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Climate Change Impacts & Adaptation

Local Solutions for the Strafford Region

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Authors:
Elizabeth Durfee
Colin Lentz

Strafford Regional Planning Commission

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Introduction

Purpose

The Climate Change Impacts and Adaptation appendix discusses observed and projected climate change in Southern New Hampshire and the impacts climate change will have on our communities, as well as identifies appropriate adaptation strategies to protect assets and address vulnerabilities in the region. This appendix includes an overview of climate change projections in the region and a discussion of both impacts and adaptation strategies in six planning sectors: built environment, human health, water resources, natural systems, agriculture, and society.

This appendix includes several maps that highlight the vulnerability of critical infrastructure, community assets, and populations at a community and regional level. A suite of federal, state, and local programs and resources is included to serve as guidance for communities that seek to increase resiliency to the increases in temperature, extreme precipitation events, and sea level and flooding anticipated in this region.

The information, tools, and adaptation strategies provided in this document are intended to assist communities with reducing vulnerability to climate change and proactively responding to the impacts that increases in temperature, extreme precipitation events, and sea level rise will have on the built environment and quality of life.

Vision

The region will be well prepared to respond to the impacts that increases in temperature, extreme precipitation events, and sea level will have on the built environment and quality of life. The region will strive to take a leadership role in building sustainable communities that account for the needs of current and future generations. The region will take a collaborative, inclusive, and proactive approach to climate adaptation planning that will increase the resiliency of community members and infrastructure to adapt to changing conditions.

The region contributes to climate change mitigation efforts through measures that reduce heat-trapping emissions and enhance the ability to store carbon across the landscape.

Executive Summary

Climate has changed and will continue to change in Southern New Hampshire and the Strafford Region. Regional projections of climate change from *Climate Change in Southern New Hampshire: Past, Present, and Future* and *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future* include:

- Increased seasonal temperatures and frequency and duration of heat waves
- Decreased snow and ice cover
- Increased precipitation and extreme precipitation events
- Increased drought
- Sea level rise and coastal flooding
- Increased sea surface temperature
- Increased growing season and changes in plant hardiness zones

The rate at which climate will continue to change is dependent on a number of factors including: population growth, peak, and decline; economic growth and associated fossil fuel use; adoption of less fossil-fuel industries and cleaner, more efficient technologies; and carbon dioxide concentrations in the atmosphere. High and low emissions scenarios are used in climate change projections to account for this uncertainty.

Climate change will have widespread impacts on people, the economy, and the build and natural environments within the region. The projected increase in precipitation and extreme precipitation events, in particular, pose a threat to the built environment. Climate change will increase the risk of flooding of buildings and infrastructure located in proximity to streams, rivers, and the coast. In many instances, existing infrastructure may not have the capacity to handle greater volumes of water. Temperature, extreme weather events, reduced air quality, and an increase in vector-borne diseases may impact the health of residents in the region. Factors including age, socioeconomic status, and existing health conditions contribute to vulnerability of the region's population. Climate change will impact water resources, forests, and sensitive species. Temperature and precipitation change will lead to greater volumes of pollutant containing stormwater runoff entering the region's streams and rivers, which will impact drinking water quality, aquatic biota, and recreation opportunities. As the climate warms, species will continue to shift north, resulting in a change of forest composition and habitat. Climate change is a threat to economically and culturally significant species such as sugar maple. Invasive species and pests will become an increasing threat to natural habitats as well as to agriculture. While warmer temperatures may provide farmers with the opportunity to grown new crops, warmer winters and a decline in snow and ice cover will negatively impact the winter recreation industry.

Planning and preparedness is essential to minimizing the impacts of climate change. There are a range of adaptation strategies at the individual, community, and regional level to increase resiliency to climate change. Integrating climate change planning into existing planning documents is a key aspect of adaptation planning. Increasing awareness of health implications, expanding access to resources, identifying at risk infrastructure, and enhancing existing emergency preparation and planning and stormwater management efforts will be important to minimizing risks to people, and the build and natural environments. Identifying opportunities to enhance conservation efforts and diversify recreation and tourism activities, for example, will also strengthen the region's ability to thrive under change.

Communities in the region already implementing a range of adaptation strategies that enhance quality of life and reduce risk associated with climate change. Pairing adaptation and climate change mitigation efforts can be an effective and resource-efficient strategy to increase resilience and mitigate future climate change.

There are many initiatives, tools, and resources available to support and guide local and regional adaptation planning. Vulnerability mapping is one tool that can assist local and regional decision makers with prioritizing action and identifying at risk areas and populations. SRPC can assist communities with climate change adaptation and guide implementation of priority projects in the region.

Observed and Projected Climate Change

Background and Overview

The Earth's climate has and will continue to change. Since the 1970s, the rate at which the climate has changed has accelerated. Scientific evidence indicates that human activities are a significant and increasing driver of global climate change.[1] Burning fossil fuel (coal, oil, and natural gas), deforestation, and raising livestock release heat-trapping gasses including carbon dioxide, methane, and nitrogen oxide into the atmosphere. The increased concentration of these greenhouse gasses in the atmosphere affects the global climate system and leads to varying impacts by region.[2]

Climate in the Northeast is spatially and temporally variable and often affected by extreme weather events.[3] Since 1970, the Northeast has warmed at an annual rate of almost 0.5°F per decade, with temperatures in winter rising even faster (1.3°F per decade from 1970-2000).[4] Over the last century, average temperature and precipitation and the frequency and intensity of heat and precipitation events in the Piscataqua/Great Bay region have increased.[5] Sea level rise and coastal flooding associated with sea level rise have also increased.[6] Regional and national studies indicate that these trends will continue and intensify in the Northeast.[7]

