - **Conserving Land** -
to - **Restoration** and **green stormwater management** -
And anything in between!

12

Outreach and Engagement

Climate change is felt amongst all populations, but it is most acutely felt within populations that have emitted the fewest GHG emissions

- Very young, by definition they have done the least
- Low Income
- Indigenous Communities
- Minority groups
- Differently-abled
- Incarcerated
- Queer community
- Unhoused

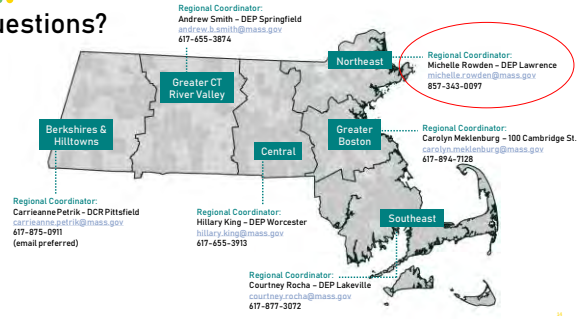
Yet, the data we have from the program does not indicate that these voices have been incorporated into planning projects

- Thousands of conversations have happened around the Commonwealth around the topic of Climate Change Mitigation and Adaptation…this is inherently good
- But we can bring in different voices

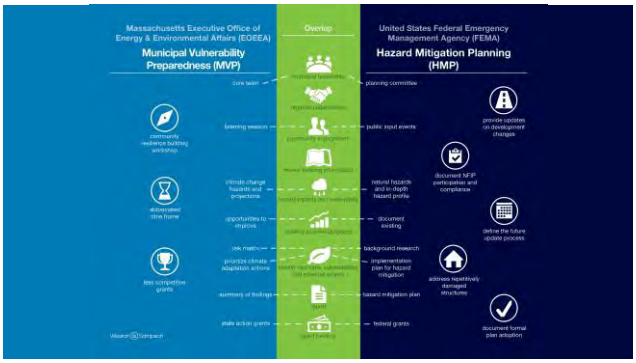
13

13

Questions?

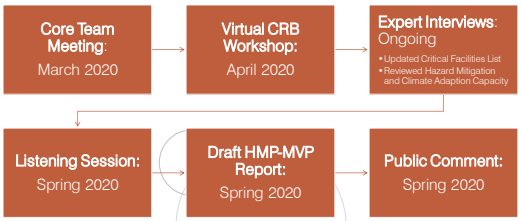


14



15

SCHEDULE



16

17

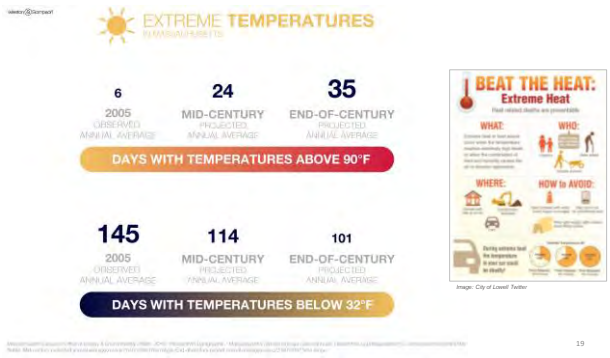
EXTREME TEMPERATURES

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

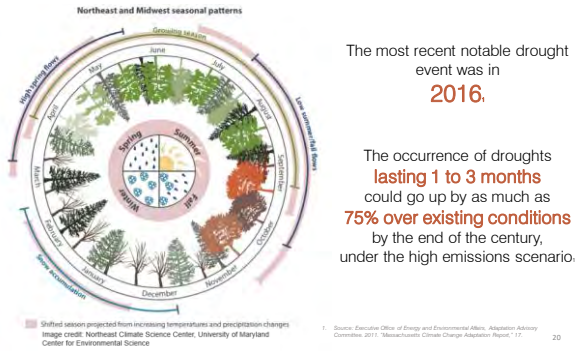
WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

Source: ResilientMA.org, "Rising Temperatures," 2017

18



19

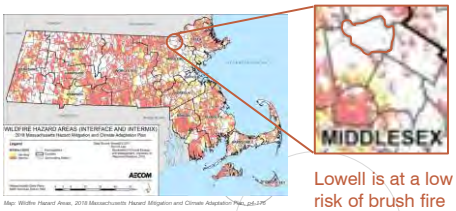


The most recent notable drought event was in **2016**.[1]

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

20

AS AN FYI: **BRUSH FIRE**



Map: Wildfire Hazard Areas, 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, pg.176

Lowell is at a low risk of brush fire

21

21

URBAN FIRE

CAUSES

- Human error and carelessness
- Density of development
- Leading causes of residential building fires in Lowell is cooking, followed by smoking
- Much of the housing stock are old, multi-family, wood buildings
- Many older structures lack sprinkler systems

DATA

- **522 fires** were reported during 2013
- **7 residents** perished in an apartment fire in 2014
- **80% of building fires** in Lowell occur in residential properties (mostly apartments)

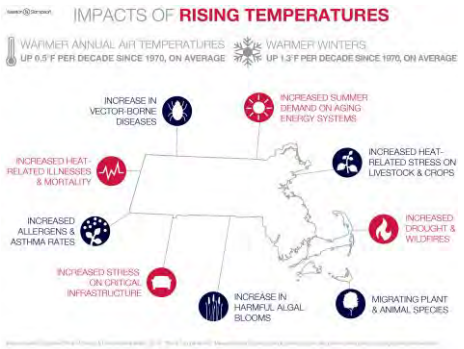
NEIGHBORHOODS MOST AT RISK OF FIRE

- The Acre
- South Lowell
- Centralville

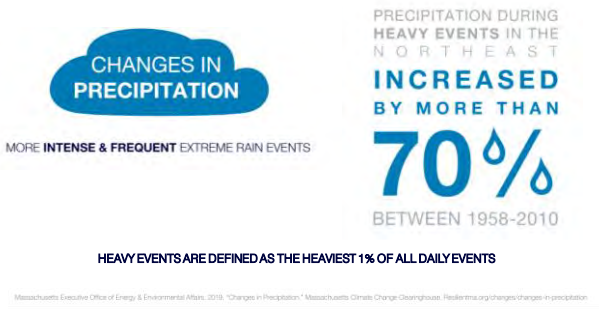
Sources: 2015 Regional HMP

22

22



23



24

EXTREME PRECIPITATION

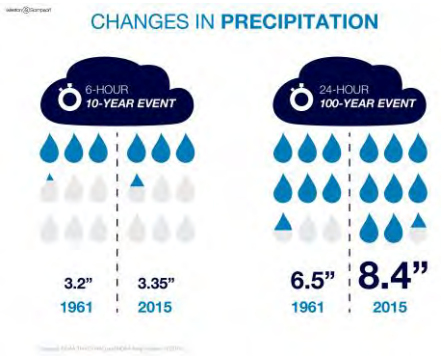
8%
Increase in extreme precipitation events by midcentury

13%
Increase in extreme precipitation events by 2100

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 19.

25

25



26

STORMWATER FLOODING

Areas with:
- Poor drainage
- High amounts of impervious surface
- Undersized culverts

City of Lowell Stormwater Management Webpage

27

27

LOCAL FLOODING NEAR WATERBODIES

- Northern banks of the Merrimack River near the Water Treatment Plant
- Land around Black Brook and the Trull Brook tributary between Phoenix Ave and Clark Road
- Areas in the 100-year floodplain along major waterways:
  - Concord River
  - Marginal Brook
  - River Meadow Brook
  - Beaver Brook
  - Clay Pit Brook (including floods in 2006 and 2007)
- Marsh along Wentworth Avenue
- The mouth of Black Brook
- The mouth of Marginal Brook

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

28

28

LOCAL FLOODING ALONG STREETS

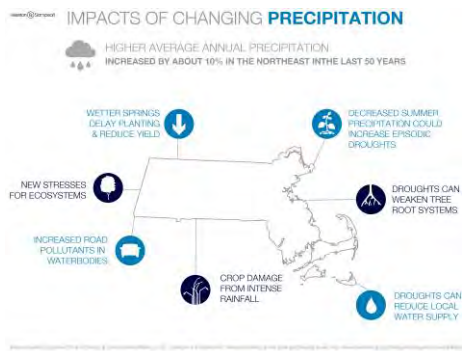
- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

A rainstorm in the summer of 2003 filled the Gorham and Moore Street intersection with up to 4' of water

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

29

29



30

30

WINTER STORMS

- The blizzard of 2013 left nearly 400,000 Massachusetts residents without power.
- "Heavy blizzards are among the most costly and disruptive weather events for Massachusetts communities."[2]
- Snowpack likely to decrease annually, but snowfall will occur with heavy intensity
- In the winter of 1995, snowfall in Lowell reached 126.5"
- Extended power outages, cost of snow removal, repairing damages, and loss of business can have a severe economic impact.
- The elderly and infirmed are populations of particular concern during these events.[3]

1. Resilient MA Climate Change Clearinghouse for the Commonwealth, "Extreme Weather," 2017
2. "Massachusetts State Hazard Mitigation and Adaptation Plan," 2018, P4-226
3. 2015 Regional HMP

Graphic: City of Lowell Twitter

31

HURRICANES AND NOR'EASTERS

Upward trend in North Atlantic hurricane activity since 1970

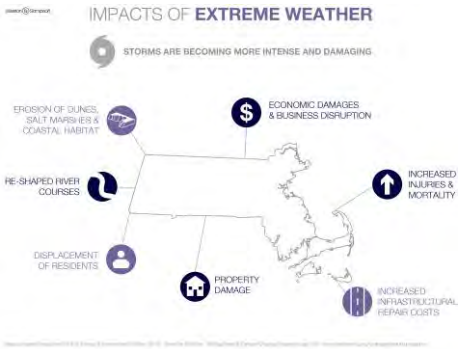
2012: Hurricane Sandy
2017: Hurricane Jose
2018: Hurricane Florence
2019: Hurricane Dorian

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

Jan 3-4, 2018: Winter Storm Grayson
March 2, 2018: Winter Storm Riley
March 8, 2018: Winter Storm Quinn
March 13, 2018: Winter Storm Skylar

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)/Northern Middlesex

32



33

Any questions
about climate hazards?

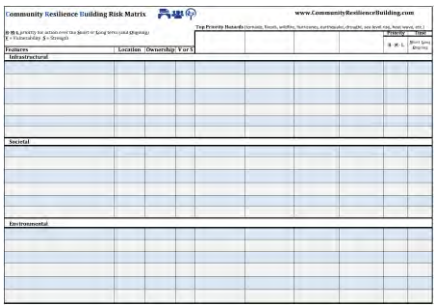
34

RISK MATRIX

Photo: City Facebook

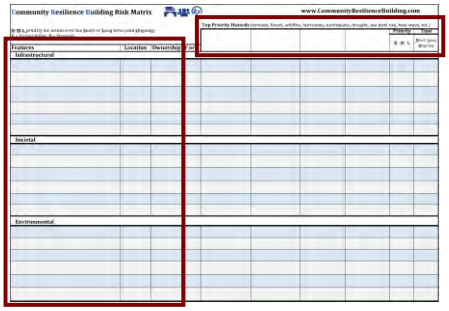
35

RISK MATRIX



36

RISK MATRIX: HAZARDS AND FEATURES



37

37

CLIMATE HAZARDS IN LOWELL

Flooding

Extreme Temperatures

Extreme Winter Weather

Wind and Microbursts

Weston & Sampson

38

38

FEATURES IN LOWELL

Photo: City Facebook

39

ENVIRONMENTAL FEATURES

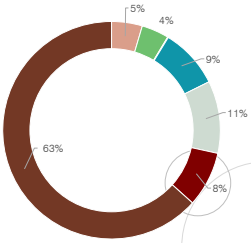
City of Lowell Open Space and Recreation Plan 2019-2023
Photo: Weston & Sampson

- 14.27 square miles
  - 13.38 square miles of land area
  - 0.89 square miles of surface water
- Major watersheds and waterways include the Merrimack and Concord Rivers
- Lowell-Tyngsborough State Forest includes 457 acres of land in Lowell
- River Meadow Brook crosses Westford, Chelmsford, and Lowell
- Beaver Brook crosses New Hampshire, Dracut, and Lowell

42

43

LAND USE



Weston & Sampson Sustainable Lowell 2025

44

44

ADAPTATION STRATEGIES: NATURAL RESOURCES

Photo by Weston & Sampson

47

ADAPTATION STRATEGY TYPES

48

48

RE-EVALUATE LOCAL REGULATIONS & POLICIES

- Floodplain Overlay District?
- Wetlands Ordinance?
- Stormwater Management Ordinance?
- Zoning Ordinance?

49

49

ADOPT NEW LOCAL REGULATIONS & POLICIES

TREE PROTECTION

GROUNDWATER PROTECTION

WATER SUPPLY PROTECTION

50

50

WETLAND RESTORATION

Wetlands in Troy, New York

51

51

LAND AQUISITION

As part of an MVP Action Grant, Mattapoisett purchased 120 acres of forest, streams, freshwater wetlands, and coastal salt marsh as conservation land to prevent development in vulnerable areas

Image from EOEAA, 2019

52

52

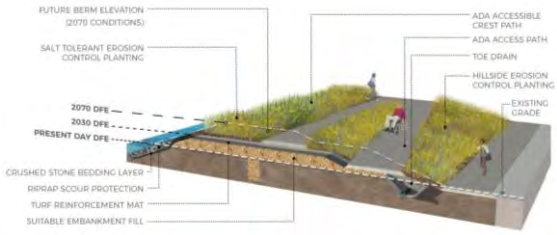
REMEDIATE CONTAMINATED SITES

Medfield State Hospital, Remediation along the Charles River

53

53

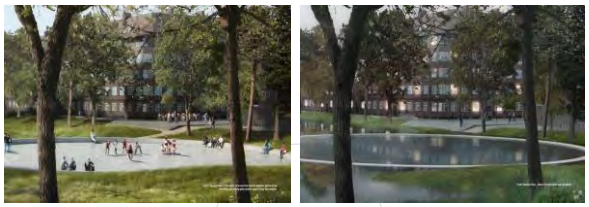
VEGETATED BERM



54

54

MULTI-PURPOSE FLOOD STORAGE



55

55

STORMWATER DETENTION & RETENTION

56

56

TREE TRIMMING OR MANAGEMENT PLAN

Tree species, placement, and maintenance recommendations by W&S for Ravena, NY

57

57

BANK RESTORATION & STABILIZATION

Live Crib Wall | Vegetated Retaining Wall | Joint Planting | Gabions

58

58

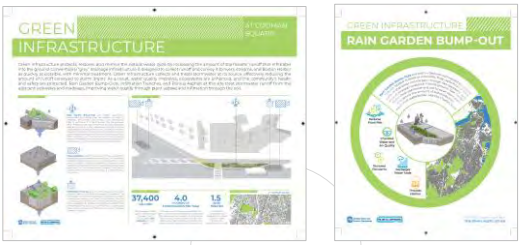
PUBLIC EDUCATION & OUTREACH

Tick Education Fact Sheet for Hopkinton, MA

59

59

EDUCATIONAL SIGNAGE



Green infrastructure signage by W&S for the Boston Water & Sewer Commission

60

60

REMOVAL OF INVASIVE SPECIES

Invasive Japanese Knotweed in Arlington, MA

61

61

City of Lowell
4/29/2020

Natural Resources

Organizers:

Adria Boynton
Indrani Ghosh
John Frey
Justin Gould
Amanda Kohn
Steve Roy

Attendees:

1. Celeste Bernardo
2. Chris Hayes
3. Christine Clancy
4. Fran Cigliano
5. Jane Calvin
6. Jared Alves
7. Jay Mason
8. Jeff Hillam
9. Katherine ?
10. Mark young
11. Rick Minard
12. Michelle Rowden (EEA)
13. Stephen Green
14. Susan Griffin
15. Yun-Ju Choi
16. Beth Lamber
17. Margaret McCarthy
18. Stephen Greene
19. Eric Lamarche
20. Diane Tradd
21. Alex Magee
22. Craig Thomas
23. Christine McCall
24. Magda Garncarz, Rep. Golden
25. +1 413-306-9043
26. +1 978-551-4432
27. +1 978-606-3419: Lisa
28. +1 978-674-4111
29. +1 978-674-4240
30. +1 978-674-4260: Henri Marchand

Notes & Comments

Active/strong feedback (theme of input):
Chris Hayes (All)
Celesete Bernardo (All)
Jared Alves (All, Beavers)
Alex Magee (All)
Christine Clancy (All)
Fran Cigliano (All)
Susan Griffin (Arborist)
Jay Mason (Grant sources, Community groups)
Diane Tradd (Trees)
Jane Calvin (Trees, Canals)
Christine McCall (Trees, Canopy)

General Consensus:
Climate adaptation to flooding is High Priority

Adding Canals to "Waterbodies" Designation *(maybe a good example to share is the C&O Canal Park in DC, currently being design by James Corner Field Operations)*

Many Strategies for Forest, Park and Street Trees – Still considered medium to high priority
(Chris Hayes mentioned "tree pit" dimensions and there is potential to expand the concept of connected street tree planters underneath sidewalks to make room for root development into a guidance document of new development strategies.

Hiring of an Arborist, either Town or Regional, to help with management and also future shading, resiliency goals

Future development is also a High Priority with a link included by Jared Alves about housing, affordability, and density
https://twitter.com/crschmidt/status/1212109720170971136

Meeting Chat

[9:39 AM] Boynton, Adria added Forms to the meeting.

[9:39 AM] Forms
Boynton, Adria created a poll
Results are visible to everyone; Names recorded

What's your favorite thing about Lowell?

- ☐ The public spaces
- ☐ The people
- ☐ The local businesses
- ☐ The community events

- ☐ Other (tell us in the chat!)

[9:40 AM] Boynton, Adria
Check out our online hazard map at: tinyurl.com/LowellMVPMap!

[9:45 AM] Susan Griffin, National Grid joined the meeting.

[9:51 AM] Katherine joined the meeting.

[9:57 AM] Chris Hayes joined the meeting.

[9:57 AM] Rowden, Michelle (EEA) joined the meeting.

[9:57 AM] William Garr joined the meeting.

[9:58 AM] William Garr left the conversation.

[9:58 AM] Fran Cigliano joined the meeting.

[9:59 AM] Rick Minard joined the meeting.

[9:59 AM] Jane Calvin joined the meeting.

[9:59 AM] Jeff Hillam joined the meeting.

[10:00 AM] Mark Young joined the meeting.

[10:01 AM] Jared Alves joined the meeting.

[10:01 AM] Yun-Ju Choi joined the meeting.

[10:01 AM] Bernardo, Celeste joined the meeting.

[10:01 AM] Christine Clancy joined the meeting.

[10:01 AM] Jay Mason joined the meeting.

[10:02 AM] Katherine
My favorite thing about Lowell: its unique character with its blending of old and new

[10:03 AM] diane tradd joined the meeting.

[10:03 AM] Stephen Greene joined the meeting.

[10:04 AM] Craig joined the meeting.

[10:04 AM] Alex Magee joined the meeting.

[10:04 AM] Eric Lamarche joined the meeting.

[10:06 AM] Chris Hayes
Please re-send the link. I think anyone who joined after something was shared in chat doesn't see it.

[10:07 AM] Chris Hayes
(At least I don't. :))

[10:08 AM] Boynton, Adria
Check out our online hazard map at: tinyurl.com/LowellMVPMap!

[10:09 AM] Boynton, Adria
Let me know if you can see the link now, Chris! Thanks for the heads-up

[10:09 AM] Chris Hayes
I can, thanks!

[10:13 AM] Christine McCall joined the meeting.

[10:14 AM] Jay Mason
I'm excited about the potential for the FUTURE Act to show Lowell's support for real MVP practices. The FUTURE Act once adopted, will allow municipalities like Lowell to work with NGrid to corrrect gas leaks, strengthen our interactions with the state DPU and incentivize infastructure for clean energy, such as District Energy (geo-thermal).

[10:37 AM] Jared Alves
I would separate the state forest/park trees from street trees

[10:37 AM] Jane Calvin
Location of tree canopy is city-wide

[10:37 AM] Fran Cigliano
Both public and private!

[10:39 AM] diane tradd
Identifying public tree canopy could increase ability for city to receive federal funding for tree planting

[10:39 AM] diane tradd
No that's fine.

[10:39 AM] Jane Calvin
add canalways and Clay Pit Brook to waterbody locations

[10:40 AM] Christine McCall
Is it possible to expand street trees to include Citywide canopy? We are losing a lot of canopy due to significant recent development

[10:41 AM] Christine Clancy
add in canals too in waterbodies if we didn't already

[10:42 AM] Christine Clancy
vulnerability, my mic won't unmute

[10:43 AM] Kohn, Amanda has left the meeting.

[10:45 AM] Christine Clancy
i agree

[10:45 AM] Jared Alves
vulnerability. We have few street trees

[10:46 AM] Christine Clancy
strength

[10:46 AM] Fran Cigliano
strength

[10:47 AM] Christine Clancy
agree

[10:47 AM] diane tradd
correct

[10:48 AM] Christine Clancy
agree - both

[10:48 AM] Jared Alves
Our site plan review regulations, etc. could directly address climate change adaptation/mitigation

[10:49 AM] Eric Lamarche left the conversation.

[10:50 AM] Jared Alves
Beavers, a protected species in MA, can be an species of concern because of their tendency to cause flooding by daming brooks/streams

[10:51 AM] Jared Alves
*damming

[10:51 AM] Christine Clancy
agree, agree with Jared's comment. DPW conducts constant maintenance on brooks due to beavers

[10:52 AM] Jay Mason

Should we consider teasing out invasives on one line, endangered species on another?