Ongoing Changes in the Earth's Climate System[1]

- ↑ *Global atmospheric temperature*
- ↑ *Global ocean temperature*
- ↑ *Sea surface temperature*
- ↑ *Sea level*
- ↑ *Atmospheric water vapor*
- ↑ *Precipitation*
- ↑ *Extreme precipitation events*
- ↑ *Melting of mountain glaciers*
- ↑ *Flux of ice from the Greenland and West Antarctic ice sheets into the ocean*
- ↑ *Thawing permafrost*
- ↑ *Methane hydrates*
- ↓ *Volume and areal extent of spring and summer Arctic sea ice*
- ↓ *Northern hemisphere snowcover*

It is important to comprehensively address both the positive and negative impacts these changes will have on the build and natural environment, human health, and the economy. From increasing access to resources to making the region and its vulnerable populations better able to cope with extreme temperatures to protecting critical assets and natural resources that enable a high quality of life in the region, adaptation planning at the local level can increase a community's ability to cope with the expected impacts that a changing climate will have on the region.

Issues of particular concern to the Strafford Regional Planning Commission and communities in the region include:

- Property and infrastructure damage associated with extreme precipitation, flooding, and with storm surge and sea level rise in coastal areas.
- Public health risks associated with contaminated water, heat waves, and increases in vector borne diseases.
- Degradation of natural resources and assets and water quality impairment in Great Bay due to temperature and precipitation-driven ecological changes and increased stormwater runoff.
- Economic impacts associated with weather-related business closures and declining viability of weather-dependent industries.
- Access to resources and emergency planning during extreme weather events.

Planning for these changes will increase the resiliency of communities to adapt to and thrive under new environmental conditions with minimal economic, social, and environmental impacts.

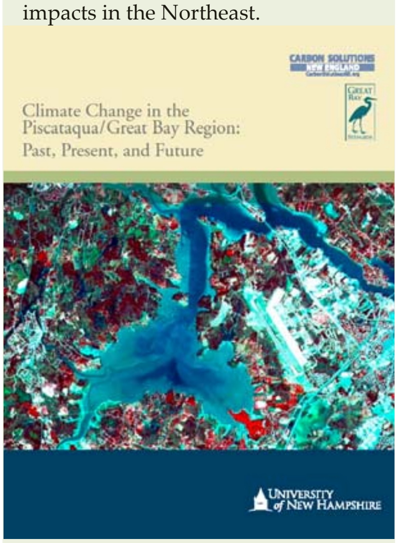
Local Climate Change Analysis

The observed and projected changes in temperature, precipitation, sea level and surface temperature, flooding, lake ice-out, and growing season that are summarized in this section are based on two recent analyses of climate change

Regional Climate Change Reports

[Climate Change in Southern New Hampshire: Past, Present, and Future]() and [Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future]() were prepared by a team of scientists and planners on behalf of New Hampshire's nine Regional Planning Commissions (RPCs). The climate analysis uses statistical techniques to downscale regional temperature and precipitation simulations generated by global climate models to describe expected climate change and impacts in Southern New Hampshire. Data from meteorological stations located south of 43.90°N latitude was used in the Southern New Hampshire report. Data for the Piscataqua/Great Bay Region was collected from four meteorological stations (Durham and Concord, NH; Lawrence, MA; and Portland, ME) located in and around the Piscataqua/Great Bay watershed.

The **National Climate Assessment** (NCA) is an informational resource about climate change, including observed changes, anticipated future trends, and the current status of the climate that is produced through the U.S. Global Change Research Program (USGCRP). To date, three NCA reports have been produced. The [Third NCA Report](), released in 2014, includes regional impacts and sectors impacted by climate change. This report provides broader information about observed and projected climate change and impacts in the Northeast.



in Southern New Hampshire and the Piscataqua/Great Bay Region. Regional information from the National Climate Assessment's is provided to supplement these studies.

Scenario Modeling

The rate at which climate will continue to change is dependent on a number of factors including: population growth, peak, and decline; economic growth and associated fossil fuel use; adoption of less fossil-fuel industries and cleaner, more efficient technologies; and carbon dioxide concentrations in the atmosphere. Because there is uncertainty about future emissions levels and the effect emissions levels and other factors will have on complex natural systems, modeling two emissions scenarios – one high and one low - provides a plausible range in which future conditions will fall.

Timeframe is also important to consider. While near term projections do not always differ dramatically under high and low emissions scenarios, end of the century projections of low versus high emissions scenarios often vary substantially. Additionally, because exposure and sensitivity to climate change impacts varies and because of the potential for adaptation strategies to reduce vulnerability, it is challenging to predict the impacts that climate change will have on different sectors and populations across the region.

The two regional studies that were prepared by Cameron Wake, PhD et al. provide the foundation of this chapter section model near-, mid-, and end-of-century projections under both a high (A1fi) and low (B1) emissions scenario (see Figure 1 and Table 1).

Table 1. Characteristics of high and low emissions scenarios.