[10:53 AM] Jared Alves
Are we expecting invasive plants, like Japanese Knotweed, to thrive in our changing climate (if we become more like Atlanta's climate today)

[10:54 AM] Magda Garncarz, Rep. Golden's Office joined the meeting.

[11:00 AM] Craig left the conversation.

[11:06 AM] Chris Hayes
I guess you can't hear me. But

[11:06 AM] Jared Alves
Strengthen the local wetlands ordinance, e.g., increase the size of buffer zones and treat buffer zones as a protected area in their own right (MACC has ideas)

[11:07 AM] Jared Alves
Yes!

[11:07 AM] Chris Hayes
when we are doing trail projects, we are also doing bank restoration during those. I know of a bank restoration study on Merrimack River near LMA

[11:07 AM] Chris Hayes
And bank restoration is included in PFO

[11:07 AM] Jay Mason
Coordinate with dam operator for mitigation potentials.

[11:08 AM] Chris Hayes
I wonder if we should diversify funding sources, i.e., combine trail and bank mitigation sources

[11:08 AM] Chris Hayes
I don't know what kind of action item that would be

[11:09 AM] Chris Hayes
I think ownership of dams was discussed last webinar and the operators plans could be referenced

[11:09 AM] Christine Clancy
Yes, there is an emergency management plan that addresses some of that

[11:10 AM] Christine Clancy
but that could be reviewed and potentially improved

[11:10 AM] Jared Alves

Extreme weather events: Evaluate alternatives to excessive salting/sanding that can harm waterbodies and wetlands

[11:11 AM] Christine Clancy
also storage locations in cities and limitations near bodies of water

[11:11 AM] Christine Clancy
snow storage

[11:11 AM] Chris Hayes
Y'know, building on my comment, reporting/mapping all at-risk banks would help us prioritize these type of shared trail/bank projects?

[11:12 AM] Christine Clancy
yes, we have limited snow storage

[11:12 AM] Chris Hayes
Snow storage is also an impact on park/public spaces.

[11:13 AM] Chris Hayes
As the piled snow damages parks.

[11:16 AM] Christine Clancy
inventory of city tree canopy

[11:16 AM] Chris Hayes
Hiring arborist is something I've thought would be good from perspective of street trees

[11:16 AM] Jared Alves
Yes to hiring an aborist

[11:17 AM] Christine Clancy
and hiring of arborist, maybe shared regionally

[11:17 AM] Fran Cigliano
hiring an arborist

[11:17 AM] Christine Clancy
and inventory of street trees - in GIS

[11:17 AM] Chris Hayes
Find strategies for street trees to damage infrastructure. We've lost canopy because we've cut down mature trees to save sidewalks/neighboring buidlings.

[11:17 AM] Jared Alves
identify a list of preferred street tree and other tree species for new developments

[11:17 AM] Chris Hayes
And getting them to grow in the harsh urban conditions. Potential better tree pit development, etc.

[11:18 AM] Fran Cigliano
agreed to inventory of city/street trees - would be helpful to better understand and quantify how the inventory is evolving over time

[11:18 AM] Jane Calvin
or train existing staff to be certified as an arborist. There is at least one existing tree crew staffperson that has strong skills.

[11:18 AM] Fran Cigliano
Would be helpful to have stronger tree replacement requirements

[11:18 AM] Christine Clancy
identify city standard tree pruning and removal within ROW, and working around trees within ROW during construction

[11:19 AM] Jared Alves
Evaluate city tree ordinance and whether to include private trees in some capacity, especially for new development (e.g., replace 1:1 or pay into a tree fund)

[11:19 AM] Susan Griffin, National Grid
National Grid's arborist can assist with removal of hazard trees that threaten power lines and can also assist with a list of appropriate street trees.

[11:20 AM] Chris Hayes
Tree selection types, underground root barriers, stronger root paths away from infrastructure, newer sidewalk details that can accomodate some level of roots, and pruning are probably some things.

[11:21 AM] Chris Hayes
Stricter adherence/informcement of our existing ordinance

[11:21 AM] Chris Hayes
Enforcement

[11:22 AM] Chris Hayes
Also, the salt question can also be a question of impact to trees, not just water

[11:22 AM] Chris Hayes
For winter weather

[11:23 AM] Jared Alves
Parks: add splash pads, shade trees, etc. to cope with extreme heat events

[11:24 AM] Chris Hayes
Evaluate waterside park infrastructure for flood-resistance

[11:24 AM] Fran Cigliano
Focus tree planting in environmental justice neighborhoods/public spaces where tree canopy is most scarce

[11:25 AM] Chris Hayes
Public education on benefits of trees?

[11:25 AM] Jeff Hillam
Hey all, this was a great call. Thanks for putting it together. I have a hard stop in a few minutes. So I have to hop off the call. All the best. Look forward to continue communicating.

[11:25 AM] Fran Cigliano
agreed with Chris ^

[11:25 AM] Jeff Hillam left the conversation.

[11:25 AM] Jane Calvin
Can South Common be modified for flood storage?

[11:26 AM] Christine Clancy
action item could be to develop maintenance plan amongst various stakeholders

[11:26 AM] Fran Cigliano
investigate whether Lowell can participate in Greening the Gateway cities program - its a DCR grant program.

[11:28 AM] Rowden, Michelle (EEA) left the conversation.

[11:28 AM] Christine McCall
Thank you! I will be leaving right at 11:30A.

[11:30 AM] Christine Clancy
develop prioritization plan and estimated level of efforts to cleanup contaminated sites

[11:30 AM] Jay Mason
Identify grant sources for testing sites.

[11:31 AM] Jay Mason left the conversation.

[11:31 AM] Christine McCall left the conversation.

[11:32 AM] Christine Clancy left the conversation.

[11:32 AM] Jane Calvin left the conversation.

[11:32 AM] Jared Alves
Allow incremental increases in density in Lowell to avoid greenfield housing development in Lowell and outside the city's boundaries. This thread is instructive:
https://twitter.com/crschmidt/status/1212109720170971136

[11:34 AM] Jared Alves
Evaluate minimum parking requirements and consider setting maximums instead (city starting a parking study this year)

[11:35 AM] Jay Mason joined the meeting.

[11:36 AM] Jay Mason
Was neighborhood groups mentioned. The Friends of Tyler Park do this.

[11:36 AM] Chris Hayes
I have to say, having trained supervision on volunteer teams is super-helpful.

[11:37 AM] Chris Hayes
There's a huge difference when someone from Jane's organization is shepherding volunteers. I wonder if we can expand this?

[11:37 AM] Alex Magee
The city does coordinate with the state on mosquito spraying - continuing this would be good in general especially in years that have bad EEE and WNV

[11:38 AM] Jared Alves
Increase city expertise to evaluate developments and recommend native plant species/removal of invasives

[11:38 AM] Alex Magee
A guidance document on beaver related maintenance, with best practices on dam maintenance/removal, beaver deceiver installation, etc.

[11:38 AM] Fran Cigliano
agree with jared on native plant species training/education

[11:38 AM] diane tradd left the conversation.

[11:41 AM] Alex Magee
I would say in general waterbodies and wetlands are a high priority, with different priorities lying within each sub category

[11:42 AM] Alex Magee
Considering their potential widespread impacts from weather events I would go further to say water body should be our highest priority

[11:42 AM] Chris Hayes
I'd ask whether there should be a priority on issues for Environmental Justice neighborhoods for each feature.

[11:43 AM] Chris Hayes
Nothing specific in mind, just more general.

[11:44 AM] Alex Magee
I think all water related issues need to be met with at least middle and long term responses and planning

[11:46 AM] Alex Magee
I would place trees in general as a medium priority

[11:47 AM] Alex Magee
Id say ongoing with trees

[11:47 AM] Fran Cigliano
i think trees should be at least mid-priority, improvements to tree canopy are high visibility and provide multiple aesthetic/health/water quality benefits

[11:48 AM] Chris Hayes
Anything that prevents losing assets might be higher priority. I.e., losing a mature tree, having a water impact are harder or impossible to reverse

[11:48 AM] Alex Magee
I see it

[11:48 AM] Jared Alves
What are the time frames for short/long/ongoing? We need to start planting trees today to have benefits years from now

[11:50 AM] Jared Alves
For any of the policy actions, we should probably be updating them within the next 1-3 years

[11:51 AM] Alex Magee
I would place parks/public spaces in medium priority as well

[11:51 AM] Jared Alves
short term works

[11:51 AM] Alex Magee
agreed

[11:51 AM] Jared Alves
yes

[11:52 AM] Fran Cigliano
yes, short term

[11:53 AM] Alex Magee
I would say this is location specific - some areas much lower priority than others based on geography, contamination, exposure risk, etc

[11:53 AM] Jared Alves
Lower priority?

[11:53 AM] Fran Cigliano
ongoing

[11:54 AM] Alex Magee
High priority, short/long/ongoing I think on this category

[11:54 AM] Jared Alves
^ agree with Alex

[11:54 AM] Jay Mason left the conversation.

[11:54 AM] Fran Cigliano
high priority

[11:54 AM] Alex Magee
correct, development

[11:56 AM] Alex Magee
low/medium I would say when compared with others on the list

[11:56 AM] Fran Cigliano
agree with Alex

[11:56 AM] Jared Alves
Agree

[11:56 AM] Jared Alves
Ongoing

[11:56 AM] Fran Cigliano
some could be short-term

[11:56 AM] Alex Magee
ongoing I think, this is an annual problem

[11:56 AM] Rick Minard left the conversation.

[11:57 AM] Alex Magee
low/mdium as well

[11:57 AM] Fran Cigliano
yes, low/medium

[11:57 AM] Jared Alves
agree

[11:57 AM] Alex Magee
the beaver issues do cause problems for our pawtucketville residents

[11:57 AM] Alex Magee
such as flooding etc. so for a specific group of residents they are a real annual issue

[11:58 AM] Alex Magee
shortterm and ongoing

[11:58 AM] Jared Alves
agree

[11:58 AM] Alex Magee
if we had a guiding policy document we could point to it would help I think

[11:58 AM] Jared Alves
Right because we're already installing beaver deceivers today, but it would be nice to summarize best practices

[11:59 AM] Alex Magee
^ yes

[11:59 AM] Alex Magee
Beaver vendors are surprisingly hard to find as well

[11:59 AM] Alex Magee
so this is just a tricky, time sensitive, hard problem for us to deal with

[12:00 PM] Jared Alves
None from me, thank you!

[12:00 PM] Alex Magee
Thanks Adria and others at WS, appreciate it

[12:00 PM] Chris Hayes
Thank you!

[12:00 PM] Jared Alves left the conversation.

[12:00 PM] Stephen Greene left the conversation.

[12:00 PM] Katherine left the conversation.

[12:01 PM] Fran Cigliano
Thank you for your time!

[12:01 PM] Boynton, Adria
Thanks everyone for joining us today!

[12:01 PM] Fran Cigliano left the conversation.

[12:01 PM] Magda Garncarz, Rep. Golden's Office left the conversation.

[12:01 PM] Susan Griffin, National Grid
Efficient and well organized session. Nice job!

[12:01 PM] Susan Griffin, National Grid left the conversation.

[12:01 PM] Chris Hayes left the conversation.

[12:01 PM] Boynton, Adria
Thanks for joining us Susan!

[12:01 PM] Alex Magee left the conversation.

[12:05 PM] Mark Young left the conversation.

Meeting ended 2h 31m 12:05 PM

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Virtual Community Resilience Building (CRB) Workshop Webinar
April 30, 2020 | 2:00-3:30PM
Microsoft Teams Meeting

Welcome and Introductions	5 minutes
MVP Program Overview	10 minutes
Overview of Hazards and Climate Change Data	15 minutes
Risk Matrix	15 minutes
Action Items	40 minutes
Wrap Up and Next Steps	5 minutes

Weston & Sampson

CITY OF LOWELL

Community Resilience Building (CRB) Workshop Webinar:

Community Health and the Economy

April 30, 2020

Weston & Sampson Photo: Merrimack River, Weston & Sampson

1

WELCOME FROM W&S AND RIVERMOOR ENERGY

ADRIA BOYNTON

STEVE ROY

INDRANI GHOSH

AMANDA KOHN

JOHN FREY

JOHN TOURTELOTTE

Weston & Sampson RIVERMOOR ENERGY Photo: Kinetic Sculpture Festival, W&S 2

2

WELCOME PARTICIPANTS

Weston & Sampson Photo: Kinetic Sculpture Festival, W&S 3

3

LOGISTICS

- This webinar is being recorded
- Overview of Microsoft Teams
  - Tell us what your favorite thing about Lowell is in the chat!
- Materials shared for comment:
  - Risk Matrix
  - Hazard Maps: tinyurl.com/LowellMVPMap!
- Materials shared for reference:
  - Critical facilities list
  - PDF of presentation
  - Agenda

4

WEBINAR OUTLINE

PRESENTATION:

- Overview of the MVP and HMP Programs
- Historic and Future Climate Change Impacts

DISCUSSION:

- Pre-Selected Hazards
- Pre-Selected Features
- Identify and Prioritize Action Items

Photo: City Facebook

5

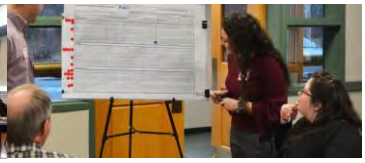
Municipal Vulnerability Preparedness Program

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

6

MVP Core Principles

- Furthering a community identified priority action to address climate change impacts.
- Utilizing best available climate change data for a proactive solution. Data from local-level climate change vulnerability studies may also be used.
- Employing nature-based solutions.
- Involving Environmental Justice Populations in meaningful decision-making, as defined and outlined in the 2017 EEA EJ Policy, and giving special consideration to Climate Vulnerable Populations.
- Achieving broad and multiple community benefits.
- Committing to monitoring project success and maintaining the project into the future.
- Utilizing regional solutions toward regional benefit.
- Pursuing approaches from which other MVP communities and the state can learn.



7

Planning GRANT

$15,000- $100,000 per plan
Some expanded scopes
$1M available

Action GRANT

Open to MVP communities
$25,000- $2M per project,
$5M regional projects
$10M available

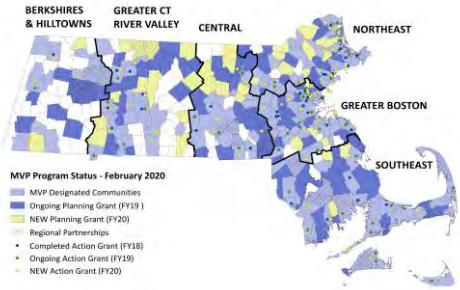
8

Three Years of MVP

MVP Designations
82% of the Commonwealth
287 communities

Action Grant Projects
FY 18: 37
FY 19: 36
FY 20: 54

Total Awards
$33M+ in planning and action grants to date



9

Action Grant Project Types

- Planning, Assessments, and Regulatory Updates
- Nature-based Solutions for Ecological and Public Health
- Resilient Redesigns and Retrofits for Critical Facilities and Infrastructure

10

Climate Data and Projections

11

What are Nature Based Solutions (NBS)?

Projects that **restore**, **protect**, and/or **manage** natural systems and/or mimic natural processes to address hazards like flooding, erosion, drought, and heat islands in ways that are **cost-effective**, **low maintenance**, and **multi-beneficial** for public health, safety, and well-being.

From - **Conserving Land** -
to - **Restoration** and **green stormwater management** -
And anything in between!

12

Outreach and Engagement

Climate change is felt amongst all populations, but it is most acutely felt within populations that have emitted the fewest GHG emissions

- Very young, by definition they have done the least
- Low Income
- Indigenous Communities
- Minority groups
- Differently-abled
- Incarcerated
- Queer community
- Unhoused

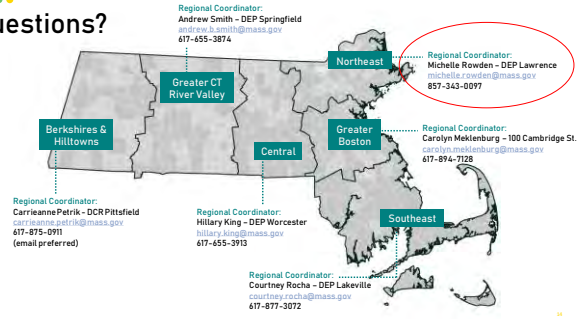
Yet, the data we have from the program does not indicate that these voices have been incorporated into planning projects

- Thousands of conversations have happened around the Commonwealth around the topic of Climate Change Mitigation and Adaptation…this is inherently good
- But we can bring in different voices

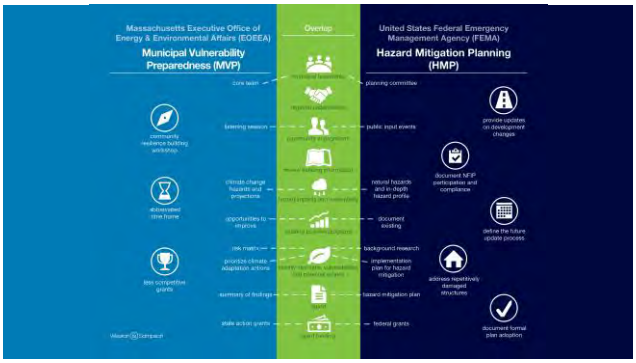
13

13

Questions?

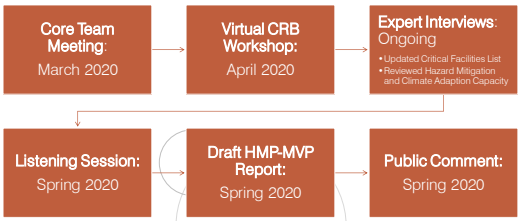


14



15

SCHEDULE



16

17

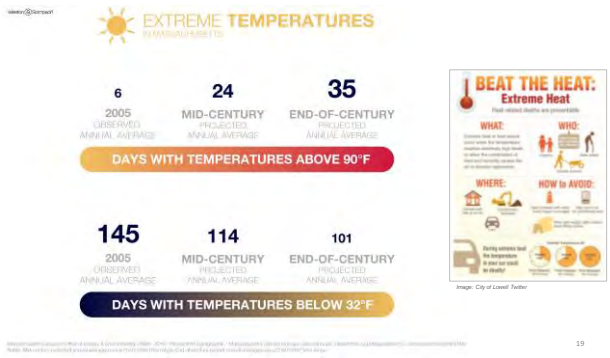
EXTREME TEMPERATURES

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

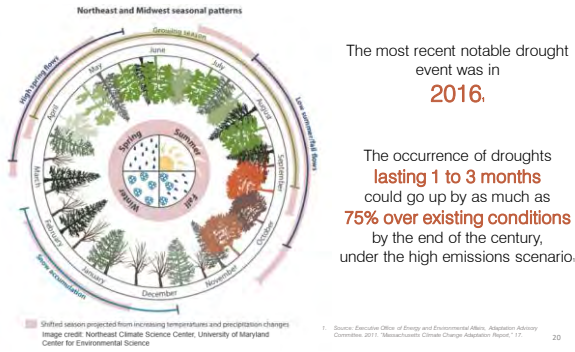
WARMER WINTERS
UP 1.3°F PER DECADE SINCE 1970, ON AVERAGE

Source: ResilientMA.org, "Rising Temperatures," 2017

18



19

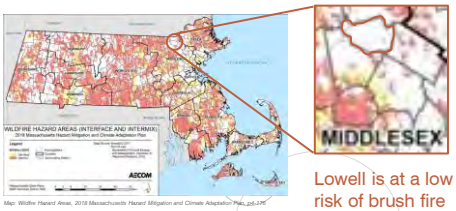


The most recent notable drought event was in **2016**.[1]

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

20

AS AN FYI: **BRUSH FIRE**



Map: Wildfire Hazard Areas, 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan, pg.176

Lowell is at a low risk of brush fire

21

21

URBAN FIRE

CAUSES

- Human error and carelessness
- Density of development
- Leading causes of residential building fires in Lowell is cooking, followed by smoking
- Much of the housing stock are old, multi-family, wood buildings
- Many older structures lack sprinkler systems

DATA

- **522 fires** were reported during 2013
- **7 residents** perished in an apartment fire in 2014
- **80% of building fires** in Lowell occur in residential properties (mostly apartments)

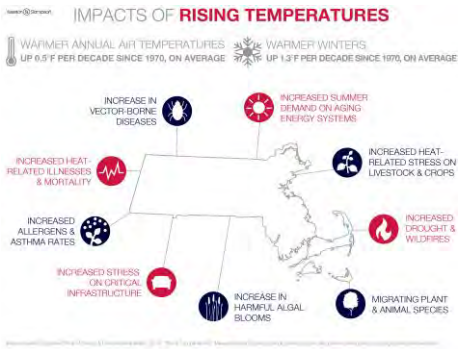
NEIGHBORHOODS MOST AT RISK OF FIRE

- The Acre
- South Lowell
- Centralville

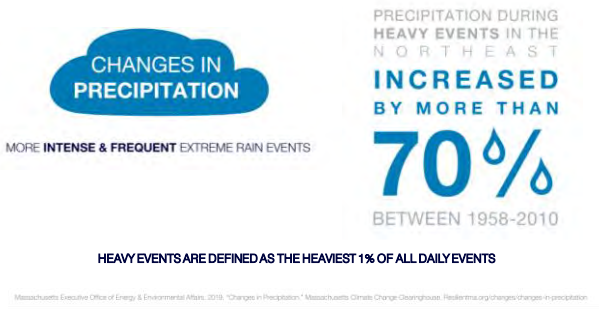
Sources: 2015 Regional HMP

22

22



23



24

EXTREME PRECIPITATION

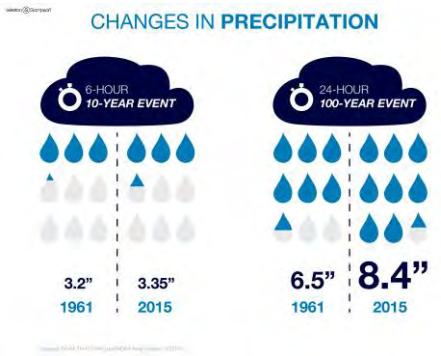
8%
Increase in extreme precipitation events by midcentury

13%
Increase in extreme precipitation events by 2100

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 19.