	High Emissions (Scenario A1fi)	Low Emissions (ScenarioB1)
Economic growth	Fossil fuel-intensive	High
Global population	Peaks mid-century and then declines	Peaks mid-century and then declines
Technology	New and more efficient technologies introduced toward end of century	Shift to less fossil fuel-intensive industries and introduction of clean and resource-efficient technologies
CO_2 concentrations by 2100	940 ppm (triple pre- industrial levels)	550 ppm (double pre-industrial levels)

Scenarios developed by the Intergovernmental Panel on Climate Change to characterize pathways of societal development and emissions that are used to project near and long term changes in climate. **[Source: Wake, C. et al. 2014]**

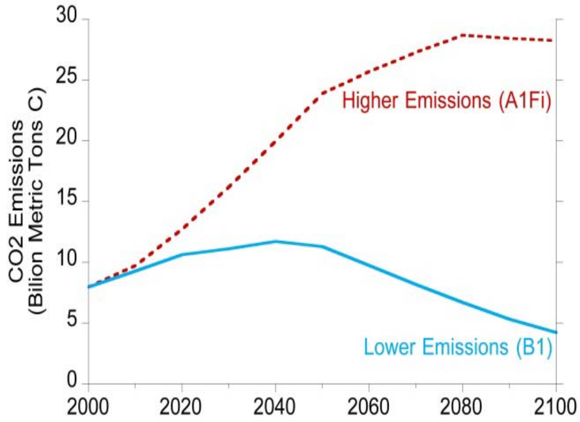


Figure 1. Projected future global emissions of carbon dioxide from fossil fuel burning.

[Source: Wake, C. et al. 2014]

Temperature

Observed Temperature Change

The Northeast is getting warmer. Between 1895 and 2011, the average annual temperature increased by approximately 2°F in the Northeast.[8] The rate of temperature change has increased in the last 40 years in New Hampshire.[9] Data from weather stations within or near the Piscataqua/Great Bay watershed indicate that mean annual temperature in the region has increased by 1.3 to 1.7°F since 1970.[10] During this period, the average annual maximum temperature across Southern New Hampshire increased by 1.1 to 2.6°F.[11]

Temperature change varies by season. In both the Piscataqua/Great Bay Region and Southern New Hampshire, winter temperatures have increased more than summer temperatures (2.7 to4.2°F since 1970).[12] On average, the number of hot days has increased only slightly in Southern New Hampshire since 1960, while the number of cold days and the temperature on the coldest day of the year has increased significantly.[13]

An analysis of annual and extreme temperature trends in the Piscataqua/Great Bay Region shows that temperature on the warmest summer nights increased significantly between 1949 and 2009. This indicates that the number of heat waves has likely increased.[14] In addition, the temperature on the coldest winter nights also warmed significantly in Durham, NH and Portland, ME, signifying fewer days with extremely cold nighttime temperatures.[15]

Projected Temperature Change

Projected increases in global-scale temperature of 2 to 13°F are expected.[16] In the Northeast, temperature and the frequency, intensity, and duration of heat waves are expected to increase.[17] By the end of the century, summer in New Hampshire could be as warm as summer in North Carolina (Figure 2).[18] By 2080, the projected increase in temperature in the Northeast ranges from 4.5°F to 10°F under a high emissions scenario where emission continue to increase, and 3°F to 6°F under a reduced emissions scenario.[19] In addition to this warming, the frequency, intensity, and duration of cold air outbreaks are expected to decrease.[20]

By the end of the century, summer in New Hampshire could be as warm as summer in North Carolina.

Over the next 100 years, annual maximum and minimum temperature in the Piscataqua/Great Bay region are expected to increase 4.5°F to 9.0°F.[21] Similarly, in Southern New Hampshire, annual maximum and minimum temperature is projected to increase by 4°F to 9°F by 2070 to 2099, with the largest maximum temperature increase occurring in spring and summer.[22] By the end of the century, temperature on the hottest and coldest day of the year in Southern New Hampshire are expected to warm under both low and high emissions scenarios. Additionally, the region will experience fewer cold and very cold days (under 32°F and under 0°F) and up to approximately 22 more extremely hot

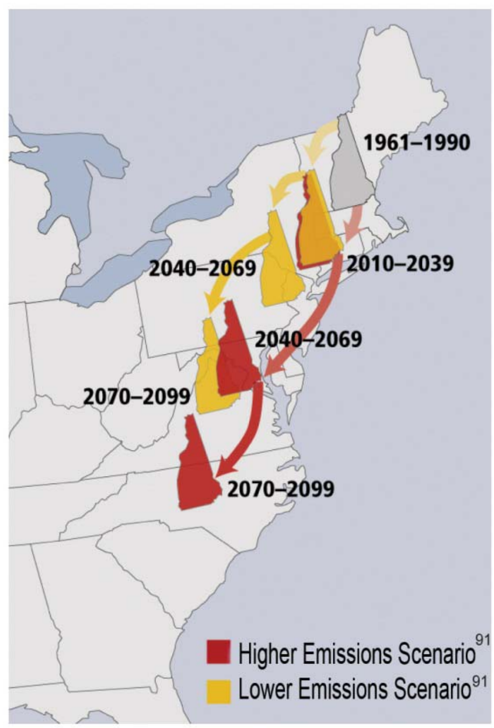


Figure 2. Projection of how summer temperatures will feel under high and low emissions scenarios in New Hampshire.

[Source: Frumhoff et al. 2007]

days (over 95°F) per year. See Table 2 for near, mid, and end of century temperature projections under high and low emissions scenarios in Southern New Hampshire.

Table 2. Southern New Hampshire near term, mid-century, and end-of-century temperature projections under high and low emissions scenarios.