25

25



26

STORMWATER FLOODING

Areas with:
- Poor drainage
- High amounts of impervious surface
- Undersized culverts

City of Lowell Stormwater Management Webpage

27

27

LOCAL FLOODING NEAR WATERBODIES

- Northern banks of the Merrimack River near the Water Treatment Plant
- Land around Black Brook and the Trull Brook tributary between Phoenix Ave and Clark Road
- Areas in the 100-year floodplain along major waterways:
  - Concord River
  - Marginal Brook
  - River Meadow Brook
  - Beaver Brook
  - Clay Pit Brook (including floods in 2006 and 2007)
- Marsh along Wentworth Avenue
- The mouth of Black Brook
- The mouth of Marginal Brook

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

28

28

LOCAL FLOODING ALONG STREETS

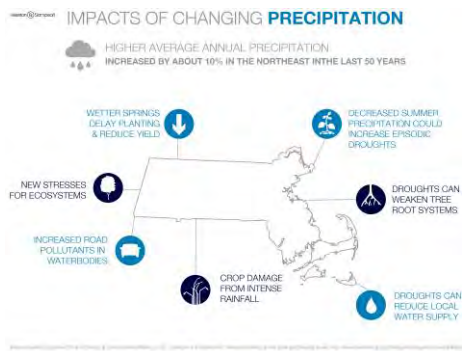
- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

A rainstorm in the summer of 2003 filled the Gorham and Moore Street intersection with up to 4' of water

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

29

29



30

30

WINTER STORMS

- The blizzard of 2013 left nearly 400,000 Massachusetts residents without power.
- "Heavy blizzards are among the most costly and disruptive weather events for Massachusetts communities."[2]
- Snowpack likely to decrease annually, but snowfall will occur with heavy intensity
- In the winter of 1995, snowfall in Lowell reached 126.5"
- Extended power outages, cost of snow removal, repairing damages, and loss of business can have a severe economic impact.
- The elderly and infirmed are populations of particular concern during these events.[3]

1. Resilient MA Climate Change Clearinghouse for the Commonwealth, "Extreme Weather," 2017
2. "Massachusetts State Hazard Mitigation and Adaptation Plan," 2018, P4-226
3. 2015 Regional HMP

Graphic: City of Lowell Twitter

31

HURRICANES AND NOR'EASTERS

Upward trend in North Atlantic hurricane activity since 1970

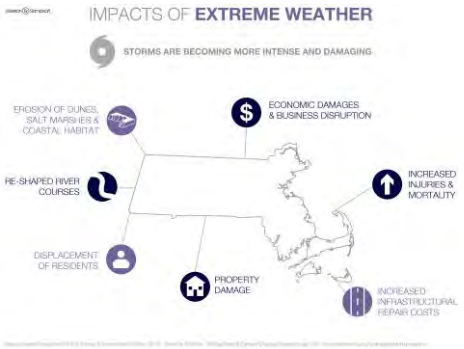
2012: Hurricane Sandy
2017: Hurricane Jose
2018: Hurricane Florence
2019: Hurricane Dorian

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

Jan 3-4, 2018: Winter Storm Grayson
March 2, 2018: Winter Storm Riley
March 8, 2018: Winter Storm Quinn
March 13, 2018: Winter Storm Skylar

Source: Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)/Northern Middlesex

32



33

Any questions
about climate hazards?

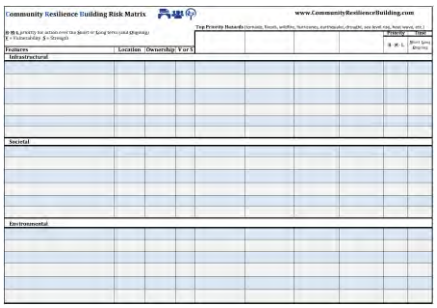
34

RISK MATRIX

Photo: City Facebook

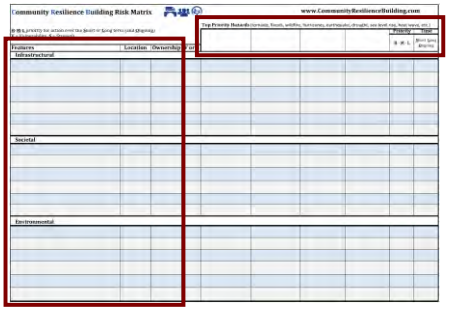
35

RISK MATRIX



36

RISK MATRIX: HAZARDS AND FEATURES



37

CLIMATE HAZARDS IN LOWELL

Flooding

Extreme Temperatures

Extreme Winter Weather

Wind and Microbursts

Weston & Sampson

38

FEATURES IN LOWELL

Photo: City Facebook

39

SOCIETAL FEATURES

Population	Lowell	Massachusetts
2018	111,670 residents	6,902,149
2010	106,528 residents	6,547,790
Age		
Under 18 years	21.8%	19.8%
65+ years	10.6%	16.5%
Economics		
Median household income, 2014-2018	$51,987	$77,378
Persons in poverty	20.7%	10.0%
Additional Information		
Bachelor's degree or higher:	23.0%	42.9%
With a disability	9.0%	7.9%
Language other than English spoken at home	43.5%	23.6%

Source: U.S. Census Bureau, "Quick Facts: Lowell City, Massachusetts."

45

SOCIETAL FEATURES

- There are 428 public safety personnel in Lowell.
- Lowell is home to the second largest Cambodian refugee population in the U.S.[2]
- The Lowell Office of Cultural Affairs and Special Events plans yearly community events, including:
  - 4th of July Celebration
  - Monster Bash
  - City of Lights Parade & Celebration
  - Winterfest
  - St. Patrick's Day Dinner

1. 2015 Regional HMP
2. Cambodian Mutual Assistance Association of Greater Lowell, Inc.

Photo: Weston & Sampson

46

ADAPTATION STRATEGIES: COMMUNITY RESILIENCE

Photo by Weston & Sampson

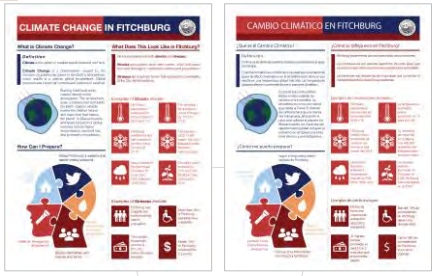
47

ADAPTATION STRATEGY TYPES

48

49

TRANSLATING MATERIALS



50

MULTI-PRONGED APPROACH

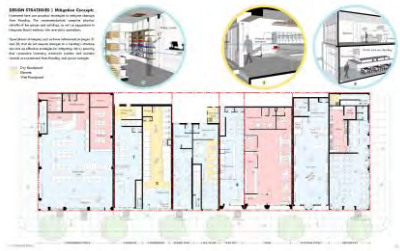
51

PUBLIC HEALTH

- Wellness checks
- Database of residents at risk of isolation
- Community Emergency Response Teams (CERT)
- Mobile markets
- Housing upgrades and investment

52

LOCAL BUSINESSES

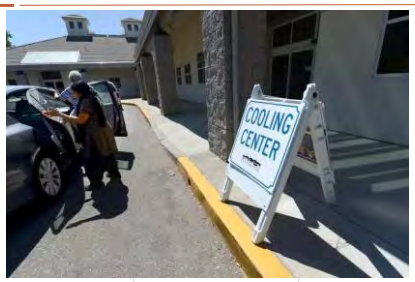


53

WORK WITH VOLUNTEERS

54

SHELTERS, HEATING AND COOLING CENTERS



55

RENEWABLE ENERGY/MICRO-GRIDS

56

ADDITIONAL ADAPTATION STRATEGIES

57

RIVERMOOR ENERGY

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

April 30, 2020

To: Adria Boynton, Weston & Sampson
Cc: Amanda Kohn, Weston & Sampson
Cc: Steve Roy, Weston & Sampson

RE: Rivermoor's Notes from April 30 "Lowell MVP Workshop for Community Health and the Economy"

Community Health and the Economy:

- **Risk and Isolation of Residents during extreme weather events & other social disruptions**
  - Marianne: Concerned about communications to communities at risk of isolation during extreme weather events
  - Need for increased literacy training for underserved communities
  - Jared: Idea of a truck with loud speakers to broadcast community updates and guidance in multiple languages
  - Chris: Leverage non-profit networks to work with community during periods of stress
  - Simplify outreach using pictures, infographics, and share information verbally through trusted social & community networks

- **Vulnerable Populations**
  - Populations who have challenges adapting to social stress, extreme weather, etc.
  - Low-income communities
  - Environmental justice communities
  - Homeless population
  - English as a second language populations and communities

- **Diverse Populations which are English as a 2nd Language (ESL)**
  - Should City hire more social workers / community workers who can provide translation services and outrage in native languages?
  - There is a need for more translation of City communications and materials

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

- Michelle: Leverage non-profit community partners to help in this area
  - Non-Profit Alliance of Greater Lowell: https://npalowell.org/members/
  - Lowell Community Partners: https://www.lowellma.gov/1122/Community-Partners

- **Services that community non-profit partners can provide:**
  - Tree planting
  - Training and outreach in working with diverse populations and ESL populations
  - Lowell Park & Recreation Department: youth outreach and camps, etc.
  - Public art to communicate important themes such as flooding risk in low-lying neighborhoods
  - Wellness calls by local non-profits and community organizations to vulnerable populations, elderly, low-income, etc.?
  - Danielle: Lowell Park & Recreation Trust manages "planting days" in Lowell. Merrimack Valley Housing Partnership plants a new tree for each new resident who moves in

- **Energy Resiliency**
  - Chris: Lowell should invest in energy resiliency and microgrids to protect critical city services to older neighborhoods and to help with the impacts of flooding. Flood prevention measures are also needed.
  - Christine: Review city emergency generators and also privately-owned critical services
    - What are the needs at critical facilities?
    - Needs assessment
    - Katherine Moses: says she agrees this should be done / is a need
    - See more below under "local businesses" / grocery

- **Public Schools**
  - Lowell should develop strategies to have schools help with community outreach by having students communicate with parents who may be ESL
  - Beverly: Social service and faith-based organizations can help schools with this effort

John H. Tourtelotte
Managing Director

Riverside Center
275 Grove Street, Suite 2-400
Newton, MA 02466

(617) 680-5136

- **Flooding:**
  - Identify neighborhoods that may be cut off from communities and City services due to flooding

- **Housing and Eviction Support:**
  - Jared Alves: create a strategy and/or fund to provide short-term financial support to prevent eviction

- **Local Businesses:**
  - Question by facilitator Amanda Kohn: Are "toolkits" for businesses needed to inform Lowell citizens on how to obtain essential services? (May include grocery, pharmacy, healthcare, childcare, fresh water, etc.)
  - Christine of Lowell says that she likes this idea.
    - Also, short term financial support for local businesses during extreme events or social disruption (pandemic) is needed
  - Beverly: During severe winter storms, mobile generators and refrigerated trucks are brought in to support local grocery stores and other local essential businesses. Opportunity to plan this in a more organized way?
  - Christine: Review city emergency generators and also privately-owned critical services
    - What are the needs at critical facilities?
    - Needs assessment
    - Katherine Moses: says she agrees this should be done / is a need

- **Community Shelters**
    - Update City's Existing Emergency Management Plan
    - Christine: rank facilities as high needs, ongoing needs, short-term needs, etc.
    - Microgrids could be put in place for shelters and neighborhood services for energy resiliency
    - Cooling centers, heating centers, emergency shelters, meals, community gathering points, etc.

Lowell MVP
April 30, 2020

Societal Webinar

Attendees

1. Chris Hayes 2. Christine McCall 3. Danielle McFadden 4. Eric Lamarche 5. Fran Cigliano 6. John T 7. Katherine Moses 8. Lil Hartman 9. Magda Garncarz– on phone 10. Maryann Ballotta 11. Michelle Rowden	12. Yun-Jun Choi 13. Jared Alves 14. Henry – on phone 15. Mark Young – on phone 16. Beverly Woods 17. Adria Boynton 18. Amanda Kohn 19. Alex Magee 20. Christine Clancy 21. Celeste Bernardo 22. Allison Lamey

7 people on phone (including Henry, Mark, Madga, Allison, and Eric)

Meeting Notes

Favorite Things about Lowell

- Greater Lowell Chamber of Commerce - I am a lifelong resident of Lowell and what I love the most about it is the people and the partnerships!
- The immigrant history is my favorite part of Lowell.
- The people!

Risk Matrix Discussion – V & S

- Added non-profit community
- Housing stock, built environment
    - At risk of flooding or other hazard
    - Low income house is critical, but was not the focus of the comment.
- Shelter list
    - Senior Center is the FEMA designated shelter. The high school is under construction, but they thought the plan would be to make it shelter.
    - Tsongas Center is a disaster too.
    - "When I went to Lowell High School, we would evacuate to the Tsongas Arena"
- At risk of isolation

Strategies

- John—food pantries, food pickup, etc?

    - I believe the the Lowell Public School system has designated stations where they are handing out meals to students on a daily basis, but not sure about specific locations.
    - yes, I believe so. I cannot speak to this directly
    - The Merrimack Valley Food Bank is an important resource
    -
- We might be missing our health dept/ public health colleagues on this call--and their knowledge about existing strengths/weaknesses--if they are tied up with the COVID response
    - The Merrimack Valley Food Bank is an important resource
    - The City's new Health Director just started last week I believe
    - Mill City Grows has a mobile farmers market that could be expanded if needed
    - Definitely think a fact sheet RE vector-bourne diseases would be helpful!

Michelle—planting trees and engaging community in planting and edu.

Mural on flood risk. Planting trees to reduce urban heat in key places.

Meeting Chat

[1:47 PM] Boynton, Adria
Welcome to Lowell's MVP webinar on Community Health and the Economy!

[1:47 PM] Boynton, Adria
Tell us in the chat what your favorite thing about Lowell is.

[1:47 PM] Boynton, Adria
And check out our online hazard map at: tinyurl.com/LowellMVPMap

[1:48 PM] John Tourtelotte joined the meeting.

[1:55 PM] Eric Lamarche joined the meeting.

[1:55 PM] Magda Garncarz (Rep. Golden's Office) joined the meeting.

[1:56 PM] Danielle McFadden joined the meeting.

[1:56 PM] Christine McCall joined the meeting.

[1:56 PM] Katherine Moses joined the meeting.

[1:56 PM] Rowden, Michelle (EEA) joined the meeting.

[1:57 PM] Chris Hayes joined the meeting.

[1:57 PM] Christine McCall
The people!

[1:58 PM] Danielle McFadden
Danielle McFadden - Greater Lowell Chamber of Commerce - I am a lifelong resident of Lowell and what I love the most about it is the people and the partnerships!

[1:58 PM] Chris Hayes
The immigrant history is my favorite part of Lowell.

[1:59 PM] Maryann Ballotta joined the meeting.

[1:59 PM] Fran Cigliano joined the meeting.

[2:00 PM] Lil Hartman joined the meeting.

[2:00 PM] Yun-Ju Choi joined the meeting.

[2:00 PM] Danielle McFadden
yes

[2:00 PM] Chris Hayes
Yes

[2:01 PM] Jared Alves joined the meeting.

[2:01 PM] Mark Young joined the meeting.

[2:04 PM] Beverly Woods joined the meeting.

[2:09 PM] Alex Magee joined the meeting.

[2:09 PM] Christine Clancy joined the meeting.

[2:10 PM] Bernardo, Celeste joined the meeting.

[2:14 PM] Allison Lamey joined the meeting.

[2:20 PM] Alex Magee
Id like to thank Michelle for joining us!
(1 liked)

[2:21 PM] Rowden, Michelle (EEA)
Thanks for having me Alex!

[2:25 PM] Danielle McFadden left the conversation.

[2:25 PM] Danielle McFadden joined the meeting.

[2:35 PM] Alex Magee
can you prompt the question one more time?

[2:35 PM] Alex Magee
someone has their scanner going!

[2:36 PM] Danielle McFadden
Does the nonprofit community fit somewhere?

[2:39 PM] Danielle McFadden
Yes

[2:39 PM] Alex Magee
yes

[2:39 PM] Chris Hayes
Yes

[2:40 PM] Chris Hayes
Maybe both?

[2:40 PM] Danielle McFadden
I agree

[2:40 PM] Katherine Moses
Yes

[2:40 PM] Alex Magee
yes

[2:40 PM] Lil Hartman
This column feels confusing. Can we skip it?

[2:40 PM] Maryann Ballotta
Agree

[2:40 PM] Mark Young
yes

[2:44 PM] Kohn, Amanda
Lil Hartman -- is this conversation helping reduce confusion?

[2:45 PM] Alex Magee
The Tsongas Center is a disaster shelter as well

[2:46 PM] Alex Magee
some kind of classification I think

[2:46 PM] Lil Hartman
The senior center is primary shelter, not sure if my voice came through

[2:46 PM] Lil Hartman
FEMA-designated

[2:46 PM] Alex Magee
Yes it did Lil

[2:46 PM] Fran Cigliano
When I went to Lowell High SChool, we would evacuate to the Tsongas Arena

[2:46 PM] Alex Magee
ok

[2:47 PM] Beverly Woods
vulnerability

[2:47 PM] Christine McCall
I agree with Beverly

[2:47 PM] Jared Alves
Yes

[2:47 PM] Maryann Ballotta
Also agree

[2:48 PM] Jared Alves
vulnerability

[2:48 PM] Maryann Ballotta
I think it's a vulnerability

[2:48 PM] Katherine Moses
Agree

[2:48 PM] Mark Young
Vulnerability

[2:49 PM] Christine McCall
strength

[2:49 PM] Beverly Woods
strength

[2:49 PM] Maryann Ballotta

strength

[2:49 PM] Christine McCall
vulnerability

[2:49 PM] Fran Cigliano
vulnerability

[2:50 PM] Danielle McFadden
Strength

[2:50 PM] Beverly Woods
strength

[2:50 PM] Katherine Moses
Strength

[2:50 PM] Maryann Ballotta
Agree

[2:50 PM] Allison Lamey
AGree

[2:51 PM] Beverly Woods
both

[2:51 PM] Allison Lamey
Both!

[2:51 PM] Danielle McFadden
Both

[3:03 PM] Beverly Woods
homeowner/public education

[3:04 PM] Beverly Woods
you captured it well

[3:05 PM] Maryann Ballotta
Can you repeat the question please

[3:05 PM] Christine Clancy
yes, I believe so. I cannot speak to this directly

[3:05 PM] Christine Clancy
but we can follow up on that

[3:06 PM] Fran Cigliano
I believe the the Lowell Public School system has designated stations where they are handing out meals to students on a daily basis, but not sure about specific locations.

[3:06 PM] Chris Hayes
Are insects (mosquitoes) a problem spreading disease? This isn't my area of speciality

[3:07 PM] Jared Alves
We might be missing our health dept/ public health colleagues on this call--and their knowledge about existing strengths/weaknesses--if they are tied up with the COVID response

[3:07 PM] Fran Cigliano
Good point Jared

[3:08 PM] Chris Hayes
Good thought, Jared!

[3:08 PM] Fran Cigliano
The Merrimack Valley Food Bank is an important resource

[3:08 PM] Maryann Ballotta
The City's new Health Director just started last week I believe

[3:09 PM] Beverly Woods
Mill City Grows has a mobile farmers market that could be expanded if needed

[3:09 PM] Fran Cigliano
Definitely think a fact sheet RE vector-bourne diseases would be helpful!

[3:10 PM] Chris Hayes
It seems like including something about insect control might be useful, but I don't know what.

[3:10 PM] Chris Hayes
I know City did spraying in previous years.

[3:11 PM] Alex Magee
we will be doing mosquioto spraying this year

[3:11 PM] Kohn, Amanda
Do you know if Lowell is a part of a mosquito control district?

[3:11 PM] Alex Magee
City coordinates through state for program

[3:12 PM] Alex Magee

Should we mention the homeless shelter? Privately owned by SMOC

[3:13 PM] Alex Magee
Added space during extreme cold events

[3:13 PM] Alex Magee
added staff during biohazard/pandemics as we are seeing now

[3:13 PM] Maryann Ballotta
I believe the shelter could use a lot of what you mentioned

[3:13 PM] Lil Hartman
We're hoping to install alarms to trigger when our food storage temps get high (power/equipment failures).

[3:13 PM] Jared Alves
Short-term shelters during power outages caused by snow and/or brown out caused by heat

[3:13 PM] Alex Magee
surge capacaity when they need to space guests out

[3:13 PM] Alex Magee
or really any public health emergency I suppose

[3:14 PM] Alex Magee
senior center

[3:15 PM] Chris Hayes
Do we have written communication policy for announcing heat/cooling station? And for other community announcements of a similar nature?

[3:15 PM] Chris Hayes
I think Manager's office does good job, but something that could continue through administrations, shared by various departments?

[3:15 PM] Chris Hayes
Just curious thought/question

[3:16 PM] Katherine Moses
Possible strengthening of emergency generators for shelter with potential power outages for longer durations.

[3:16 PM] Alex Magee
emergency manager (fire cheif) is in charge of these calls typically in coordination with LPD and Managers office

[3:16 PM] Alex Magee
answer to Jared's comms question

[3:17 PM] Alex Magee
Typically they come in a press release which goes to lcoal media

[3:17 PM] Alex Magee
and then is shared on website and social media

[3:17 PM] Jared Alves
What about contingency plans to access necessary supplies, including food?

[3:17 PM] Alex Magee
I guess I am not sure how to do that - any ideas out there?

[3:18 PM] Maryann Ballotta
In regards to communications, what about having a formal plan in place with LTC, radio, tv shows when we need to get the messages out through a variety of avenues?

[3:19 PM] Christine Clancy
leveraging with other organization groups. Developing that contact/distribution list

[3:19 PM] Alex Magee
yes I think formalizing this effort we already do now

[3:19 PM] Katherine Moses
Agree

[3:19 PM] Alex Magee
typically things are shared to WCAP and LTC now

[3:19 PM] Danielle McFadden
The Chamber can definitely help with that too.

[3:20 PM] Maryann Ballotta
We need to leverage our partners in the city to help get the information out

[3:20 PM] Allison Lamey
Information needs to be translated into multiple languages for those with limited English proficiency

[3:20 PM] Jared Alves
Spreading information through Variable messaging signs, sandwich boards, etc. so not just digital/TV. Just heard about a community in Florida that is alerting migrant farmworkers about COVID dangers in several languages using a truck with loudspeakers

[3:21 PM] Maryann Ballotta

That's in reference to preparing in those at risk of isolation

[3:21 PM] Chris Hayes
Limited literacy is also a problem

[3:21 PM] Alex Magee
Jared's been listening to NPR!

[3:21 PM] Christine McCall
Didn't Boston do that, too?

[3:22 PM] Jared Alves
Haha I love NPR

[3:22 PM] Jared Alves
Yup! to Christine's question

[3:22 PM] Alex Magee
Yes Boston is doing it as well

[3:22 PM] Christine McCall
I love NPR, too!

[3:23 PM] Chris Hayes
Oh interesting. I was just thinking about continuing to leverage our nonprofit networks.

[3:23 PM] Christine Clancy
good idea, but also important that any developed literature try to simplify items when possible to pictures

[3:23 PM] Chris Hayes
To share information verbally.

[3:23 PM] Chris Hayes
Oh good idea Christine

[3:23 PM] Fran Cigliano
I agree with Christine about focusing on photos/visuals

[3:24 PM] Rowden, Michelle (EEA)
Is the EJ community included in this topic

[3:24 PM] Jared Alves
What about the city hiring in-house translators for Khmer, Spanish, etc.

[3:25 PM] Katherine Moses

Would this also include those with ?disabilities

[3:25 PM] Lil Hartman
HHS now has LanguageLine for translation

[3:25 PM] Katherine Moses
Sorry. I missed that.

[3:26 PM] Danielle McFadden
Lowell Parks and Conversation Trust does this.

[3:26 PM] Danielle McFadden
Conservation

[3:27 PM] Christine McCall
Lowell Parks and Conservation Trusts partners with Merrimack Valley Housing Partnership and plants a new tree for every new homeowner; I think that is a cool model we could try to scale

[3:27 PM] Allison Lamey
Lowell Parks and Conservation Trust offers tree planting for new homeowners and with city projects! They're a great resource

[3:27 PM] Christine McCall
Allison and Danielle -- great minds!

[3:27 PM] Chris Hayes
I have a 3:30 to get to, but when you get to it, is there a possibility of investigating micro-grants for climate resiliency (advanced fire resiliency, floodproofing, energy efficiency, flood mitigation strategies) for housing, including (critically) our denser, older housing in the inner neighborhoods?

[3:28 PM] Beverly Woods
How about partnering with the schools as a means of getting information to the parents? Many times the children are more English proficient and serve as an information conduit for parents.

[3:29 PM] Chris Hayes
Thanks!

[3:29 PM] Chris Hayes left the conversation.

[3:30 PM] Alex Magee left the conversation.

[3:30 PM] Christine McCall left the conversation.

[3:31 PM] Beverly Woods
Using the social service and faith-based organizations to provide support to the homeless

[3:31 PM] Jared Alves
Some informal housing is in flood prone areas, so the city could evaluate identifying areas for people to erect tents in safer, designated areas. I believe some communities in CA have experimented with this

[3:32 PM] Christine Clancy
there is an emergency management plan, but I think reviewing that plan and expanding upon it for various hazards/risks will be beneficial to the City

[3:33 PM] Rowden, Michelle (EEA) left the conversation.

[3:33 PM] Jared Alves
Short-term tenant support if an extreme weather event prevents them from working and puts them at greater risk of eviction

[3:35 PM] Christine Clancy
toolkits for businesses are a good idea

[3:35 PM] Jared Alves
Agree on short-term support for local businesses too

[3:35 PM] Katherine Moses
Agree

[3:35 PM] Beverly Woods
during severe winter storms with an extended power outage, mobile generators and refrigerated trucks have been utilized

[3:35 PM] Lil Hartman
Database of at-risk populations (seniors living alone for example) shared with emergency service providers and senior center. Wellness calls

[3:36 PM] Beverly Woods
businesses-particularly grocery stores

[3:37 PM] Christine Clancy
one more idea for municipal and emergency services- review available City resources for emergency generators and if there is more of a need/redundancy

[3:37 PM] Katherine Moses
Agree

[3:38 PM] Allison Lamey
My apologies but I have to jump off. Thank you.

[3:38 PM] Kohn, Amanda

Thanks Allison

[3:39 PM] Beverly Woods
high

[3:40 PM] Christine Clancy
agree

[3:40 PM] Beverly Woods
agree

[3:40 PM] Maryann Ballotta
agree

[3:40 PM] Jared Alves
For local businesses: Assess ability of local businesses to contribute to different crisis responses, e.g., a local Lowell business has been sewing masks and gowns to contribute to the COVID response. We have several businesses opening marijuana cultivation facilities, could these shift to food production in a crisis, to help sustain food banks?

[3:40 PM] Eric Lamarche left the conversation.

[3:40 PM] Christine Clancy
high, ongoing, short term

[3:40 PM] Katherine Moses
Agree

[3:40 PM] Maryann Ballotta
Yes, agree

[3:40 PM] Beverly Woods
agree

[3:41 PM] Mark Young
Agree

[3:41 PM] Maryann Ballotta
I'm sorry, I'm going to have to jump off also. Thank you

[3:41 PM] Maryann Ballotta left the conversation.

[3:42 PM] Katherine Moses
High. Short term and ongoing

[3:42 PM] Jared Alves

Yes

[3:42 PM] Danielle McFadden
Very sorry - I have to hop off.

[3:42 PM] Danielle McFadden left the conversation.

[3:43 PM] Jared Alves
Agree

[3:43 PM] Katherine Moses
Agree

[3:43 PM] Christine Clancy
high, ongoing, short

[3:43 PM] Katherine Moses
Agree

[3:43 PM] Christine Clancy
sorry have to jump off

[3:44 PM] Jared Alves
agree

[3:44 PM] Katherine Moses
Agree

[3:44 PM] Christine Clancy left the conversation.

[3:45 PM] Beverly Woods
medium/ongoing

[3:45 PM] Jared Alves
Medium, ongoing

[3:45 PM] Allison Lamey left the conversation.

[3:45 PM] Jared Alves
High, ongoing

[3:45 PM] Beverly Woods
agree

[3:46 PM] Jared Alves
Thank you!

[3:46 PM] Mark Young left the conversation.

[3:46 PM] Jared Alves left the conversation.

[3:46 PM] Fran Cigliano left the conversation.

[3:46 PM] Katherine Moses left the conversation.

[3:47 PM] Magda Garncarz (Rep. Golden's Office) left the conversation.

[4:11 PM] Lil Hartman left the conversation.

Meeting ended 2h 31m 4:13 PM

Community Resilience Building Risk Matrix

www.CommunityResilienceBuilding.org

H-**M**-**L** priority for action over the **S**hort or **L**ong term (and **O**ngoing)
V = Vulnerability **S** = Strength

Top Priority Hazards (tornado, floods, wildfire, hurricanes, earthquake, drought, sea level rise, heat wave, etc.)

Features	Location	Ownership	V or S	Flooding	Extreme Winter Weather	Wind and Microbursts	Extreme Temperatures	Priority H - M - L	Time Short Long Ongoing
Infrastructural									
Energy resilience	City-wide	Municipal	V/S		Increase insulation of multi-family housing. Need to warming stations.	Renewable microgrid to support existing backup.	Need for cooling stations.	M	L (with some short-term opportunities)
Communications (fiber optic, internet, phone, cell)	City-wide	Municipal communications (CodeRED), Twitter	V/S	Expand outreach to vulnerable populations. Increase use of CodeRED. Continue use of social media, partner with local organizations with existing communications to their members (leverage existing networks). Assess alternative methods for residents without landlines or access to internet.				M	S and Long-term goals
Public buildings (including schools)	Multiple buildings	Municipal	V	Assess relative threat of public buildings to climate impacts. Plan for the needs (energy to operate, floodproofing, relocate building and services)	Salt shed - roof needs repair.			M	L (salt shed is short-term)
Roads, bridges, and public transit	City-wide	Federal State, Municipal, Private	V	Identify bridges at risk and have an emergency plan for each.	Revisit plan for snow removal. Publish and make a more formal emergency plan.	Update tree pruing and maintenance program to proactively remove hazardous	Giant Hogweed near rail lines off of Boylston- flowers cause sores. Increase education and	H	S/L depending on goals
Water supply and distribution	City-wide	Municipal	S - source, V- distribution/aging infrastructure	Invest capital in aging infrastructure. Water Plant Intake Station at flood risk - floodproof station.	Protect distribution system from freeze/thaw cycle. Have resources in place to address breaks when they become evident. Assess and track "hot spots" with more frequent breaks and identify a solution			H	O/S/L depending on item
Stormwater system (drainage system, culverts, catch basins)	City-wide (there are some areas that are not a vulnerability) (Culverts near Clay Pitt Brook)	Public	V	Culverts near Clay Pitt Brook -- assess existing conditions. Assess and map the entire drainage system. Assess maintenance program for flooding caused by beavers, work with beaver consultant, study best practices for beaver deceivers and other methods. Ensure appropriate capacity and size of catch basins in vulnerable areas. continue to encourage low impact development (infiltration bains, rain gardens) and assess options for regulatory mechanisms.				H	S/O
Wastewater infrastructure	City-wide	Municipal	S - recent upgrades, financial investment, V - collection system is vulnerable	Vulnerable pump and combined sewer overflow stations (Tildon St PS and Rosemont St PS) - assess for floodproofing. Combined outfalls need backflow prevention		Update emergency generator at the Water Utility (consider options for PV/battery storage systems). Integrate new battery storage to existing PV array and backup generator at the Water Treatment Plant (one resilient system that could operate independently from the grid). Similar approach at Wastewater Plant would decrease vulnerability to black outs or brownouts		H	L
Canal system and walls	City-wide	Multiple (City does not own)	V - age	Inventory and assessment of the walls, identify needed repairs. Public outreach and education related to trash removal from/not throwing trash in canals. FERC is re-licensing and conducting studies - review those materials and participate in that process proactively.				H	S - smaller assessments , L - overall assessment
Dams and gate houses (Pawtucket gate house and Francis Gate)	8 dams in Lowell	DCR, City, Hull Street Energy, Centennial Island Hydroelectric. Gate houses are maintained by Park Service	S - dams that are re-certified, V - some gate houses' age and condition	Assess/model impact of the 500-year flood on the gate houses and develop an overall response plan. Earthen dam near Beaver Brook Bridge - address vulnerabilities.				H (high risk, high priority)	S - 500-year modeling, L - implementation
Societal									
Public health (vector-borne diseases)	City-wide	N/A	V	Homeowner/public education related to risks of ticks, etc., and how to protect yourself. Expand the Mill City Grows mobile farmers market. Fact sheet on vector borne diseases. Insect control, continue mosquito spraying.				H	O

Shelters	City-wide (high school, senior center, homeless shelter owned by SMOC)	Public, Private	V/S		Homeless shelter needs added space during extreme cold events. Inventory of supplies, additional staff, volunteers, and training. Short-term shelters during power outages caused by snow and/or brown out caused by heat. Contingency plans to access necessary supplies, including food.	Possible strengthening of emergency generators for shelter with potential power outages for longer durations. Formal plan in place with LTC, radio, tv shows, the Chamber, when we need to get the messages out through a variety of avenues. leveraging with other organization groups. Developing that contact/distribution list	Homeless shelter added staff during biohazard/pandemics. Install alarms at Senior Center and schools to trigger when our food storage temps get high (power/equipment failures). Surge capacaity when they need to space guests out or any public helath emergency.	H	O/S
At risk of isolation (could include seniors, children, residents with disabilities, residents with limited English proficiency)	City-wide	N/A	V	Leverage our partners in the city to help get the information out. Translate information into multiple languages for those with limited English proficiency. Spreading information through variable messaging signs, sandwich boards, etc. so not just digital/TV. Potentially make announcments in several languages using a truck with loudspeakers. Continue to leverage nonprofit networks to address limited literacy. Simplify outreach using accessible visuals and share information verbally. City hiring in-house translators for Khmer, Spanish, etc. Create streamlined translation effort. Leverage the existing HHS Language Line resource. Partnering with the schools as a means of getting information to the parents. Developing a database of at-risk populations (seniors living alone for example) shared with emergency service providers and senior center. Conducting wellness calls.				H	O/S
Challenges to prepare or adapt (could include low-income residents, residents experiencing homelessness)	City-wide	N/A	V	Some informal housing is in flood prone areas: City could evaluate identifying areas for people to erect tents in safer, designated areas. Assess best practices, including communities in CA have experimented with this, and make a plan.	Using the social service and faith-based organizations to provide support to the homeless			H	O/S
Municipal and emergency services	City-wide	N/A	S	Update existing emergency management plan.	Review available City resources and capacity for emergency generators.			H	O/S
Housing (low income and other)	Locations vulnerable to climate impacts	Multiple	V	Investigating micro-grants for climate resiliency (advanced fire resiliency, floodproofing, energy efficiency, flood mitigation strategies) for housing, including (critically) our denser, older housing in the inner neighborhoods. Short-term tenant support if an extreme weather event prevents them from working and puts them at greater risk of eviction.				H	O/S
Non-profit community	City-wide	N/A	S	Volunteer, community, and training programs and planting days for street trees. Coordinate with parks and recreation, Lowell Parks and Conservation Trust.				M	O
Local businesses	City-wide	Private	V/S	Share toolkit: how to improve your resilience as a business. Provide short-term support for local businesses.	during severe winter storms with an extended power outage, mobile generators and refrigerated trucks have been utilized - continue and		Assess ability of local businesses to contribute to different crisis responses, e.g., a local Lowell business has been sewing masks and	H	O
Environmental									
Waterbodies and wetlands	Merrimack and Concord Rivers, River Meadow Brook, Beaver Brook, Canalways/Canals, Clay Pit Brook, Black Brook, Flaggies Brook	Multiple	V	Update our floodplain overlay district. Strengthen the local wetlands ordinance, e.g., increase the size of buffer zones and treat buffer zones as a protected area in their own right. Study best practices, including recommendations from MACC. Coordinate with dam operator for mitigation potential. How are they controling canal levels during floods? Plan for flood mitigation that coordinates with Hydropower entity, seek opportunities for reviewing and improving plan. Seek diverse funding sources for trail and bank mitigation projects. Map all at-risk banks to	Evaluate alternatives to excessive salting/sanding that can harm waterbodies and wetlands. Identify snow storage locations in cities and limitations near bodies of water. Identify snow storage options for private landowners and provide education and outreach related to potentially harmful impact of dumping snow near waterbodies.			H	M/L
State forest and park trees	Lowell-Tyngsborough State Forest and other	Multiple (including DCR)	V/S			identify city standard tree pruning and removal within ROW, and working around trees within ROW during construction		M/H	O

Street trees and citywide tree canopy	City-wide	Both public and private	V	Develop better tree pit development, etc. to encourage growth in harsh urban conditions.	Evaluate options to minimize impact of salt from winter weather on trees	**Inventory of city tree canopy in GIS - evaluate changes over time.** Hire a City Arborist, potentially shared regionally, or train existing staff to be certified as an arborist. Create a replacement plan for lost trees along with funding source. Strengthen tree replacement requirements. Evaluate city tree ordinance and whether to include private trees in some capacity, especially for new development (e.g., replace 1:1 or pay into a tree fund). Work with the National Grid's arborist to assist with removal of hazard trees that threaten power lines and can also assist with a list of appropriate street trees. Tree selection types, underground root barriers, stronger root paths away from infrastructure, newer	identify a list of preferred street tree and other tree species for new developments. Public education on benefits of trees.	M/H	S/O
Parks and public spaces	City-wide (Eastern Canal Park, Lelacheur Park, JFK Plaza, National Park, and others)	Public, DCR	S	Evaluate waterside park infrastructure for flood-resistance. Evaluate parks along roadways and waterways to increase LID stormwater management to alleviate flooding. Incorporate educational component. Assess opportunities for South Common to be modified for flood storage.	Identify snow storage locations that avoid damaging parks.	Develop maintenance plan amongst various stakeholders	Add splash pads, shade trees, etc. to cope with extreme heat events. Focus tree planting in environmental justice neighborhoods/public spaces where tree canopy is most scarce.investigate whether Lowell can participate in Greening the Gateway cities program (DCR grant program)	M	S
Contaminated sites	Silresim Superfund Site, multiple brownfield sites	Public	V	Where applicable, cleanup of existing soil and cap to avoid infiltration, protect from flooding, and provide expanded floodplain. develop prioritization plan and estimated level of efforts to cleanup contaminated sites. Identify grant sources for testing sites.				Varies - L priority for some locations	O
Development and land use regulations	City-wide	Multiple	S/V	Better integrating Stormwater Team standards with Planning Office regulations. Allow incremental increases in density in Lowell to avoid greenfield housing development in Lowell and outside the city's boundaries. Evaluate minimum parking requirements and consider setting maximums instead.				H	S/L/O
Invasives	City-wide	N/A	V	Education and outreach with visual materials re: specific species common in Lowell and their impacts (for public and City staff). Work with neighborhood groups to remove invasives (for example, the Friends of Tyler Park). Expand resources and provide trained supervision as a resource for volunteer teams. Continue the city's coordination with the state on mosquito spraying				L/M	O/S
Endangered species	Lowell-Tyngsborough State Forest and other	N/A	S/V	Increase city expertise to evaluate developments and recommend native plant species/removal of invasives. A **guidance document** on beaver related maintenance, with best practices on dam maintenance/removal, beaver deceiver installation, etc. Summarize best practices based on current work, and include information on beaver vendors				L/M	S/O

***Prioritize issues to environmental justice neighborhoods across features**

Lowell Community Resilience Building Pre-Workshop Survey

As a leader in our community, we are sure that you are busier than ever. Thank you for taking the time to fill out this survey. Your experience, ideas, and comments will improve our planning process as we analyze the potential for future climate impacts and look at the historic consequences of natural hazard events. #ResilientLowell

This survey will be available until April 30, 2020. If you have additional input, questions, or barriers to participating, please contact Adria Boynton (Resiliency Specialist at Weston & Sampson) at boyntona@wseinc.com or (978) 278-3592.

1. What climate hazard are you most concerned about? Rank the following options, with the first option being the hazard you are most concerned about.
   - ___ Extreme temperatures
   - ___ Flooding
   - ___ Winter weather (snowstorms, blizzards)
   - ___ Ice storms
   - ___ Drought
   - ___ Fire
   - ___ Severe wind (nor'easter, tornado, thunderstorm)
   - ___ Not applicable to me (I am a representative from a surrounding community)

2. How have these climate hazards impacted you or your department or the City more broadly? Memories of climate hazards could include impacts from:

   - flooding of local roads
   - drought conditions in 2016
   - four Nor'easters in one month in 2018
   - heat waves with multiple days over 90 degrees F

Short answer response

3. How prepared do you feel Lowell is for extreme climate hazard events?
   - ☐ Very prepared
   - ☐ Somewhat prepared
   - ☐ Not prepared
   - ☐ Not applicable to me (I am a representative from a surrounding community)
   - ☐ Other

4. Please explain your reason for selecting your answer in Question 3.

Short answer response

5. What does Lowell do well to to mitigate climate hazards or prepare for climate change? Examples could include, but are not limited to:

   - City shelters, warming centers, and cooling centers
   - Regional collaboration, including Mutual Aid Agreements with Police Departments in neighboring communities

Short answer response

6. What are the opportunities to address potential natural or climatic hazards? Examples could include, but are not limited to:

   - Providing transportation to shelters for vulnerable populations, including elderly and low-income residents
   - Addressing frequently flooded roads, including Gorham Street or Wentworth Avenue

Short answer response

7. What resources does your department need to be more prepared?
   - ☐ Funding for climate adaptation projects
   - ☐ Staff and training
   - ☐ Supplies or equipment
   - ☐ Additional guidance related to department operations before, during, and after a hazard event
   - ☐ Data or studies showing the projected impacts of future climate hazards in Lowell
   - ☐ Not applicable to me (I am a representative from a surrounding community)
   - ☐ Other

8. How does your department share information with the public?
   - ☐ Public events, including virtual webinars
   - ☐ Printed media, including reports, fact sheets, or brochures
   - ☐ Online, including through the City website, Facebook, and Twitter
   - ☐ Strategic outreach to specific populations, such as elderly residents or other groups
   - ☐ Not applicable to me (I am a representative from a surrounding community)
   - ☐ Other

9. We recognize the preparation and response to any challenge in our community has overlapping strategies and challenges. We are interested in documenting the community experience of COVID-19. What worked well, and what could improve?