	Historical Average (1980-2009)	**Change from Historical (+ or -)**					
		Short Term (2010-2039)		Mid Term (2040-2069)		Long Term (2070-2099)	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
			Temperature (°F)				
Annual TMin	34.5	+1.7	+2	2.9	5.1	3.8	8.8
Winter TMin	12.8	2.3	2.6	3.6	5.6	5.0	9.3
Spring TMin	31.2	4.0	2.5	5.6	5.2	6.8	8.5
Summer TMin	54.9	1.6	2.2	2.8	5.6	3.5	9.8
Fall TMin	35.3	0.3	1.7	0.6	5.0	1.1	8.3
TMin on coldest day of year	-15.8	4.0	4.4	6.2	10.2	8.0	17.4
Annual Max	57.2	+1.7	+1.7	3	4.8	4.1	8.3
Winter TMax	33.4	1.7	1.6	2.5	3.5	3.6	6.1
Spring TMax	55.7	2.5	1.5	4.9	4.7	6.6	8.7
Summer TMax	79.6	1.8	2.1	3.3	5.7	4.1	9.6
Fall TMax	59.7	0.9	1.7	1.3	5.3	1.5	8.6
TMax on hottest day of year	93.1	1.8	1.4	3.0	4.8	4..6	9.0
			Temperature Extreme (days/year)				
<32°F	164	-9.5	-10.9	-15.8	-25.5	-19.5	-19.5
<0°F	16	-5	-5.1	-7.8	-10.6	-9	-14.2
>90°F	6.7	4.2	5.2	11.1	21.7	16.2	47.3
>95°F	1	0.8	1.2	2.7	7	5.1	21.8

Note: Southern NH data is averaged from 25 stations. Where historical data was not available, values were derived from downscaled GCM simulations. [Source: Wake et al. 2014]

Precipitation

Observed Precipitation Change

Between 1895 and 2011, annual rainfall in the Northeast increased by 5 inches, or more than 10%.[23] In recent decades, the Northeast experienced a greater increase (74%) in the amount of precipitation falling in very heavy events than any other U.S. region.[24]

The Piscataqua/Great Bay Region has received 6 more inches (8%) of precipitation today than 100 years ago. Precipitation measured at weather stations in the Piscataqua/Great Bay Region increased by 5 to 20% during this period.[25] Throughout Southern New Hampshire, precipitation increased at a greater rate (2 to 3 times greater) than the long term average.[26] Precipitation change in the region is variable by season. Of the 6 more inches the

Piscataqua/Great bay Region receives today than it did 100 years ago, much of this precipitation occurred in the fall.[27] Recent trends indicate that that winter precipitation has declined due to less snowfall between December and February.

Extreme precipitation events – events with more than 1 inch of rain in 24 hours and more than 4 inches of rain in 48 hours –increased between 1949 and 2009. [28,29] In the last two decades, the region has seen a significant increase in 4 inch in 48 hour precipitation events than in the previous 4 decades.[30]

As temperature has increased, snowfall has decreased. Between 1970 and 2012, the number of snow covered days declined by 6.6 days per decade in Durham and 2.9 days per decade in Hanover. [31]

Projected Precipitation Change

The total amount and intensity of precipitation in New England is expected to rise as temperature increases as warmer air can hold more moisture.[32] Over the next 100 years, wetter conditions and more extreme precipitation events are expected.[33]

Under high emissions scenario, winter precipitation in the Northeast is projected to increase from 1-29% by the end of this century.[34] In spring, summer, and fall, precipitation projections are variable; however, both the frequency of heavy rainfalls and seasonal drought risk are expected to increase.[35] More frequent short and medium-term droughts can be expected by 2070 to 2099 in the Northeast.[36]

In the Piscataqua/Great Bay Region, annual precipitation is expected to increase slightly more under a higher emissions scenario than a lower emissions scenario.[37] However, the seasonal distribution of precipitation differs under high and low emissions scenarios, with the greatest change expected in winter, spring and summer under high emissions scenarios.[38] Precipitation is expected to increase in winter and spring, which may result in greater snowfall depending on the temperature. However, the number of snow covered days is expected to decrease.[39] Because fresh snow has a high reflectivity (or albedo), snow-covered surfaces absorb less sunlight and heat than less reflective surfaces. Therefore, fewer days with snow cover has a positive (increasing) impact on temperature, which has a negative (decreasing) impact on snowcover.[40] By midcentury and under a high emissions scenario, the region will have one less month of snowcover.[41] By the end of the century, Southern New Hampshire will see as much as 53 fewer snow-covered days.[42] See Table 3 for additional precipitation data and trends in Southern New Hampshire.

Table 3. Southern New Hampshire near term, mid-century, and end-of-century precipitation projections under high and low emissions scenarios.

	Historical Average (1980-2009)	**Change from Historical (+ or -) (inches)**					
		Short Term (2010-2039)		Mid Term (2040-2069)		Long Term (2070-2099)	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Precipitation							
Annual Mean	43.8	4.3	3.1	5.4	5.9	7.4	8.8
1" in 24 hrs (events/year)	10.4	1.6	1.6	2.2	2.8	2.9	4.3
2" in 48 hrs (events/year)	3.7	2	2	1	3	1.5	4.2
4" in 48 hrs (events/decade)	4.3	2.6	0.7	3.9	4	6.1	7.6
Snow Covered Days	105	-9.6	-16.3	-15	-37.1	-23.7	-52.9

Note: Southern NH data is averaged from 25 stations. Where historical data was not available, values were derived from downscaled GCM simulations. [Source: Wake et al. 2014]

Sea Level Rise

Sea level rise is caused by change in both the volume of water in oceans and the amount of water the sea can hold (eustatic change) and the height of land (isostatic change). As temperatures increase, melting land-based ice, including glaciers and ice sheets, and thermal expansion of the ocean cause sea level rise.[43] At the local level, factors including tectonic uplift and down dropping, isostatic rebound and depression, coastal subsidence, land surface changes from compaction, dewatering, fluid extraction, and diagenetic processes influence vertical land motion and lead to variations in relative sea level rise.[44] In addition to melting ice and land subsidence, changes in ocean circulation may also contribute to the increased sea level rise the Northeast has experienced over the last century.[45] These factors make New Hampshire particularly vulnerable to sea level rise.[46]

Eustatic changes in sea level are the result of changes in the volume of water in oceans or the shape of an ocean basin that impacts the amount of water the sea can hold. Eustatic change is a global effect.