Short answer response

10. Are there any additional comments or questions you would like to share with the project team?

Short answer response

11. Thank you for completing the survey. Please enter your name below.

Short answer response

Pre-Workshop Survey Responses

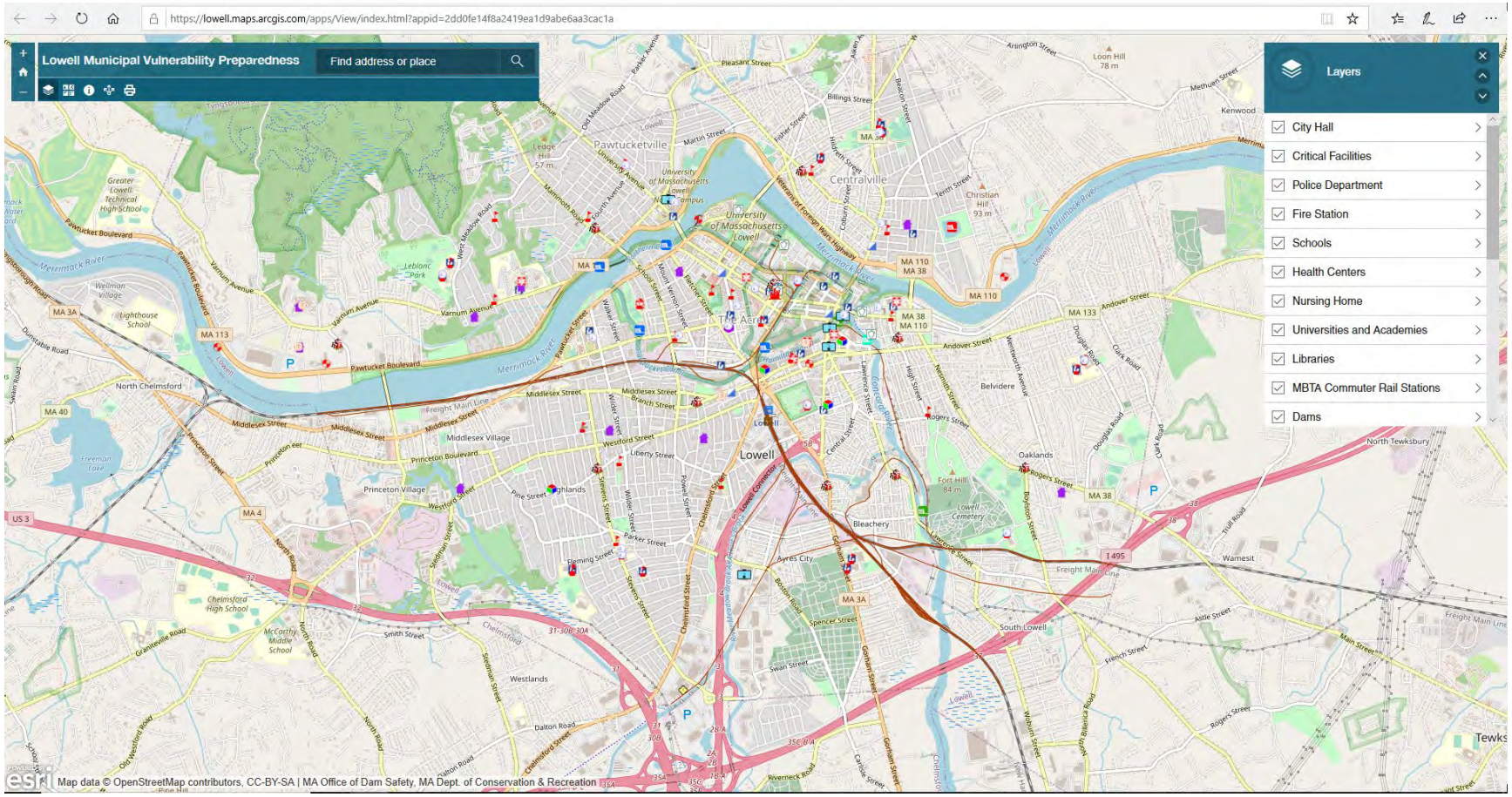
What climate hazard are you most concerned about?	How have these climate hazards impacted you or your department or the City more broadly? Memories of climate hazards could include impacts from: - flooding of local roads - drought conditions in 2...	How prepared do you feel Lowell is for extreme climate hazard events?
	Lowell has experienced all of these extremes, requiring substantial investment from municipal, state, and federal resources.	Somewhat prepared
Flooding;Winter weather (snowstorms, blizzards);Ice storms;Severe Wind (nor'easter, tornado, thunderstorm);Extreme temperatures;Drought;Fire;Not applicable to me (I am a representative from a surrounding community);	Two hundred year flood storms within 5 years. Mid-2000's. Severe snowstorm in 2015	Somewhat prepared
	Severe climate hazards impact structural integrity of buildings	Somewhat prepared

Please explain your reason for selecting your answer in Question 3.	What does Lowell do well to to mitigate climate hazards or prepare for climate change? Examples could include, but are not limited to: - City shelters, warming centers, and cooling centers - Regio...	What are the opportunities to address potential natural or climatic hazards? Examples could include, but are not limited to: - Providing transportation to shelters for vulnerable populations, incl...
I know that Lowell is aware of the dangers of climate change and are actively looking for solutions in both adaptation and prevention. However, implementation might not be where it could be, which is why I am glad we have the opportunity to become and MVP community	Extensive investment in energy efficiency and encouragement of renewable energy. Good response/communication with community in times of extreme weather/disaster	Creating more resilient infrastructure, particularly: - Looking at increasing renewable energy resiliency to supplement existing infrastructure - Strengthening and looking to expand infrastructure to respond/adapt to more severe storms - Increasing communication with our most vulnerable residents
City of Lowell could be more proactive about informing residents about what to do before, during, an after an event (plus their rights and responsibilities if they are in a hazard area).		
I know the City has a talented team that works on emergency response.		

What resources does your department need to be more prepared?	How does your department share information with the public?	We recognize the preparation and response to any challenge in our community has overlapping strategies and challenges. We are interested in documenting the community experience of COVID-19. What w...
Funding for climate adaptation projects;Staff and training;Supplies or equipment;Additional guidance related to department operations before, during, and after a hazard event;Data or studies showing the projected impacts of future climate hazards in Lowell;	Public events, including virtual webinars;Printed media, including reports, fact sheets, or brochures;Online, including through the City website, Facebook, and Twitter;Strategic outreach to specific populations, such as elderly residents or other groups;	Not sure about all of the steps that have been taken.
Funding for climate adaptation projects;Staff and training;Additional guidance related to department operations before, during, and after a hazard event;Data or studies showing the projected impacts of future climate hazards in Lowell;	Public events, including virtual webinars;Printed media, including reports, fact sheets, or brochures;Online, including through the City website, Facebook, and Twitter;Strategic outreach to specific populations, such as elderly residents or other groups;	
Staff and training;Supplies or equipment;	Online, including through the City website, Facebook, and Twitter;Strategic outreach to specific populations, such as elderly residents or other groups;	Internal information could be shared better and more efficiently.

Are there any additional comments or questions you would like to share with the project team?
Thank you for helping Lowell with this project.

Lowell MVP Online Hazard Map



Lowell's online hazard map was used as an engagement tool during the Community Resilience Building (CRB) Workshop. The interactive online map allowed participants to zoom in and out, and included a list of critical facilities as layers that could be turned on or off.

Appendix D

Listening Session

MAY 28TH AT 6:00PM

HAZARD MITIGATION & CLIMATE ADAPTATION

ONLINE WEBINAR

Please come to share your experiences and ideas!

We will present the results of Lowell's hazard mitigation and climate adaptation planning process to-date.

Please register at:

tinyurl.com/LowellMVPWebinar

Registrations will be accepted until noon on May 28th. Upon registration, you will be entered into a giveaway for one of five $50 gift cards to local restaurants!

Please reach out if you have questions or barriers to participating.

Katherine Moses, Energy Manager, Department of Planning & Development
kmoses@lowellma.gov | lowellma.gov

THE CITY OF LOWELL
THERE'S A LOT TO *like*

Weston & Sampson

This project was funded through the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness (MVP) Planning Grant

CITY OF LOWELL

Municipal Vulnerability Preparedness (MVP) Planning Grant and Hazard Mitigation Plan (HMP) Project

Public Listening Session webinar
May 28, 2020 | 6:00-7:00PM
Microsoft Teams Meeting

Welcome, Introductions, Overview of Microsoft Teams	5 minutes
Overview of MVP and MHP	5 minutes
Overview of Hazards and Climate Change Data	10 minutes
Strengths and Vulnerabilities	15 minutes
Priority Action Items	20 minutes
Wrap Up and Next Steps	5 minutes

Weston & Sampson

CITY OF LOWELL

Public Listening Session Webinar

May 28, 2020

Weston & Sampson Photo: Merrimack River, Weston & Sampson

1

WELCOME FROM THE PROJECT TEAM

ADRIA BOYNTON

STEVE ROY

INDRANI GHOSH

AMANDA KOHN

RUPSA ROY

JOHN TOURTELOTTE
RIVERWOOD ENERGY

Weston & Sampson Photo: Kinetic Sculpture Festival, W&S 2

2

WELCOME PARTICIPANTS

Translation support is available in **Spanish, Portuguese, and Khmer**

Thank you to our translators; Jeanette Cantu, Maria Dickinson, Tooch Van, and Thavy Hout!

Weston & Sampson Photo: Kinetic Sculpture Festival, W&S 3

3

WEBINAR LOGISTICS

- This webinar is being **recorded**
- Overview of Microsoft Teams
  - Tell us what your favorite thing is about Lowell **in the chat!**
- The webinar is paired with **online surveys**
  - A link is included at the end of the presentation

4

4

WEBINAR OUTLINE

- Overview of MVP and HMP
- Overview of Climate Change
- Strengths and Vulnerabilities
- Priority Action Items
- Next Steps

Tell us about your climate adaptation priorities by taking our **online survey!**

Photo: City Facebook

5

MVP & HMP OVERVIEW

Photo: City Facebook

6

MVP Program Goals

7

MVP Process

1. **MVP Planning Grant**
   - Define climate hazards
   - Identify community vulnerabilities and strengths
   - Develop and prioritize adaptation actions
   - Receive MVP designation

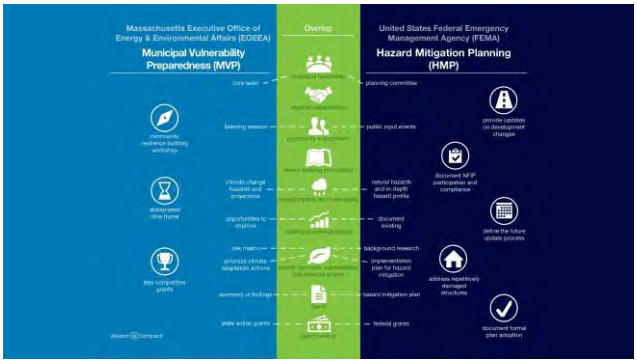
   ** We're also updating Lowell's Hazard Mitigation Plan!*

2. **MVP Action Grant**
   1. Implement priority adaptation actions identified during the planning process

8

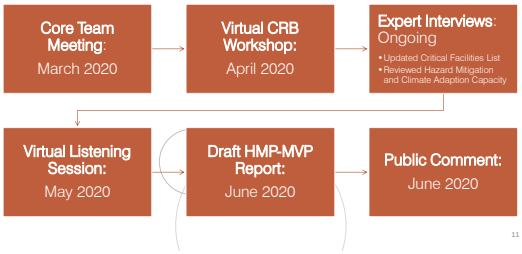
What Can the MVP Action Grant Fund?

9



10

SCHEDULE



11

COMMUNITY RESILIENCE BUILDING WORKSHOP

Focused on Four Hazards

Identified:
- Vulnerabilities
- Strengths
- Priority Action Items

Across Three Categories:
- Infrastructure
- Societal
- Environmental

12

Any questions
about the MVP program or the hazard mitigation planning process?

13

CLIMATE HAZARDS

Photo: City Facebook

14

TOP HAZARDS IN LOWELL

Flooding

Extreme Temperatures

Extreme Winter Weather

Wind and Microbursts

Weston & Sampson

15

EXTREME TEMPERATURES

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

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

Source: ResilientMA.org, "Rising Temperatures," 2017

16

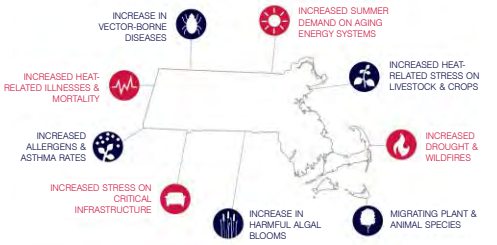
EXTREME TEMPERATURES IN MASSACHUSETTS

17

IMPACTS OF RISING TEMPERATURES

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

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



18

CHANGES IN **PRECIPITATION**

MORE INTENSE & FREQUENT EXTREME RAIN EVENTS

PRECIPITATION DURING **HEAVY EVENTS** IN THE NORTHEAST HAS **INCREASED** BY MORE THAN

70%

BETWEEN 1958-2010

HEAVY EVENTS ARE DEFINED AS THE HEAVIEST 1% OF ALL DAILY EVENTS

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

19

19

EXTREME PRECIPITATION

8%

Increase in extreme precipitation events by midcentury

13%

Increase in extreme precipitation events by 2100

Extreme precipitation events are defined as events with greater than 2" of rain per day

Source: Executive Office of Energy and Environmental Affairs, Adaptation Advisory Committee. 2011. "Massachusetts Climate Change Adaptation Report," 19.

20

20

LOCAL FLOODING NEAR WATERBODIES

- Northern banks of the Merrimack River near the Water Treatment Plant
- Land around Black Brook and the Trull Brook tributary between Phoenix Ave and Clark Road
- Areas in the 100-year floodplain along major waterways:
  - Concord River
  - Marginal Brook
  - River Meadow Brook
  - Beaver Brook
  - Clay Pitt Brook (including floods in 2006 and 2007)
- Marsh along Wentworth Avenue
- The mouth of Black Brook
- The mouth of Marginal Brook

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

21

21

LOCAL FLOODING ALONG STREETS

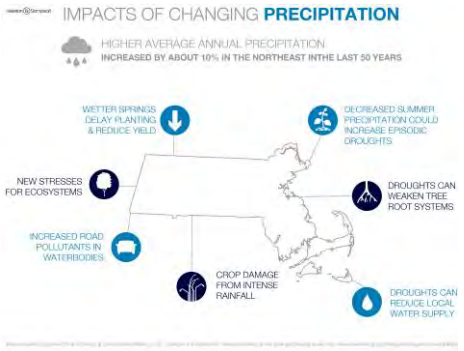
- Wentworth Avenue/Douglas Road area
- Area behind the Wentworth Health Care Facility
- Along Douglas Road near the Janas Skating Rink
- Intersection of Gorham Street (Route 3A, evacuation route) and Moore Street
- Hadley and Pratt Streets
- North of Princeton Street along Black Brook
- Area north of Varnum Avenue and east of Laurel Lane
- Area south of Varnum Avenue and east of Lebanon Street
- Area west of Bridge Street and North of Billings Street
- Area north of Cawley Stadium
- Area south of Hollis Avenue

A rainstorm in the summer of 2003 filled the Gorham and Moore Street intersection with up to 4' of water

Hazard Mitigation Plan for the Northern Middlesex Region: 2015 Update

22

22



23

23

EXTREME WINTER WEATHER

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

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

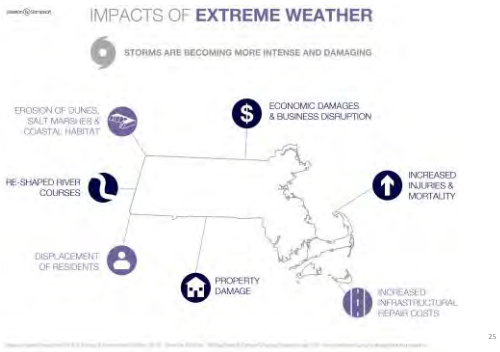
Nor'easters along the Atlantic coast are increasing in frequency and intensity

Jan 3-4, 2018: Winter Storm Grayson
March 2, 2018: Winter Storm Riley
March 8, 2018: Winter Storm Quinn
March 13, 2018: Winter Storm Skylar

Sources: ResilientMA, Climate Science Special Report, Fourth National Climate Assessment (NCA4), Volume prepared by the U.S. Global Change Research Program (USGCRP)/Northern Middlesex

24

24



25

What climate changes have you observed?

What memories do you have of local natural hazards?

26

STRENGTHS & VULNERABILITIES

Photo by Weston & Sampson

27

INFRASTRUCTURE

Vulnerabilities

- Public buildings, including schools
- Roads, bridges, and public transit
- Stormwater system, including the drainage system, culverts, and catch basins
- Aging canal system and walls

28

INFRASTRUCTURE

Both Strengths and Vulnerabilities

- Energy resilience
- Communications, including fiber optic, internet, phones and cell phones, and municipal communication through CodeRED or social media
- Water supply and distribution. Supply is a strength, but distribution and aging infrastructure are vulnerabilities.
- Wastewater infrastructure. Recent upgrades and financial investments are strengths, but the collection system is vulnerable to climate impacts.
- Dams and gate houses, including the Pawtucket gate house and Francis Gate. Dams that are re-certified are strengths. The age and condition of some gate houses are vulnerabilities.

29

ENVIRONMENTAL

Vulnerabilities

- Waterbodies and wetlands, including the Merrimack and Concord Rivers, River Meadow Brook, Beaver Brook, Clay Pitt Brook, and others
- Street trees and citywide tree canopy
- Contaminated sites including the Silresim Superfund Site and brownfield sites
- Invasive species, including both plants and insects

30

ENVIRONMENTAL

Strengths

- Parks and public spaces, including Eastern Canal Park, Lelacheur Park, JFK Plaza, National Park, and others

Both Strengths and Vulnerabilities

- State forest and park trees, including the Lowell-Tyngsborough State Forest
- Development and land use regulations
- Endangered species, including native plant species

31

31

SOCIETY

Vulnerabilities

- Public health concerns, including vector-borne diseases
- Residents at risk of isolation, including seniors, children, residents with disabilities, and residents with limited English proficiency if emergency communications are in English
- Residents with challenges to prepare or adapt to extreme events, including low-income residents and residents experiencing homelessness
- Housing, including low income housing and other housing

32

32

SOCIETY

Strengths

- Municipal and emergency services
- The non-profit community and volunteers

Both Strengths and Vulnerabilities

- Shelters including the high school, senior center, and homeless shelter
- Local businesses

33

33

What do you view as some of Lowell's top vulnerabilities and strengths?

34

34

HAZARD MITIGATION & CLIMATE ADAPTATION STRATEGIES

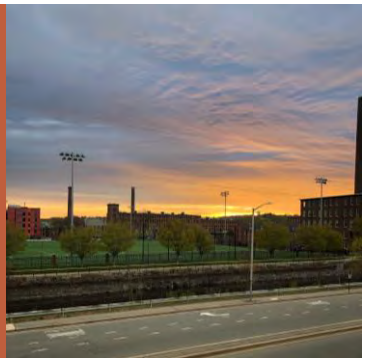


Photo by Weston & Sampson

35

EXISTING HAZARD PROTECTION

- Greater Lowell Regional Emergency Planning Committee
- Upper Merrimack Valley Medical Reserve Corp
- Communication Infrastructure, including social media and CodeRED
- Emergency shelters
- Backup generators
- Open Space and Recreation Plan 2019-2023
- Comprehensive Emergency Management Plan
- Participation in the National Flood Insurance Program (NFIP)
- Stormwater System maintenance, including removing debris from catch basins
- Tree maintenance
- Snow plowing and removal
- Public education on fire risk
- Green Communities Program
- Complete Streets Implementation Plan
- 100% Renewable Resolution

36

36

HIGH PRIORITIES: INFRASTRUCTURE

- Roads, bridges, and public transit:
  - Identify at-risk bridges and develop an emergency plan for each.
  - Update snow removal plan and enforce rules for clearing sidewalks. Develop a formal parking ban. Buy new plow equipment.
  - Update tree pruning and maintenance program. Hire a City Arborist and work with the National Grid. Develop a list of appropriate street trees.
  - Develop an emergency tornado response plan for the LRTA Bus system.
- Water supply and distribution:
  - Invest in aging infrastructure. Protect the distribution system from the freeze/thaw cycle and proactively secure funding to address breaks. Assess and track "hot spots" with frequent breaks and identify potential solutions.
  - Floodproof the Water Plant Intake Station.

37

37

HIGH PRIORITIES: INFRASTRUCTURE

- Stormwater system:
  - Upgrade culverts near Clay Pitt Brook. Assess and map the entire drainage system. Ensure appropriate capacity of catch basins.
  - Develop a beaver management program.
  - Continue to encourage Low Impact Development and assess options for regulatory mechanisms.
- Wastewater Infrastructure:
  - Assess floodproofing options for vulnerable pump and combined sewer overflow stations.
  - Add backflow prevention to combined outfalls.
  - Integrate new battery storage to the existing solar array and backup generator at the Water Treatment Plant. Consider a similar approach at the Wastewater Plant.

38

38

HIGH PRIORITIES: INFRASTRUCTURE

- Canal system and walls:
  - Conduct an inventory and assessment of the walls and identify needed repairs.
  - Increase public education and outreach related to trash removal and encourage residents and visitors to avoid throwing trash in the canals.
  - Participate in the ongoing Federal Energy Regulatory Commission (FERC) study and re-licensing process and review their materials.
  - Manage trees along the canals through increased coordination with DCR.
- Dams and gate houses:
  - Model and assess the impact of the 500-year flood on the gate houses and develop and overall response plan.
  - Identify and address vulnerabilities of the earthen dam near Beaver Brook Bridge.
  - Coordinate with dam operators and the hydropower entity on flood mitigation.

39

39

HIGH PRIORITIES: ENVIRONMENT

- Waterbodies and wetlands:
  - Update the floodplain overlay district and local wetlands ordinance.
  - Map at-risk banks and seek funding for combined trail and bank mitigation projects
  - Evaluate alternatives to salting/sanding. Identify snow storage locations and provide education on environmentally friendly snow clearing.
- Development and land use regulations:
  - Integrate the Stormwater Team standards with Planning Office regulations.
  - Evaluate options for setting maximum parking requirements

40

40

HIGH PRIORITIES: SOCIETY

- Public health:
  - Increase public education related to the risks of vector-borne diseases (ticks) and how to protect yourself.
- Shelters:
  - Increase capacity of homeless shelter during extreme cold events.
  - Increase capacity of shelter system to allow for social distancing if needed.
  - Inventory shelter supplies and increase staff, volunteers, and training. Develop contingency plans. Install alarms for high food storage temperatures.
  - Identify potential short-term shelters for use during power outages.
  - Develop a formal plan with the City, LTC, local organizations, and others to get the word out about risks and resources. Develop a contact or distribution list.

41

41

HIGH PRIORITIES: SOCIETY

- Residents at risk of isolation:
  - Work with local partners to share information and get the word out.
  - Translate announcements into multiple languages. Use accessible visuals.
  - Partner with schools to share information with parents. Share information through a range of means, including digital, TV, and messaging signs.
  - Develop a database of at-risk residents with emergency service providers and the senior center. Conduct wellness checks.
- Residents with challenges to prepare or adapt:
  - Evaluate safe areas for informal housing (outside of flood-prone areas). Assess best practices.
  - Work with social services and local organizations to provide support to residents experiencing homelessness.

42

42

HIGH PRIORITIES: SOCIETY

- Municipal and emergency services:
  - Update the existing Emergency Management Plan.
  - Review available City resources and capacity, including emergency generators.
- Housing:
  - Identify grants for climate-resilient housing, including floodproofing, fire resilience, and energy efficiency for denser and older housing.
  - Provide short-term tenant support if an extreme events prevents residents from working and puts them at risk of eviction.
- Local businesses:
  - Develop and share a toolkit for improving your business' resilience. Provide short-term support for local businesses, including mobile generators and refrigerated trucks during extended power outages.
  - Assess ability of local businesses to assist with crisis response, including sewing masks or assisting with food production for food banks.

43

43

What project ideas do you think are the highest priorities?

44

44

Want to be part of the solution?

- Start by visiting our project webpage to learn more, watch our videos, and **take our online survey!**

  tinyurl.com/LowellMVP

- Then, share on Facebook and Twitter with the hashtag **#ResilientLowell**

45

Lowell Virtual Public Listening Session

Attendees

1. Susan Griffin
2. Gunther W
3. James Conlon
4. Jane Calvin
5. Katherine
6. Kevin
7. Rick Minard
8. Rupsa
9. Thavy Hout
10. Yun-Ju Choi
11. 603-930-7930 (Maria)
12. Amanda Kohn
13. Adria Boynton
14. Lindsey Adams
15. Indrani Ghosh
16. Jeanette Cantu
17. Stephen Malagodi
18. Michelle Rowden

Meeting Notes

Favorite Things

- Rivers
- Diversity
- Food options
- Eating near the canals
- “What America is all about!”
- My favorite thing about Lowell is how it honors its heritage while looking toward its future.
- I guess my favorite thing about Lowell is the theater scene, and the community events that were happening.
- i love how the folk festival allows us to experience diverse cultures
- The rivers and beautiful open spaces.
- “There's a lot to like about Lowell"

Questions –

-microgrids for each town to keep town offices open. Has this been discussed in Lowell?

Meeting Chat

[5/7 12:51 PM] Boynton, Adria joined the meeting.

[5/8 12:44 PM] Boynton, Adria renamed the meeting to Lowell Listening Session.

[5/8 12:44 PM] Kohn, Amanda and Roy, Steven joined the meeting.

[5:44 PM] Gunther W joined the meeting.

[5:44 PM] Cantu, Jeanette joined the meeting.

[5:44 PM] Boynton, Adria
Welcome to Lowell's MVP Listening Session!

[5:45 PM] Boynton, Adria
Test out the chat function by telling us who you are and what your favorite thing is about Lowell!

[5:46 PM] Gunther W
"There's a lot to like about Lowell"
(1 liked)

[5:48 PM] Kevin joined the meeting.

[5:48 PM] Kevin
I can here you okey
[5:49 PM] Kevin
*okay

[5:49 PM] Boynton, Adria
Great, thank you!

[5:50 PM] Kevin
I guess my favorite thing about Lowell is the theater scene, and the community events that were happening.
(1 liked)

[5:53 PM] Katherine joined the meeting.

[5:54 PM] Katherine
I forgot that my microphone doesn't work on this computer.

[5:54 PM] Katherine
I can hear you.

[5:54 PM] Katherine
Sounds good. Thank you.
(1 liked)

[5:56 PM] Katherine

My favorite thing about Lowell is how it honors its heritage while looking toward its future.
(1 liked)

[5:56 PM] Adams, Lindsey joined the meeting.

[5:58 PM] Roy, Rupsa joined the meeting.

[5:59 PM] Kevin
I just finished my the semester, and not going to lie. It was kinda a rough transition.

[5:59 PM] Jane Calvin joined the meeting.

[6:00 PM] Rick Minard joined the meeting.

[6:00 PM] Yun-Ju Choi joined the meeting.

[6:00 PM] Ghosh, Indrani joined the meeting.

[6:02 PM] Katherine
Sounds good.

[6:03 PM] James Conlon joined the meeting.

[6:03 PM] Thavy Hout (CMAA) joined the meeting.

[6:03 PM] Griffin, Susan joined the meeting.

[6:05 PM] Jane Calvin left the conversation.
[6:05 PM] Jane Calvin joined the meeting.

[6:10 PM] stephenmalagodi joined the meeting.

[6:11 PM] Jane Calvin
The rivers and beautiful open spaces.

[6:11 PM] Rowden, Michelle (EEA) joined the meeting.

[6:12 PM] James Conlon
i love how the folk festival allows us to experience diverse cultures

[6:17 PM] stephenmalagodi
when were those stakeholder sessions and what did you do to publicize them?

[6:21 PM] stephenmalagodi
Was the Lowell Sustainablility Council one of the contacted stakeholders?

[6:23 PM] Katherine

To answer Stephen Malagodi's question: yes, the Lowell Sustainability Council was one of the contacted stakeholders.

[6:29 PM] Kevin
I have noticed more frequent temperature changes. For just a couple of weeks ago it was snowing a little bit.

[6:29 PM] Gunther W
Do you remember the winter of 2014? 110 inches of snow from Jan 10th the Feb 15th...

[6:32 PM] Thavy Hout (CMAA) left the conversation.

[6:35 PM] Kevin
I view the Canal system we have here as a strength, but it does also need much to be desired.

[6:35 PM] stephenmalagodi
Old housing stock, housing for the elderly not air conditioned.

[6:35 PM] Gunther W
Strength... green space protection

[6:36 PM] Gunther W
Concord River walkway... with planned extension.

[6:36 PM] Kevin
One particular weakness I believe it the road infrastructure we have.

[6:36 PM] stephenmalagodi
Lowell has 45% impermeable surface.

[6:37 PM] Kevin
The impact from the winter events constantly destroy the road ways

[6:46 PM] stephenmalagodi
Need to prepare for mold mitigation due to increasing temperatures and rainfall.

[6:48 PM] Kevin
Looking at the gate houses seems to be at great importance. Especially for flooding protections

[6:48 PM] Kevin
Question: Does the city own the Gate Houses?

[6:48 PM] Rick Minard
Investing in energy efficiency in low-income housing not only helps residents survive weather extremes but also helps reduce carbon emissions

[6:51 PM] Gunther W
A lot of this echos work DPD did in 2011/2012 to create "Sustainable Lowell 2025" Specifically Ch 4 - Goals (https://www.lowellma.gov/DocumentCenter/View/1461/Sustainable-Lowell-2025-PDF)... has progress been made last 8 years?

[6:54 PM] Kevin
Will these slides be publicly available?

[6:55 PM] Kohn, Amanda
https://www.lowellma.gov/1425/Municipal-Vulnerability-Preparedness-MVP

[6:55 PM] Rick Minard
Thank you! Good work.

[6:55 PM] Katherine
I appreciate everyone's participation. Another thing I like about Lowell is its focus on solutions, based on community feedback.

[6:56 PM] Gunther W
If you are interested, I'm willing to share a document I authored about a year ago... Disaster Material Management Plan (for Lowell) a requirement for MEMA & FEMA

[6:56 PM] Rowden, Michelle (EEA) left the conversation.

[6:56 PM] Griffin, Susan left the conversation.

[6:57 PM] Rick Minard left the conversation.

[6:57 PM] Kevin
Will there be another meeting like this in the future?

[6:57 PM] James Conlon
Thank you, have a good night.

[6:58 PM] Kohn, Amanda
The final report will also be available soon.

[6:58 PM] Kohn, Amanda
The final draft of the report is due to the state by June 30th so this has been a quick planning process, but there are plans to keep engaging about climate resilience!

[6:58 PM] Kevin
Okay
Thank you, have a good night.

[6:59 PM] Gunther W
Keep up this important work! Keep us updated... please. Thanks! -Gunther

[6:59 PM] stephenmalagodi left the conversation.

[6:59 PM] Katherine
Also, please feel free to share this information with your networks.

[7:00 PM] Gunther W left the conversation.

[7:00 PM] Katherine left the conversation.

[7:00 PM] Kevin left the conversation.

Lowell Project Webpage

Government Departments Business How Do I...

THE CITY OF LOWELL

Share Site Tools Search

FAQ

Home › Departments › Planning & Development › Planning Projects › Municipal Vulnerability Preparedness (MVP) Plan

Municipal Vulnerability Preparedness (MVP) and Hazard Mitigation Plan (HMP)

The City of Lowell was awarded funding to complete the Municipal Vulnerability Preparedness (MVP) Planning Grant program and update the City's Hazard Mitigation Plan (HMP).

- The MVP grant program provides technical and financial support for cities and towns across the Commonwealth to plan for, and mitigate the impacts from, climate change.
- The HMP is part of a Federal Emergency Management Agency (FEMA) program that involves identifying the risks and vulnerabilities associated with natural disasters, and developing long-term strategies for protecting people and property from future hazard events.

By completing this project, Lowell will be eligible for federal FEMA Grant programs, as well as state MVP Action Grants for the implementation of climate adaptation projects. Your input on this project is essential!

The Lowell MVP-HMP project involves the following work:

- Convening a Core Team of municipal department heads who provided key input through meetings, online surveys, and interviews.
- Engaging stakeholders through virtual Community Resilience Building (CRB) webinars
- Developing an interactive, online hazard map
- Engaging the public through a project webpage, online video and survey, and an upcoming interactive meeting.
- Conducting a vulnerability and risk assessment of historic hazards and the potential impact of climate change.
- Reviewing progress on the previous hazard mitigation plan.
- Documenting the City's capacity to mitigate and respond to hazards.
- Developing an action and implementation strategy.

We will share an update on this process and ask for public feedback as part of a **virtual public listening session at 6:00PM on May 28th**. Registrations will be accepted here until noon on May 28th. We are providing translation services in Spanish, Portuguese, and Khmer. Upon registration, you will be entered into a giveaway for one of five $50 gift cards to local restaurants!

Want to be part of the solution? Watch our quick video and take our online survey!

View the videos below and click to access surveys in English, Español, and Português.

Stay tuned for additional materials in Portuguese and Khmer!

For more Information
Check out our additional resources!

- Online Webinar Flyer
- Press Release

Contact Us

Click here to share a question or a comment with the project team!

FAQ

FAQ

What is Climate Change?

Climate change is a shift in weather patterns and annual trends. In Lowell, we can expect hotter temperatures, more severe storms, and more flooding.

What are Climate Hazards?

Climate hazards are weather events that can affect human health, livelihoods, homes, businesses, and natural resources. In Lowell, that can include heavy rainfall and flooding, extreme temperatures, drought, fire, severe winter weather, and severe wind events.

What's at Risk to Climate Impacts?

Climate change can impact local features in Lowell, including:

- Our infrastructure, including public transportation and roads
- Our society, including public services and vulnerable residents
- And our environment, including waterbodies and our trees

How Could Climate Change Impact Me?

Climate change can lead to increased stress on the challenges we already face and how we operate in our day to day lives. That might include:

- Increased cost of necessities like food and electric utilities
- Increase in repair costs for damages from storms, and more expensive insurance
- Increase in health risks from public health concerns including asthma and Lyme disease
- The possibility of missing school or work due to an extreme event
- Impacts on the outdoor spaces where we relax, play, and exercise

The Lowell project webpage included information on the MVP and HMP processes, links to the online hazard map, multiple videos and surveys in several languages, answers to frequently asked questions, and more.

Lowell Municipal Vulnerability Preparedness and Hazard Mitigation Survey

Hello! We hope you are doing well during these uncertain times, and thank you for taking our survey.

Climate change has the potential to impact how we approach housing, how we support our community's health, how we build our infrastructure, and how we protect the environment. Your voice represents a unique aspect of the Lowell community and we'd love to hear your thoughts, experiences, and ideas. By taking this survey you will help us prepare for a more resilient future. #ResilientLowell

If you have additional input, questions, or barriers to participating, please contact Adria Boynton (Resiliency Specialist at Weston & Sampson) at boyntona@wseinc.com or (978) 278-3592.

1. Before watching this video, on a scale of 1-5 (5 being very knowledgeable), how would you rate your knowledge of local hazard and climate impacts?
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ 4
   - ☐ 5

2. After watching this video, on a scale of 1-5 (5 being very knowledgeable), how would you rate your knowledge of local hazard and climate impacts?
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ 4
   - ☐ 5

3. What climate hazard are you most concerned about?
   - ☐ Extreme temperatures
   - ☐ Flooding
   - ☐ Winter weather (snowstorms and blizzards)
   - ☐ Ice storms
   - ☐ Drought
   - ☐ Fire
   - ☐ Severe wind (nor'easter, tornado, thunderstorms)

4. How have these climate hazards impacted you, or what impacts have you seen in your community? Memories of recent climate hazards could include:

   - flooding of local roads
   - the winter of 2014-2015, when Lowell experienced over 10 feet of snow
   - four Nor'easters in one month in 2018
   - heat waves with multiple days over 90 degrees F

- drought conditions in 2016

Enter your answer

5. How prepared do you think Lowell is for future climate hazard events?
   - ☐ Very prepared
   - ☐ Somewhat prepared
   - ☐ Not prepared
   - ☐ Other

6. Please explain your reason for selecting your answer in Question 5.

   Enter your answer

7. What steps have you already taken to prepare for extreme climate hazard events? Check all that apply.
   - ☐ I have a kit in case of emergencies (which may include food, water, flashlights, batteries, and other supplies)
   - ☐ I receive news, updates, and information about emergency preparedness in Lowell
   - ☐ I know where the nearest local shelter is
   - ☐ Other

8. What resources do you need to feel more prepared? Check all that apply.
   - ☐ Training on how to be better prepared
   - ☐ The financial resources to take action
   - ☐ More information on what I can do on my own
   - ☐ More information on what the City is doing
   - ☐ Other

9. How would you like to receive information about resiliency projects and actions in Lowell? Check all that apply.
   - ☐ Public events, including virtual webinars
   - ☐ Printed media, including reports, fact sheets, or brochures
   - ☐ Online, including through the City of Lowell website, Twitter, and Facebook
   - ☐ Local groups and organizations, including newsletters and existing meetings
   - ☐ Other

10. We recognize the preparation and response to any challenge in our community has overlapping strategies and challenges. We are interested in documenting the community experience of COVID-19. What worked well, and what could improve?

    Enter your answer

11. Are there any additional comments or questions you would like to share with the project team?

Enter your answer

12. Thank you for completing this survey. If you are interested in receiving additional updates related to climate initiatives in Lowell, please enter your email below.

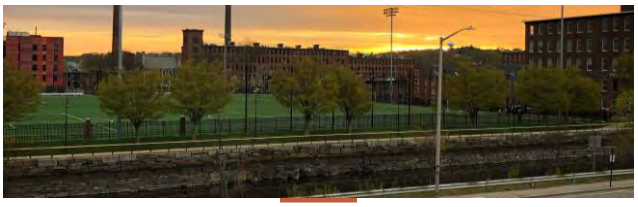
Enter your answer

13. The following questions are not required. However, by answering these demographic questions, you will help us assess if our survey has broad participation. Please select all that apply.
    - ☐ I am a renter.
    - ☐ I own a business.
    - ☐ I am a veteran.

14. Please select your age range.
    - ☐ Under 18
    - ☐ 18-24
    - ☐ 25-35
    - ☐ 36-45
    - ☐ 46-55
    - ☐ 56-65
    - ☐ 66-75
    - ☐ Over 75

15. How would you describe yourself?
    - ☐ White
    - ☐ Black or African-American
    - ☐ American Indian or Alaskan Native
    - ☐ Asian
    - ☐ Native Hawaiian or other Pacific islander
    - ☐ Multiple races
    - ☐ Other

16. Are you of Hispanic, Latino, or of Spanish origin?
    - ☐ Yes
    - ☐ No



CITY OF LOWELL

Municipal Vulnerability Preparedness (**MVP**) and Hazard Mitigation Plan (**HMP**) Project Overview

Weston & Sampson Photo by Weston & Sampson

1

WATCH THE VIDEO

- What are climate hazards in Lowell?
- What's at risk?
- What are we doing about it?

TAKE THE SURVEY

to tell us about your experiences, ideas, and questions!

2

CLIMATE CHANGE

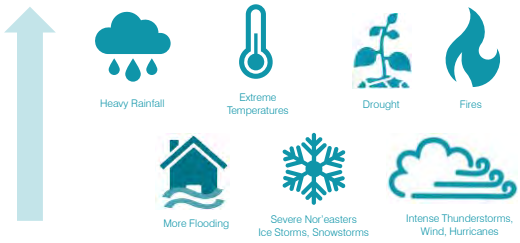
Climate change:
a shift in weather patterns and annual trends. In Lowell, we can expect hotter temperatures, more severe storms, and more flooding.

Climate hazards:
weather events that can affect human health, livelihoods, homes, businesses, and natural resources

Photo by W&S

3

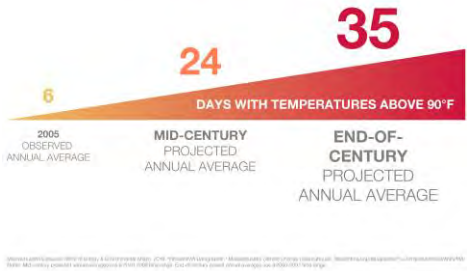
CLIMATE HAZARDS IN LOWELL



Weston & Sampson

4

EXTREME TEMPERATURES



5

IMPACTS OF RISING TEMPERATURES

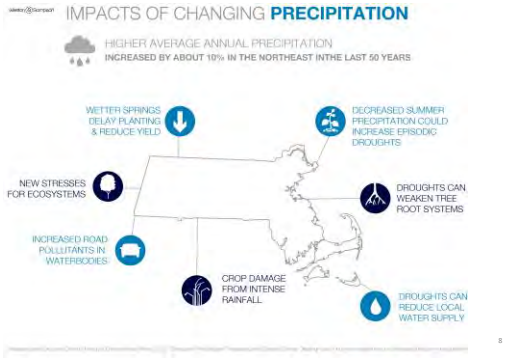
WARMER ANNUAL AIR TEMPERATURES: UP 0.5°F PER DECADE SINCE 1970, ON AVERAGE

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

6

CHANGES IN
PRECIPITATION
PRECIPITATION DURING
HEAVY EVENTS IN THE
NORTHEAST
INCREASED
BY MORE THAN
70%
BETWEEN 1958-2010

7


IMPACTS OF CHANGING PRECIPITATION
HIGHER AVERAGE ANNUAL PRECIPITATION
INCREASED BY ABOUT 10% IN THE NORTHEAST INTHE LAST 50 YEARS
WETTER SPRINGS DELAY PLANTING & REDUCE YIELD
DECREASED SUMMER PRECIPITATION COULD INCREASE EPISODIC DROUGHTS
NEW STRESSES FOR ECOSYSTEMS
DROUGHTS CAN WEAKEN TREE ROOT SYSTEMS
INCREASED ROAD POLLUTANTS IN WATERBODIES
CROP DAMAGE FROM INTENSE RAINFALL
DROUGHTS CAN REDUCE LOCAL WATER SUPPLY

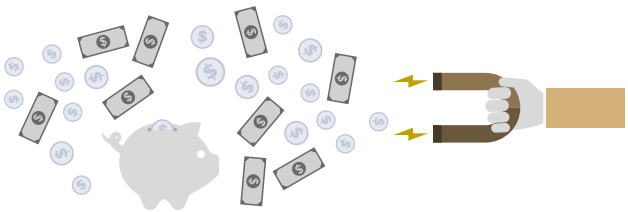
8

WHAT'S AT RISK?
Increased stress on the challenges we already face and how we operate in our day to day lives

9

WHAT DOES THIS MEAN FOR US?
$

10



11

12

13

14

Infrastructure

Public Transportation

Photo: LRTA Bus, Wikimedia Commons

Roads

Photo by W&S

Society

Public Services

Photo: Lowell Fire Department

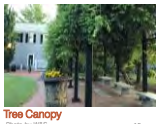
Vulnerable Residents

Photo: Lowell Fire Department

Environment

Water Bodies

Photo by W&S



Tree Canopy

Photo by W&S

15

15

WHAT ARE WE DOING ABOUT IT?