Isostatic sea level change is the result of change in the height of land. Isostatic change is a local or regional change in sea level.

Observed Sea Level Rise

Relative sea level rise has occurred for 10,000 years in New Hampshire.[47] Since 1900, the sea level has increased an average of 4 inches globally and 1 foot in the Northeast U.S.[48] During the 20th century, the long term average rate of eustatic global sea level rise was approximately 0.67 inches per decade, with greater change occurring in the second half of the century.[49] Between 1993 and 2009, sea level rose as much as 1.3 +/- 0.2 inches per decade.[50] In coastal New Hampshire, sea level at the Portsmouth Harbor tidal gauge rose 5.3 inches at a rate of approximately 0.7 inches per decade between 1926 and 2001.[51] The current 100 year coastal flood stillwater elevation at the Fort Point tide gauge at the mouth of the Piscataqua River is 11.2 feet relative to the North American Vertical Datum.[52]

Projected Sea Level Rise

Recent projections of eustatic sea level rise indicate that global average sea level is expected to increase by 39 to 55 inches, and potentially up to 75 inches by 2100.[53] Sea level is expected to rise 1.7 to 6.3 feet by 2100 in coastal New Hampshire.[54] At the mouth of the Piscataqua River, 100 year flood stillwater elevations will range from 9.4 to 12.9 feet by 2050 and 10.9 to 17.5 feet by 2100 (Figure 3). These projections are based on the maximum extents of the range of projected global eustatic sea level change: 31 inches under low emissions scenario B1 and 75 inches under high emissions scenario A1fi.

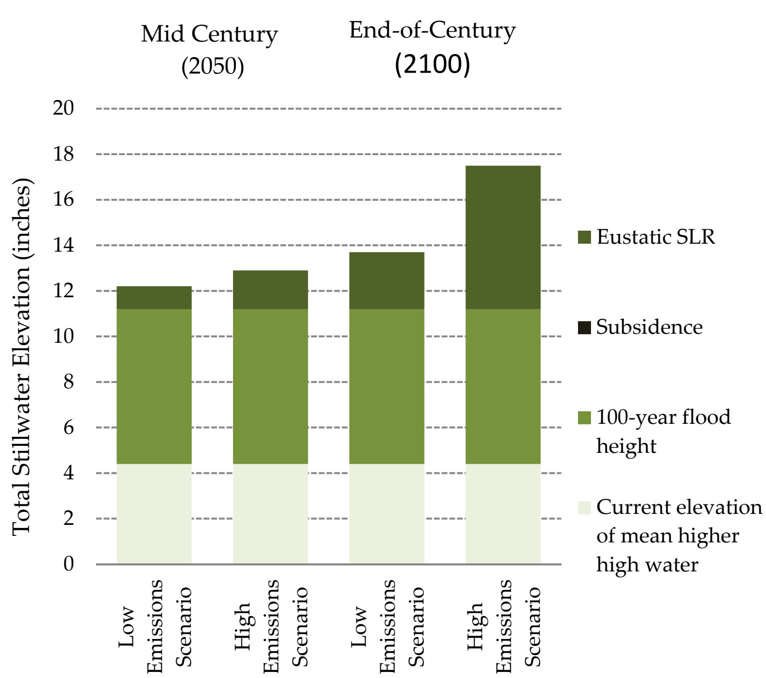


Figure 3. Estimated total projected stillwater elevation with components that contribute to sea level in 2050 and 2100 for high and low emissions scenarios (right). **[Source: Wake et al. 2010]**

Sea Surface Temperature Change

Because the ocean has a high capacity to absorb heat, it absorbed almost 80% of heat generated from global warming in the last 40 years and thus has helped to mitigate atmospheric warming. As the temperature of the ocean increases, however, it expands. This expansion accounts for approximately half of global sea level rise.[55]

Between 1887 and 2008, sea surface temperature in the Gulf of Maine was variable but increased significantly both annually and in all seasons.[56] Compared to the 1887 to 2008 trend, annual sea surface temperature warming quadrupled – increasing 0.52°F per decade -- and summer sea surface increased by 0.77°F per decade between 1970 and 2008.[57]

River Flow

Changes in river flow impact the amount of nitrogen pollution entering Great Bay and the amount of flooding that occurs within the watershed. Snowmelt and extreme precipitation events contribute to water pollution and flooding.