Making a plan to reduce our vulnerabilities and to build up our strengths

Securing financial support through state and federal programs

Photo: City Facebook

16

LOWELL'S CLIMATE ADAPTATION & HAZARD MITIGATION GOALS

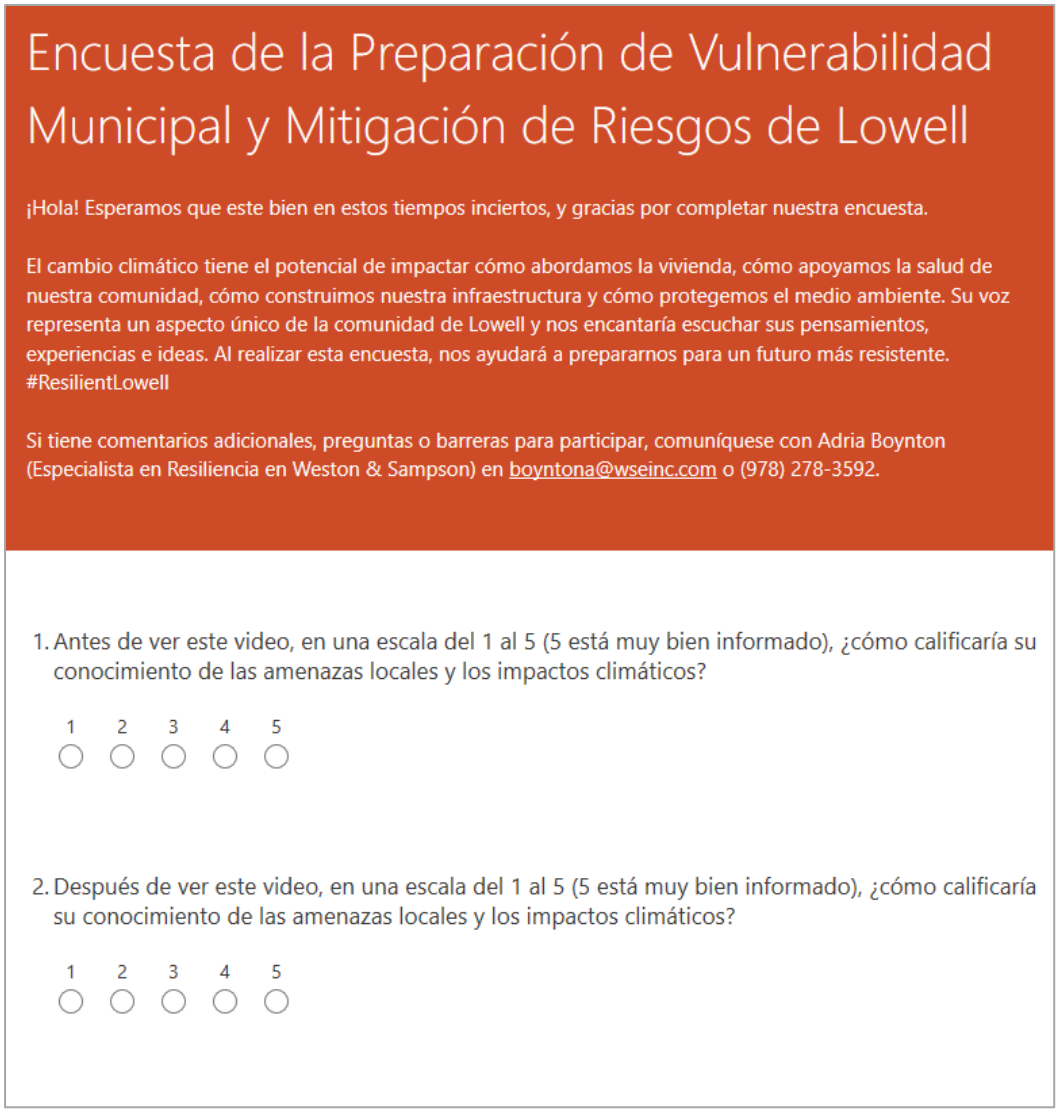
17

17

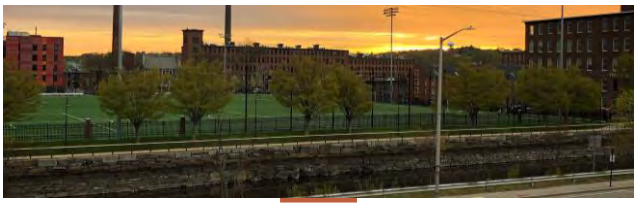
WILL YOU BE PART OF THE SOLUTION?

- **START BY TAKING OUR SURVEY:** tinyurl.com/LowellMVPSurvey1
- **THEN SHARE ON FACEBOOK AND TWITTER WITH THE HASHTAG** #ResilientLowell

18



The online surveys were designed to be used on both computers and cell phones. The Spanish survey is displayed above as one example.



CIUDAD DE LOWELL

Descripción General del Proyecto de
Preparación para la Vulnerabilidad Municipal (MVP)
y el Plan de Mitigación de Riesgos (HMP)

Weston & Sampson Foto por Weston & Sampson

1

Favor de ver el vídeo

- ¿Cuáles son los peligros climáticos en Lowell?
- ¿Cuáles son los riesgos?
- ¿Qué estamos haciendo al respecto?

COMPLETA LA ENCUESTA

para contarnos sobre tus experiencias, ideas y preguntas!

2

CAMBIO CLIMÁTICO

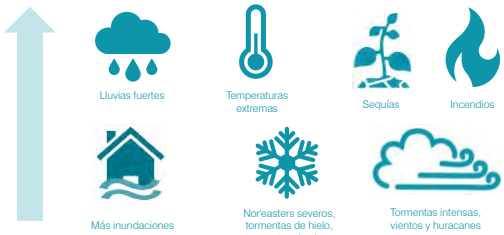
Cambio climático:
Un cambio en patrones climáticos y tendencias anuales. En Lowell, podemos esperar temperaturas más altas, tormentas más severas y más inundaciones.

Peligros climáticos:
Eventos climáticos que pueden afectar la salud humana, medios de vida, hogares, empresas y recursos naturales

Foto por W&S

3

PELIGROS CLIMÁTICOS EN LOWELL



Weston & Sampson

4

TEMPERATURAS EXTREMAS

En Massachusetts

5

IMPACTOS DE LAS TEMPERATURAS CRECIENTES

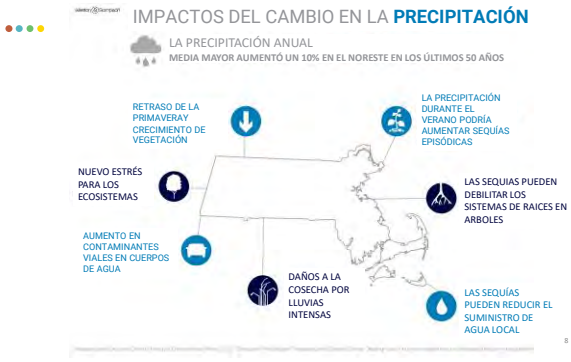
TEMPERATURAS ANUALES MÁS CÁLIDOS
HASTA 0.5°F POR DECADA DESDE 1970, EN PROMEDIO

INVIERNOS MÁS CÁLIDOS
HASTA 1.3°F POR DECADA DESDE 1970, EN PROMEDIO

6

CAMBIOS EN
LA
PRECIPITACIÓN
PRECIPITACIÓN DURANTE
TORMENTAS E INCLUSO
DURANTE LOS NOR'ESTERS HAN
AUMENTADO
POR MÁS DEL
70%
ENTRE 1958-2010

7


IMPACTOS DEL CAMBIO EN LA PRECIPITACIÓN
LA PRECIPITACIÓN ANUAL
MEDIA MAYOR AUMENTÓ UN 10% EN EL NORESTE EN LOS ÚLTIMOS 50 AÑOS
RETRASO DE LA PRIMAVERA Y CRECIMIENTO DE VEGETACIÓN
LA PRECIPITACIÓN DURANTE EL VERANO PODRÍA AUMENTAR SEQUÍAS EPISÓDICAS
NUEVO ESTRÉS PARA LOS ECOSISTEMAS
LAS SEQUIAS PUEDEN DEBILITAR LOS SISTEMAS DE RAICES EN ARBOLES
AUMENTO EN CONTAMINANTES VIALES EN CUERPOS DE AGUA
DAÑOS A LA COSECHA POR LLUVIAS INTENSAS
LAS SEQUÍAS PUEDEN REDUCIR EL SUMINISTRO DE AGUA LOCAL

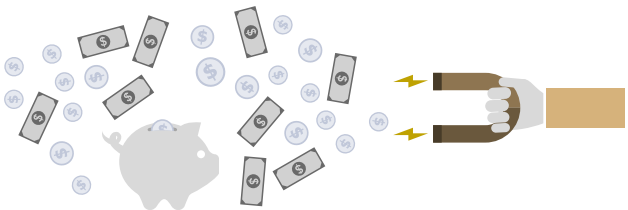
8

¿CUÁLES SON LOS RIESGOS?
Mayor estrés sobre los desafíos que ya enfrentamos y cómo operamos en nuestra vida cotidiana

9

¿QUÉ SIGNIFICA ESTO PARA NOSOTROS?
$

10



11

12

13

14

15

¿QUÉ ESTAMOS HACIENDO AL RESPECTO?

Hacer un plan para reducir nuestras vulnerabilidades y fortalecer nuestras fortalezas.

Asegurar el apoyo financiero a través de programas Estatales y Federales

16

ADAPTACIÓN DEL CLIMA DE **LOWELL** Y **METAS** DE MITIGACIÓN DE PELIGROS

17

¿SERÁS PARTE DE LA SOLUCIÓN?

- **COMIENZA LLENANDO LA ENCUESTA:** tinyurl.com/LowellMVPEncuesta
- **LUEGO COMPARTE LINK EN FACEBOOK Y TWITTER CON EL HASHTAG** #ResilientLowell

18

Lowell Municipal Vulnerability Preparedness and Hazard Mitigation Survey

Olá! Esperamos que você esteja bem durante esses tempos incertos, e obrigado por participar no nosso questionário.

As mudanças climáticas têm o potencial de impactar a forma como abordamos a habitação, como apoiamos a saúde de nossa comunidade, como construímos nossa infraestrutura e como protegemos o meio ambiente. A sua voz representa um aspecto único da comunidade de Lowell e adoraríamos ouvir as suas experiências e idéias. Respondendo ao questionário, você nos ajudará a nos preparar para um futuro mais resiliente. #ResilientLowell

Se você tiver informações adicionais, perguntas ou problemas para participar, entre em contato com Adria Boynton (Especialista em Resiliência da Weston & Sampson) no boyntona@wseinc.com ou (978) 278-3592.

1. Antes de assistir a este vídeo, em uma escala de 1-5 (5 sendo muito conhecedor), como você classificaria seu conhecimento sobre os perigos locais e os impactos climáticos?

    - 1
    - 2
    - 3
    - 4
    - 5

2. Depois de assistir a este vídeo, em uma escala de 1-5 (5 sendo muito conhecedor), como você classificaria seu conhecimento sobre os perigos locais e os impactos climáticos?

    - 1
    - 2
    - 3
    - 4
    - 5

3. Com que risco climático você está mais preocupado?

    - Temperaturas extremas
    - Inundações

- Tempestades de neve
- Tempestades de gelo
- Seca
- Fogo
- Ventos fortes (nor'easter, tornado, tempestades)

4. Como esses riscos climáticos o afetaram ou quais impactos você viu em sua comunidade? Memórias de riscos climáticos recentes podem incluir:

   - inundação de estradas locais
   - o Inverno de 2014-2015, quando Lowell experimentou mais de 3 metros de neve
   - quatro Nor'easters em um mês em 2018
   - ondas de calor com vários dias acima de 90 graus F
   - condições de seca em 2016

   Digite sua resposta

5. Quão preparado você acha que Lowell está para futuros eventos de risco climático?

   - Muito preparado
   - Um pouco preparado
   - Não está preparado.
   - Outros

6. Explique sua razão para selecionar sua resposta na Questão 5.

   Digite sua resposta

7. Que medidas você já tomou para se preparar para eventos extremos de risco climático? Verifique tudo o que se aplica.

   - Tenho um kit em caso de emergências (que podem incluir comida, água, lanternas, baterias e outros recursos materiais)
   - Recebo notícias, atualizações e informações sobre preparação de emergência em Lowell
   - Eu sei onde fica o abrigo local mais próximo.
   - Outros

8. Que recursos você precisa para se sentir mais preparado? Verifique tudo o que se aplica.

- Treinamento sobre como estar melhor preparado
- Os recursos financeiros para agir
- Mais informações sobre o que eu posso fazer para me preparar
- Mais informações sobre o que a Cidade está fazendo
- Outros

9. Gostaria de receber informações sobre projetos e ações de resiliência em Lowell? Verifique tudo o que se aplica.

- Eventos públicos, incluindo webinars virtuais
- Materiais imprimidos, incluindo relatórios, folhas de fatos ou folhetos
- Online, inclusive através do site da Cidade de Lowell, Twitter e Facebook
- Grupos e organizações locais, incluindo bolhetins informativos e reuniões existentes
- Outros

10. Reconhecemos que a preparação e a resposta a qualquer desafio em nossa comunidade tem estratégias e desafios sobrepostos. Estamos interessados em documentar a experiência comunitária da COVID-19. O que funcionou bem, e o que poderia melhorar?

Digite sua resposta

11. Há algum comentário ou pergunta adicional que você gostaria de compartilhar com a equipa do projeto?

Digite sua resposta

12. Obrigado por completar esta pesquisa. Se você estiver interessado em receber atualizações adicionais relacionadas a iniciativas climáticas em Lowell, digite seu e-mail abaixo.

Digite sua resposta

13. Não são necessárias as seguintes perguntas. No entanto, ao responder a essas perguntas demográficas, você nos ajudará a avaliar se nossa pesquisa tem ampla participação. Por favor, selecione tudo o que se aplica.

- Eu arrendo uma casa/ apartamento em Lowell
- Eu tenho um negócio em Lowell
- Eu sou um veterano

14. Por favor, selecione sua faixa etária.

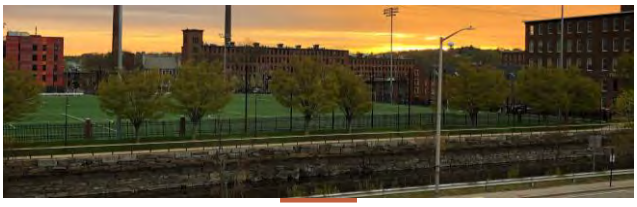
- sub-18
- 18-24
- 25-35
- 36-45
- 46-55
- 56-65
- 66-75
- Mais de 75 anos

15. Como você se descreveria?

- Branco
- Negro ou afro-americano
- Índio americano ou nativo do Alasca
- Asiático
- Nativo havaiano ou outro ilhéus do Pacífico
- Múltiplos grupos ethnicos
- Outros

16. Você é hispânico, latino ou de origem espanhola?

- Sim
- Não



CIDADE DE LOWELL

Visão geral do projeto Plano Municipal de Prevenção de Vulnerabilidades (MVP) e Plano de Mitigação de Perigos (HMP)

Weston & Sampson Foto por Weston & Sampson

1

ASSISTA O VÍDEO

- Quais são os riscos climáticos em Lowell?
- O que está em risco?
- O que estamos fazendo sobre isso?

FAÇA A PESQUISA

para nos contar sobre suas experiências, idéias e perguntas!

2

DAS ALTERAÇÕES CLIMÁTICAS

Das Alterações Climáticas: uma mudança nos padrões climáticos e nas tendências anuais. Em Lowell, podemos esperar temperaturas mais altas, tempestades mais severas e mais inundações.

Perigos climáticos: eventos climáticos que podem afetar a saúde humana, meios de subsistência, habitação, empresas e recursos naturais

Foto por W&S

3

PERIGOS CLIMÁTICOS EM LOWELL

Weston & Sampson

4

TEMPERATURAS EXTREMAS

EM MASSACHUSETTS

5

IMPACTOS DAS TEMPERATURAS ALTAS

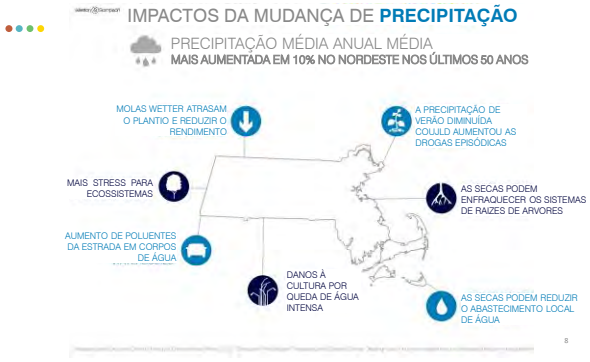
TEMPERATURAS ANUAIS MAIS QUENTES DO AR
ATÉ 0.5°F POR DÉCADA DESDE 1970, EM MÉDIA

INVERNOS MAIS QUENTES
ATÉ 1.3°F POR DÉCADA DESDE 1970, EM MÉDIA

6

ALTERAÇÕES DE PRECIPITAÇÃO
PRECIPITAÇÃO DURANTE EVENTOS FORTES NO NORDESTE
AUMENTARAM MAIS DE
70%
ENTRE 1958-2010

7


IMPACTOS DA MUDANÇA DE PRECIPITAÇÃO
PRECIPITAÇÃO MÉDIA ANUAL MÉDIA
MAIS AUMENTADA EM 10% NO NORDESTE NOS ÚLTIMOS 50 ANOS
MOLAS WETTER ATRASAM O PLANTIO E REDUZIR O RENDIMENTO
A PRECIPITAÇÃO DE VERÃO DIMINUÍDA COULD AUMENTOU AS DROGAS EPISÓDICAS
MAIS STRESS PARA ECOSSISTEMAS
AS SECAS PODEM ENFRAQUECER OS SISTEMAS DE RAIZES DE ÁRVORES
AUMENTO DE POLUENTES DA ESTRADA EM CORPOS DE ÁGUA
DANOS À CULTURA POR QUEDA DE ÁGUA INTENSA
AS SECAS PODEM REDUZIR O ABASTECIMENTO LOCAL DE ÁGUA

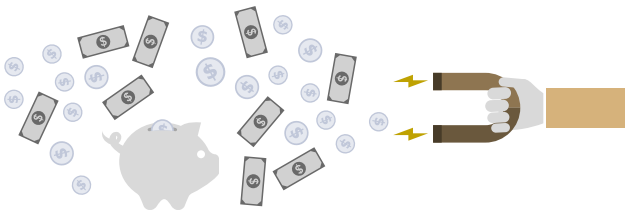
8

O QUE ESTÁ EM RISCO?
Maior stress nos desafios que já enfrentamos e como operamos no dia-a- dia

9

O QUE ISSO SIGNIFICA PARA NÓS?
$

10



11

12

13

14

A Infraestrutura

Transporte público

Foto: Ônibus LRTA , Wikimedia Commons

Estradas

Foto por W&S

Sociedade

Serviços públicos

Foto: Corpo de Bombeiros de Lowell

Residentes vulneráveis

Foto: Corpo de Bombeiros de Lowell

Meio Ambiente

Corpos de Água

Foto por W&S

Copa da árvore

Foto por W&S

15

15

O QUE ESTAMOS FAZENDO SOBRE ISSO?

Planeando reduzir nossas vulnerabilidades e fortalecer nossos pontos fortes

Garantir apoio financeiro por meio de programas estaduais e federais

Foto: Ciudade Facebook

16

OBJETIVOS DE ADAPTAÇÃO DO CLIMA DE LOWELL E DE MITIGAÇÃO DE PERIGOS

17

VOCÊ SERÁ PARTE DA SOLUÇÃO?