Seven major rivers drain into Great Bay. Daily discharge records indicate that annual discharge in the Lamprey and Oyster Rivers has increased from 1935 to the present. The change in annual discharge is primarily driven by a seasonal increase in fall discharge.[58] The average annual discharge on the Lamprey River is 105,970 cubic feet per second, representing a 212.8 cubic feet per second per year increase since 1935. On the Oyster River, annual discharge has increased by 15.2 cubic feet per second per year to 7,336 cubic feet per second.[59]

The Oyster River experienced year-round increase in discharge, while the Lamprey River decreased slightly in summer.[60] Both rivers experienced significantly later peak flow dates than identified in another study on northern New England rivers, which is likely due to the fact that spring precipitation, rather than snowmelt, drives coastal rivers.[61]

Lake Ice-Out

Lake ice-out is an indicator of late winter/early spring climate change. Earlier ice-out dates have a negative impact on the winter recreation season and can lead to increased phytoplankton productivity and oxygen depletion in lakes.[62] Between 1887 and 2010, lake ice-out dates occurred an average of 0.4 days per decade earlier on Lake Winnipesaukee and 1.6 days per decade earlier for Sebago Lake.[63] This trend is consistent with ice-out records in New Hampshire, Maine, and Massachusetts.[64]

Fisher Village on Wolfeboro Bay Circa 1930s

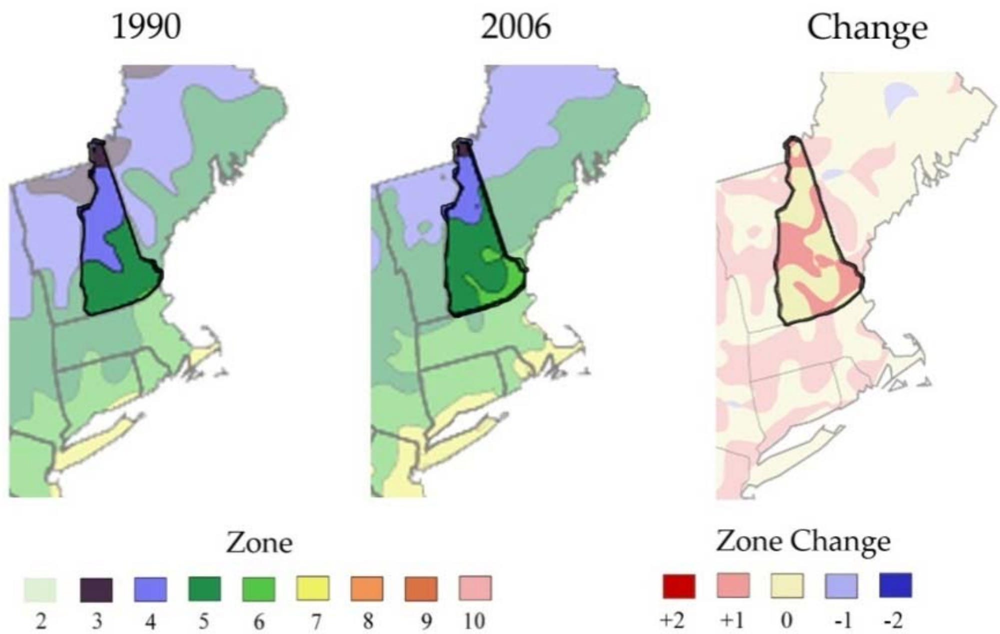
Photo credit: Winnipesaukee Forum

Growing Season and Plant Hardiness

Growing season is the number of days between the last frost of spring and the first frost of winter. In Southern New Hampshire, the growing season has increased by 12 to 42 days since 1960.[65] In Durham and Nashua, the length of the growing season increased significantly by 10 days per decade during this period.[66]

From 1990-2006, U.S. Department of Agriculture Plant Hardiness Zones have exhibited a northward shift (Figure 4). Plant hardiness zones are based on the average annual minimum temperature and divided into 10°F zones. Because temperature has increased, the plants and crops most likely to thrive at a location have changed. Approximately one-third of New Hampshire has shifted into a warmer zone and as a result, lilacs, apples, and grapes are blooming earlier across the northeast.[67]

Figure 4. Change in USDA Plant Hardiness Zones from 1990 to 2006.



[Adapted from USDA - 2014]

Impacts and Adaptation Planning

Overview

Impacts

Change in the region's environment will impact quality of life, livelihood, infrastructure, and the natural resources we value and depend on.

Across the Northeast, more winter rain will lead to increased flooding.[68] The increased frequency of 100-year floods, or severe floods with a 1% chance of happening each year, will result in excessive runoff, flooding, and damage to critical infrastructure, and degradation in water quality.[69] Sea level rise and storm surges will result in increased erosion and destruction of important coastal ecosystems.[70] There are also a number of human health implications associated with climate change.[71] Not all impacts are negative. Residents may realize decreased heating costs in winter due to warmer winter temperatures, for example.

Examples of the impacts that an increase in temperature, extreme precipitation events, and sea level rise will have on Southern New Hampshire include:

- Increased need for air conditioning
- Reduced winter heating cost
- Reduced risk of cold-related accidents and injury
- Potential for greater risk from invasive species and pests
- Reduction in number of chilling hours experienced each year required for crops such as berries and fruit
- Flooding
- Increase in the rain-to-snow precipitation ratio
- Decreased number of snow cover days
- Earlier ice-out dates
- Earlier spring runoff
- Longer growing seasons
- Rising sea levels
- Earlier spring bloom dates for lilacs.[72]

Old Turnpike Road, Northwood, NH

Photo credit: Linda Smith

Climate change impacts in other regions of the country and world will also impact the vulnerability of the Southeast New Hampshire.

Adaptation

Climate change adaptation is action taken to avoid and minimize the negative impacts and take advantage of the positive impacts of a changing and increasingly variable climate.[73] Climate adaptation is a form of hazard mitigation, a sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects.[74] Adaptation includes changes in processes, practices, and structures to reduce potential damages associated with climate change.[75]

Adaptation strategies: enable recovery or adjustment to new conditions by increasing natural resilience; facilitate proactive responses that help communities and ecosystems persist under change; and build resistance to change.[76]

Resilience: The ability of a system to absorb and rebound from weather extremes and climate variability and continue to function
[Roseen et al. 2011]

Adaptation is a multi-phase process that includes identification of impacts and vulnerability, planning and implementing, and monitoring and evaluation (Figure 5),[77] and requires strong stakeholder engagement and collaboration across planning sectors, levels of government, the public and private sectors, and political boundaries.

Examples of strategies to adapt to climate change at multiple scales include:

- Integrate climate change planning into existing community and regional plans
- Continue and expand efforts to manage stormwater pollutant loading in the Great Bay watershed
- Develop outside floodplains and modifying culverts to reduce flood risks
- Create community emergency management plans and ensure vulnerable populations have access to resources such as cooling centers
- Utilize best available precipitation, floodplain, and temperature data when modifying culverts, building codes or design standards
- Reduce impervious surface cover to minimize flooding and reduce water quality impairment associated with heavy rainfall
- Ensure hazard mitigation plans address risks associated with climate change
- Educate the public about health risks associated with heat, extreme weather events, and vector-borne diseases
- Protect sensitive species and habitats and increase removal and eradication efforts of pests and diseases
- Elevate homes and critical infrastructure that are at risk for flooding

Examples of mechanisms to respond to climate change include:

- Land use planning
- Implementing provisions to protect infrastructure
- Regulating design and construction of buildings
- Emergency preparation, response, and recovery

Many adaptation strategies can be readily integrated or are already occurring at the local planning level. Guiding adaptation principles identified in Climate Change in Southern New Hampshire Past Present and Future are summarized in the box below (Figure 6).

Adaptation Principles

- Identify vulnerable assets and resources
- Guide planning, regulation, and policies at all scales
- Inform prioritization of state, regional, and private investments in areas at risk to future conditions
- Identify possible strategies and actions that provide economic, social, and environmental benefits
- Protect public health and safety
- Improve community awareness about the region's changing climate
- Preserve regional and community character and ensure sustainable outcomes

Figure 6. Principles to guide effective adaptation planning in Southern New Hampshire. [Source: Wake et al. 2014]

Climate Change Mitigation

Mitigation is a key factor in both the success and cost reduction of adaptation and resiliency to climate change. While adaptation strategies strengthen our ability to respond to climate change, mitigation strategies reduce and prevent future climate change. Mitigation strategies reduce emission of heat-trapping greenhouse gasses through technological advances and renewable energies, increasing efficiency, and changing management practices and consumer behavior. Efforts that maintain or create new carbon sinks area also considered mitigation strategies.[78] Because the magnitude of change in precipitation, temperature, and sea level rise is linked to past and future emissions, practices that reduce the amount of carbon dioxide in the atmosphere reduce directly impact adaptation planning. Refer to the Energy Efficiency to learn about climate change mitigation efforts.

Impacts and Adaptation by Sector

Built Environment

Infrastructure Security

Extreme weather disasters in 2012 cost the American economy more than $100 billion (whitehouse.gov). In 2005, 2006, and 2007, 100-year flood events caused major damage and resulted in loss of life, high cost to affected citizens and municipalities (Figure 5). State highway repairs from these floods cost the state $5.3 million, $7 million, and $2.5 million, respectively, including $1 million for railway repairs in 2008. Across the Northeast, flooding caused $130 million in property damage during this period (NH CAP).

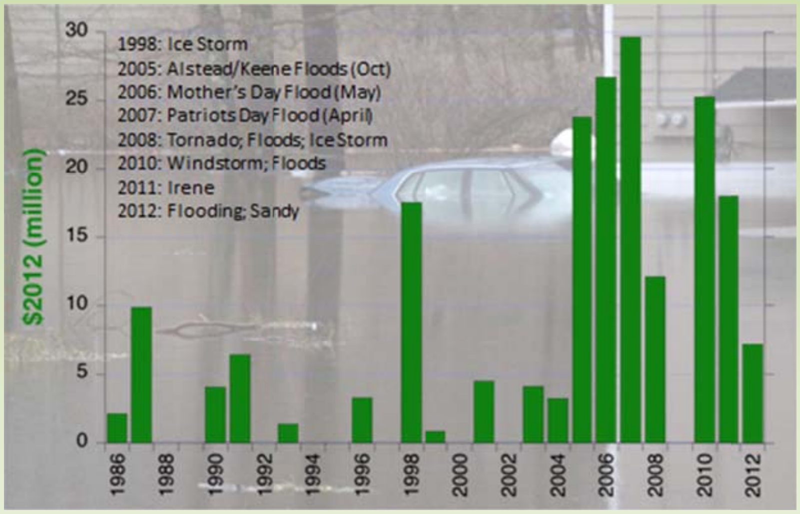


Figure 5: Federal expenditures on presidentially declared disasters and emergency declarations in New Hampshire from 1999 to 2012.

[Source: NHDES - 2012].

Recent storms have shown that much of the infrastructure in the region is inadequate to withstand the large, more frequent storms associated with climate change. Infrastructure – the pipes, wires, and roads that allow people and essential services to move throughout New Hampshire – are part of the foundation of thriving communities. The delivery of power, heating and cooling, communications, and drinking water can easily be interrupted when those structures are damaged or destroyed.