- **COMECE A NOSSA PESQUISA:** tinyurl.com/LowellMVPPesquisa
- **ENTÃO COMPARTILHE NO FACEBOOK E TWITTER COM O HASHTAG** #ResilientLowell

18

ការស្ទង់មតិលើការត្រៀមខ្លួនបង្ការនឹងភាពងាយរងគ្រោះ និងការកាត់បន្ថយស្ថានភាពគ្រោះថ្នាក់នៃទីក្រុងឡូវែល

សួស្តី! ពួកយើងសង្ឃឹមថាអ្នកមានសុខភាពល្អនៅក្នុងស្ថានភាពលំបាកនេះ ហើយយើងសូមអរគុណអ្នកដែលចំណាយពេលចូលរួមក្នុងការស្ទង់មតិរបស់យើង។

ការប្រែប្រួលអាកាសធាតុអាចជះឥទ្ធិពលលើវិធីដែលយើងធ្វើការលើបញ្ហាលំនៅស្ថាន វិធីដែលយើងឆ្លើយតបនឹងបញ្ហាសុខភាពសហគមន៍ វិធីដែលយើងសាងសង់ហេដ្ឋារចនាសម្ព័ន្ធ និងវិធីដែលយើងការពារបរិស្ថាន។
ការបញ្ចេញមតិរបស់អ្នកតំណាងអោយជ្រុងដ៏មានសារៈសំខាន់មួយនៃសហគមន៍ឡូវែលទាំងមូល ហើយយើងចង់ដឹងពីមតិ បទពិសោធន៍ និងគំនិតរបស់អ្នក។ ការដែលអ្នកចូលរួមក្នុងការស្ទង់មតិនេះ នឹងជួយដល់ពួកយើងក្នុងការត្រៀមខ្លួនសម្រាប់អនាគតដ៏រឹងមាំមួយ។

#ResilientLowell

ប្រសិនបើអ្នកមានមតិ និងសំនួរបន្ថែម ឬមានឧបសគ្គក្នុងការចូលរួម សូមទំនាក់ទំនងទៅកាន់ Adria Boynton (អ្នកឯកទេសលើភាពធន់នឹងគ្រោះអាកាសធាតុ “Resiliency Specialist” នៅក្រុមហ៊ុន Weston & Sampson) តាមរយៈអ៊ីមែល៖ boyntona@wseinc.com ឬលេខទូរស័ព្ទ (978) 278-3592។

1. មុននឹងមើលវីដេអូនេះ ក្នុងកំរិត 1-5 (5 មានចំណេះដឹងខ្ពស់) តើអ្នកវាយតំលៃចំណេះដឹងរបស់អ្នកអំពីស្ថានភាពដែលអាចបង្កឲ្យមានគ្រោះថ្នាក់ក្នុងតំបន់ និងផលប៉ះពាល់នៃអាកាសធាតុយ៉ាងដូចម្តេច?
   - ☐ 1 (មានចំណេះដឹងទាប)
   - ☐ 2
   - ☐ 3
   - ☐ 4
   - ☐ 5 (មានចំណេះដឹងខ្ពស់)

2. បន្ទាប់ពីមើលវីដេអូនេះរួចមក ក្នុងកំរិត 1-5 (5 មានចំណេះដឹងខ្ពស់) តើអ្នកវាយតំលៃចំណេះដឹងរបស់អ្នកអំពីស្ថានភាពដែលអាចបង្កឲ្យមានគ្រោះថ្នាក់ក្នុងតំបន់ និងផលប៉ះពាល់នៃអាកាសធាតុយ៉ាងដូចម្តេច?
   - ☐ 1 (មានចំណេះដឹងទាប)
   - ☐ 2
   - ☐ 3
   - ☐ 4
   - ☐ 5 (មានចំណេះដឹងខ្ពស់)

3. តើគ្រោះអាកាសធាតុណាដែលធ្វើឲ្យអ្នកព្រួយបារម្ភជាងគេ?
   - ☐ ការកើនឡើងខ្លាំង ឬការចុះខ្លាំងនៃសីតុណ្ហភាព
   - ☐ ទឹកជំនន់
   - ☐ អាកាសធាតុនៅរដូវរងារ (ព្យុះទឹកកកក្រាស និងព្យុះព្រិល)
   - ☐ ព្យុះទឹកកក
   - ☐ គ្រោះរាំងស្ងួត
   - ☐ គ្រោះអគ្គិភ័យ

- ☐ ខ្យល់ខ្លាំង (ព្យុះទឹកកកនរអ៊ីស្ព័រ ខ្យល់ព្យុះ និងផ្គរន្ទះ)

4. តើគ្រោះអាកាសធាតុទាំងនេះបានប៉ះពាល់ដល់អ្នកយ៉ាងដូចម្តេចខ្លះ ឬតើផលប៉ះពាល់ពីគ្រោះអាកាសធាតុអ្វីខ្លះដែលអ្នកបានឃើញនៅក្នុងសហគមន៍របស់អ្នក? គ្រោះអាកាសធាតុនាពេលថ្មីៗនេះរួមមាន៖

   - ទឹកជន់លិចផ្លូវធ្វើដំណើរ
   - រដូវរងារឆ្នាំ2014-2015 នៅពេលដែលទីក្រុងឡូរ៉ែលមានព្រិលកំពស់ជាង10ហ្វីត
   - ព្យុះទឹកកកនរអ៊ីស្ព័រចំនួន4ដងក្នុង1ខែកាលពីឆ្នាំ2018
   - រលកកំដៅដែលមានថ្ងៃខ្លះមានសីតុណ្ហភាពជាង 90 ហ្វារិនហៃ
   - ស្ថានភាពរាំងស្ងួតកាលពីឆ្នាំ2016

   Enter your answer សូមសរសេរចម្លើយរបស់អ្នកនៅទីនេះ

5. តើអ្នកគិតថាទីក្រុងឡូរ៉ែលត្រៀមខ្លួនក្នុងកំរិតណាដែរក្នុងការប្រឈមនឹងហេតុការណ៍គ្រោះអាកាសធាតុនាពេលអនាគត?
   - ☐ ត្រៀមខ្លួនខ្ពស់
   - ☐ ត្រៀមខ្លួនបន្តិច
   - ☐ មិនទាន់ត្រៀមខ្លួន
   - ☐ ផ្សេងៗ

6. សូមអ្នកពន្យល់ពីមូលហេតុដែលអ្នកជ្រើសរើសចម្លើយរបស់អ្នកនៅក្នុងសំនួរទី5

   Enter your answer សូមសរសេរចម្លើយរបស់អ្នកនៅទីនេះ

7. តើអ្នកបានធ្វើអ្វីខ្លះដើម្បីត្រៀមខ្លួននឹងព្រឹត្តិការណ៍គ្រោះអាកាសធាតុធ្ងន់ធ្ងរ? សូមជ្រើសរើសចំលើយខាងក្រោម (អ្នកអាចជ្រើសរើសចម្លើយលើសពី1)
   - ☐ ខ្ញុំមានឧបករណ៍ត្រៀមក្នុងករណីមានអាសន្ន (ដែលរួមមានស្បៀង ទឹក ពិល អាគុយ និងប្រដាប់ប្រដារផ្សេងៗ)
   - ☐ ខ្ញុំទទួលបានពត៌មានសំខាន់ និងទាន់ហេតុការណ៍នានាអំពីការត្រៀមខ្លួនក្នុងគ្រាអាសន្ននៅក្នុងទីក្រុងឡូរ៉ែល
   - ☐ ខ្ញុំស្គាល់ទីកន្លែងជ្រកគ្រាអាសន្នដែលនៅជិតខ្លួនបំផុត
   - ☐ ផ្សេងៗ

8. តើធនធានអ្វីខ្លះដែលអ្នកត្រូវការដើម្បីអោយមានទំនុកចិត្តថាត្រៀមខ្លួនជាងមុន? សូមជ្រើសរើសចំលើយខាងក្រោម (អ្នកអាចជ្រើសរើសចម្លើយលើសពី1)
   - ☐ ការបណ្តុះបណ្តាលលើវិធីត្រៀមខ្លួន
   - ☐ ធនធានផ្នែកហិរញ្ញវត្ថុដើម្បីត្រៀមខ្លួន
   - ☐ ពត៌មានបន្ថែមលើអ្វីដែលខ្ញុំអាចធ្វើដោយខ្លួនឯងបាន
   - ☐ ពត៌មានបន្ថែមលើអ្វីដែលទីក្រុងកំពុងធ្វើ
   - ☐ ផ្សេងៗ

9. តើអ្នកចង់ទទួលបានពត៌មានកម្មវិធី
និងសកម្មភាពទាក់ទងនឹងភាពធន់នឹងគ្រោះអាកាសធាតុនៅក្នុងទីក្រុងឡរ៉ែលតាមរយ:ណា?
សូមជ្រើសរើសចំលើយខាងក្រោម (អ្នកអាចជ្រើសរើសចម្លើយលើសពី1)

- ☐ តាមរយ:ព្រឹត្តិការណ៍សាធារណ: រួមមានសិក្ខាសាលាតាមអនឡាញជាដើម
- ☐ តាមរយ:ការបោះពុម្ពផ្សាយ រួមមាន របាយការណ៍ ការាងអង្គហេតុ ឬខិត្តប័ណ្ណ
- ☐ តាមរយ:អនឡាញ រួមមានគេហទំព័រ បណ្តាញសង្គមTwitter និងបណ្តាញសង្គមFacebook
  របស់ទីក្រុងឡរ៉ែល
- ☐ តាមរយ:ក្រុមសង្គម និងអង្គការ រួមមានព្រឹត្តិប័ត្រពត៌មាន និងការជួបប្រជុំផ្សេងៗ
- ☐ ផ្សេងៗ

10. ពួកយើងទទួលស្គាល់ថាការត្រៀមខ្លួន
និងការឆ្លើយតបនឹងបញ្ហាប្រឈមនានានៅក្នុងសហគមន៍របស់យើងមានយុទ្ធសាស្ត្រ
និងបញ្ហាប្រឈមត្រួតគ្នា។
យើងចាប់អារម្មណ៍ចង់កត់ត្រាបទពិសោធន៍របស់សហគមន៍ទាក់ទងនឹងជំងឺ COVID-19។
តើអ្វីខ្លះដែលគិតថាធ្វើបានល្អ ហើយអ្វីខ្លះដែលអ្នកគិតថាគួរកែសម្រួលឲ្យបានប្រសើរជាងនេះ?

Enter your answer សូមសរសេរចម្លើយរបស់អ្នកនៅទីនេះ

11. តើអ្នកមានវិចារ ឬសំនួរបន្ថែមសម្រាប់ក្រុមការងារគម្រោងដែរឬទេ?

Enter your answer សូមសរសេរចម្លើយរបស់អ្នកនៅទីនេះ

12. សូមអរគុណសម្រាប់ការបំពេញការស្ទង់មតិនេះ។
ប្រសិនបើអ្នកចាប់អារម្មណ៍ក្នុងការទទួលបានពត៌មានអំពីគម្រោងនានាទាក់ទងនឹងការប្រែប្រួល
អាកាសធាតុនៅក្នុងទីក្រុងឡរ៉ែល សូមបំពេញអ៊ីមែលរបស់អ្នកនៅក្នុងប្រអប់ខាងក្រោម៖

Enter your answer សូមសរសេរចម្លើយរបស់អ្នកនៅទីនេះ

13. ចាប់ពីសំនួរនេះទៅ អ្នកអាចជ្រើសរើសមិនឆ្លើយបាន។ ក៏ប៉ុន្តែ
ប្រសិនបើអ្នកជ្រើសរើសឆ្លើយនឹងសំនួរប្រជាសាស្ត្រទាំងនេះ
អ្នកនឹងជួយយើងក្នុងវាយតម្លៃថាតើការស្ទង់មតិរបស់យើងមានការចូលរួមធំទូលាយដែរឬទេ។
សូមជ្រើសរើសចំលើយខាងក្រោម (អ្នកអាចជ្រើសរើសចម្លើយលើសពី1)

- ☐ ខ្ញុំរស់នៅផ្ទះជួល
- ☐ ខ្ញុំជាម្ចាស់អាជីវកម្មមួយរូប
- ☐ ខ្ញុំគឺជាទាហានជើងចាស់

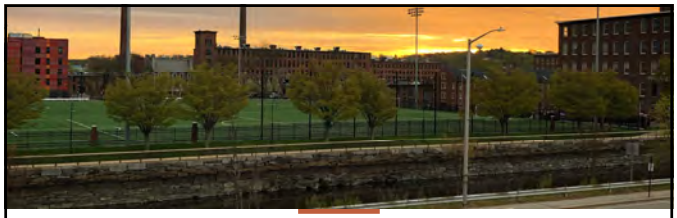
14. សូមអ្នកជ្រើសរើសជួរអាយុរបស់អ្នក។

- ☐ ក្រោម18ឆ្នាំ
- ☐ 18-24 ឆ្នាំ
- ☐ 25-35 ឆ្នាំ
- ☐ 36-45 ឆ្នាំ

- ☐ 46-55 ឆ្នាំ
- ☐ 56-65 ឆ្នាំ
- ☐ 66-75 ឆ្នាំ
- ☐ លើស75ឆ្នាំ

15. តើអ្នកពិពណ៌នាអំពីខ្លួនអ្នកយ៉ាងដូចម្តេចដែរ?
    - ☐ ជនជាតិស្បែកស
    - ☐ ជនជាតិស្បែកខ្មៅ ឬជនជាតិអាមេរិកដើមកំណើតអាហ្វ្រិក
    - ☐ ជនជាតិដើមឥណ្ឌា ឬជនជាតិដើមអាឡាស្កា
    - ☐ ជនជាតិអាស៊ី
    - ☐ ជនជាតិដើមហាវ៉ៃ ឬជនជាតិដើមនៃប្រជុំកោះប៉ាស៊ីហ្វិក
    - ☐ ពហុជាតិសាសន៍
    - ☐ ផ្សេងៗ

16. តើអ្នកមានដើមកំណើតពីសហគមន៍និយាយភាសាអេស្ប៉ាញ ពីអាមេរិកឡាទីន ឬពីអេស្ប៉ាញឬ?
    - ☐ ចាស/បាទ
    - ☐ ទេ



ទីក្រុងឡូដ

ការរៀបរាប់អំពីផែនការគម្រោងនៃការត្រៀមខ្លួនបង្ការនឹងភាពងាយរងគ្រោះ

និងការកាត់បន្ថយស្ថានភាពគ្រោះថ្នាក់

Weston & Sampson

1

ទស្សនាវីដេអូ

- តើអ្វីខ្លះជាមូលហេតុការសរសេរនៅក្នុងទីក្រុងឡូដ?
- តើមានបានន័យយ៉ាងម៉ូចខ្លះ?
- តើកូនៗគួរកត់ចំណាំអ្វីខ្លះចំពោះបញ្ហានេះ?

ចូលរួមវាយតម្លៃការស្តង់ឌីត

តើអ្នកគ្រប់គ្រងបានកត់ចំណាំពីរបៀបណាដែលរបស់អ្នក ពិនិត

និងសំណួរដែលអ្នកមាន!

2

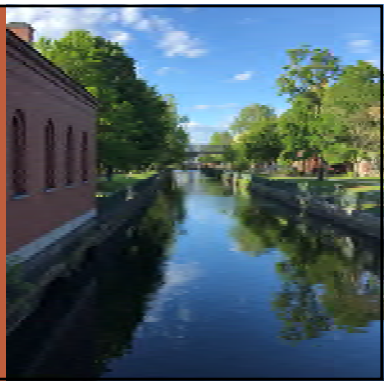
ការប្រែប្រួលអាកាសធាតុ

ការកើតឡើងនូវការប្រែប្រួលអាកាសធាតុ

ជាការកត្តាសំខាន់ដែលជំរុញការសរសេរ និងកាត់បន្ថយកម្លាំងការ នៅក្នុងទីក្រុងឡូដ ដោយសារតម្លៃជាមធ្យមនៃសីតុណ្ហភាពកើនឡើង ចុះកាត់ទឹកភ្លៀងសរុប និងទឹកជំនន់កាន់តែច្រើន។

ឥទ្ធិពលអាកាសធាតុ

ប្រវត្តិការណ៍រាប់ការសរសេរដោយសារទីតាំងលក្ខណៈពិសេសនៃ ការសរសេរជាប្រចាំឆ្នាំ លំហូរសារ ទុយកំដៅ និងផលនានាផ្សេងទៀតរបស់យើងទាំងអស់ខ្លួន។



3

ហានិភ័យអាកាសធាតុនៅក្នុងទីក្រុងឡូដ

Weston & Sampson

4

ការកើនឡើងនូវកម្លាំងសីតុណ្ហភាព

នៅក្នុងរដ្ឋម៉ាសាជូសេត

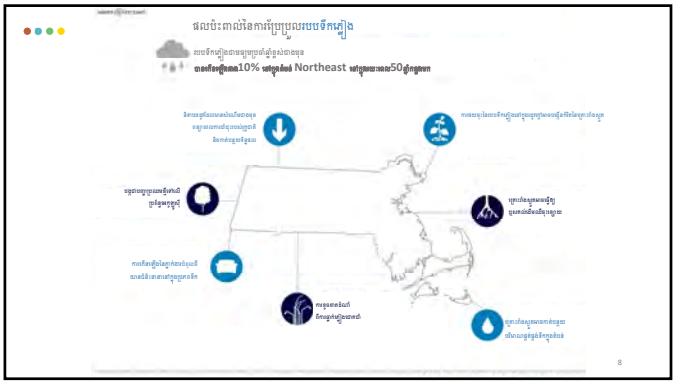
5

ផលប៉ះពាល់នៃការកើនឡើងសីតុណ្ហភាព

6

ការផ្លាស់ប្តូរ
នៃរបបទឹកភ្លៀង
របបទឹកភ្លៀងក្នុងអំឡុងពេលប្រវត្តិការណ៍ភ្លៀងធ្លាក់សន្ធរសន្ធាក់នៅក្នុង
តំបន់ NORTHEAST
បានកើនឡើងជាង
70%
រវាងឆ្នាំ 1958 និងឆ្នាំ2010
7

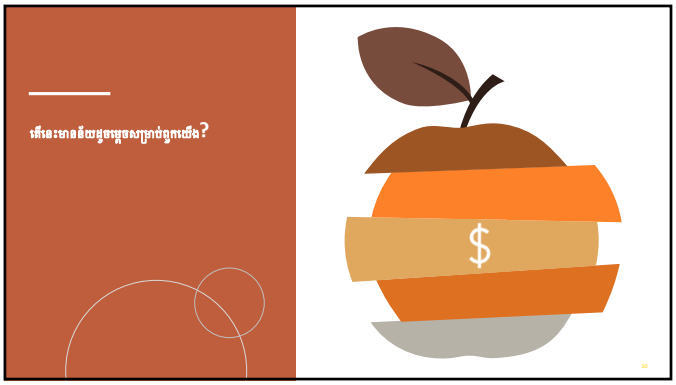
7


ផលប៉ះពាល់នៃការប្រែប្រួលរបបទឹកភ្លៀង
8

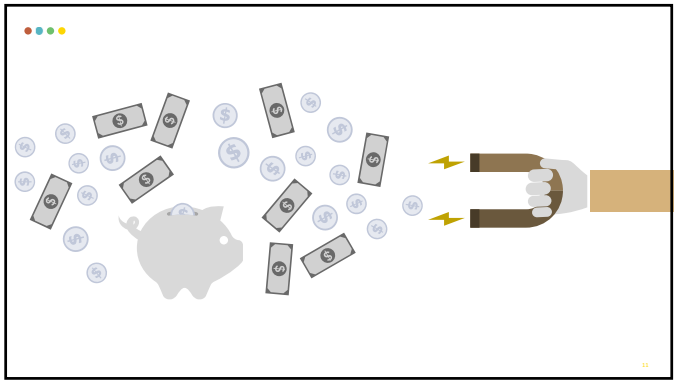
8

តើមានហានិភ័យអ្វីខ្លះ?

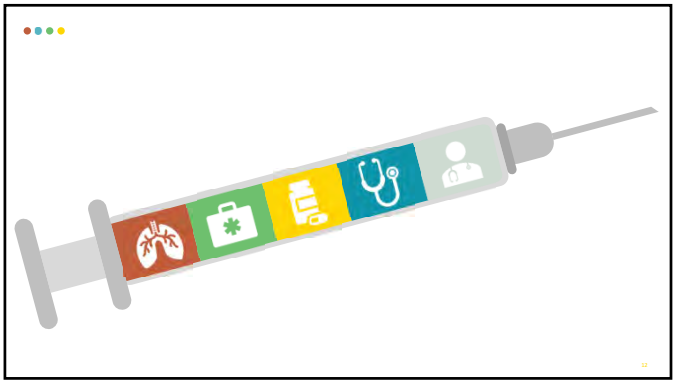
9


តើនេះមានន័យអ្វីចំពោះសហគ្រាសរបស់ខ្លួនការយើង?
$
10

10


11

11


12

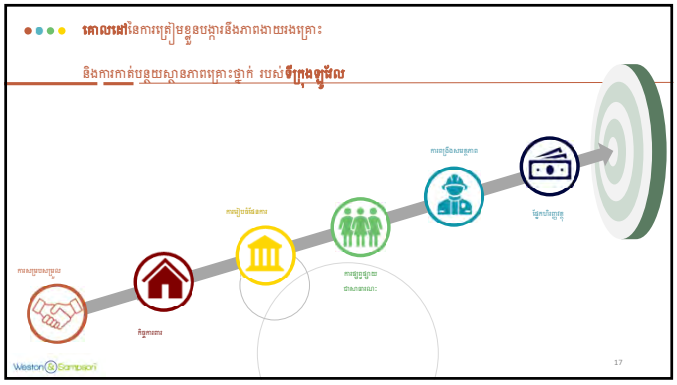
12

13

14

15

16



17

18

Appendix E

Plan Adoption

Appendix F

FEMA Approval