Our ability to adapt to the pressures of climate change is directly linked to the resilience of our infrastructure. Much of New Hampshire's infrastructure was not designed to withstand the pressures of extreme heat, bigger storms, and bigger floods. Extreme weather events are bringing more wind, rain, ice, snow, and heat that threaten the delivery of services that we take for granted. New Hampshire has experienced more damaging storm events and incurred greater weather-related costs in the past 8 years, than in the preceding 20 years combined (Figure 5).[79]

Protecting the infrastructure that ensures public health and safety, preserves the integrity of private and public property, and supports economic development is a key strategy to increase local resiliency. Investing in the protection of community infrastructure now will likely save resources for community development in the future. For example, a study of culvert and road crossing vulnerability found that the cost of a road crossing upgrade was $56,000 compared to the post-flooding road repair cost of $93,000, of which only $28,000 was covered by FEMA.[80]

Direct Impacts

Our infrastructure is threatened primarily by two major factors of regional climate change: increased precipitation and changes in seasonal temperatures patterns. Regional studies predict that overall precipitation will increase throughout New Hampshire and that, due to rising temperatures over time, much more winter precipitation will fall as rain. The damaging storms experienced in the recent past will become more common; this may be the greatest direct threat to critical infrastructure.

A1 Fernald Bridge on McCrillis Road, April 2007 Flood Damage

Photo credit: Charlie A. Brown

The transportation system is a cornerstone of the economy at a national, state, regional, and local level. The system includes critical access routes for emergency response and evacuation during storms or other events. In the predominantly rural landscape of New Hampshire, even minor roads may be vital for saving lives in an emergency. Inevitably, roads have to cross streams and rivers. According to NH DES, throughout the state there are at least 17,000 road-stream crossings.[81] Within the region there are approximately 1,170 road-stream crossings.[82] The map on page 47 displays the density of stream-road crossings within the 100 year floodplain. If the culverts and bridges at these crossing are too small to accommodate large amounts of rainwater for storms, there is a higher risk of road collapse.

The extreme events that are becoming more frequent also threaten electrical transmission and communications infrastructure. One of the major areas of vulnerability is our raised pole-and-wire transmission infrastructure. Storms that drop sudden, heavy snowfall, ice, or rain threaten pole-mounted lines that deliver electricity without which, our communities cannot function. As many power lines follow existing roads, the flooding that impacts roadbeds also affects transmission infrastructure. According to current projections, the summers in New Hampshire will have more days with temperatures over 100 degrees. As private and commercial air conditioning use increases during summer months, a heavier burden will be placed on electrical transmission infrastructure. This greater power demand will increase the risk of widespread grid failure. The New Hampshire Department of Transportation (NHDOT) has already seen impacts to state roads from prolonged and increased summer heat. Prolonged high temperatures and major differences in temperature over short periods degrade asphalt and weaken road surfaces.

Energy

Changes in temperature, precipitation, sea level, and the frequency and severity of extreme events will likely affect how much energy is produced, delivered, and consumed in the U.S.[83] Warmer summer temperatures in the Northeast will result in increased cooling demand and associated costs. Meeting peak electricity demands in summer may require investments in new energy infrastructure. Additionally, warmer temperatures that cause warmer water temperature may reduce the efficiency of power production for many existing fossil fuel and nuclear power plants that rely on water for cooling.[84]

If the nation's climate warms by 1.8 ℉, the demand for energy used for cooling would increase by about 5-20% and the demand for energy used for heating would decrease by about 3-15%. [USGCRP 2009]

Existing Infrastructure

Impervious Surfaces

Between 2000 and 2010, the Strafford Region experienced the highest growth rate in New Hampshire.[85] The increased impervious surface associated with growth and development contributes to greater volume of surface water runoff and stormwater diverted into rivers and streams. The combination of aging infrastructure, outdated design standards, and projected increases in extreme precipitation events will likely increased the destructive power of stormwater.

Culverts

Where moving water intersects a roadway, culverts are responsible for allowing water and vehicles to pass without disruption. Well-designed culverts control flooding, reduce erosion, and protect the roadway, while also maintaining the biological health of the stream, river, or wetland. Currently, the size of a culvert under a road is decided based on the probability of certain sizes of floods occurring. For instance, a culvert may be designed for a "100-year flood" based on the size of the stream or river and the area of land it drains. Because precipitation and land cover have changed since FEMA's floodplain maps were developed, culvert and bridge design standards no longer reflect current and projected environmental conditions.

A critical factor in preparing regional culverts for severe storms is identifying the location and condition of culverts in the region. To address this, Strafford Regional Planning Commission has lead ongoing data collection efforts since 2010 and has collected information about the condition of culvers in approximately half region's towns. Even the highly specialized GIS data used to map the location of existing road-stream crossings prior to in-field assessment do not contain exact records of culverts at the local level.

<u>Transportation Infrastructure</u>

According to 2013 data from the New Hampshire Department of Transportation (NHDOT), of the approximately 16,125 total miles of public roads in NH, the state maintains 4,269 miles (Class I, II, & III) and other public authorities maintain the remaining 11,856 miles (Class IV, V).[86] Of the 4,269 miles of state roads, only 19% (828 miles) are considered in good condition. Of the rest, 44% are considered in fair condition, and 37% are considered in bad condition.[87] It is hard to speak in such specific, quantitative terms about the condition of municipal roads, but road maintenance at the local level is a constant struggle. Funding at local level currently only allows for reactive maintenance and repair, which restricts community transportation resilience. Climate change will only increase the magnitude of this challenge.

Lamprey River at Packers Falls Bridge, May 2006

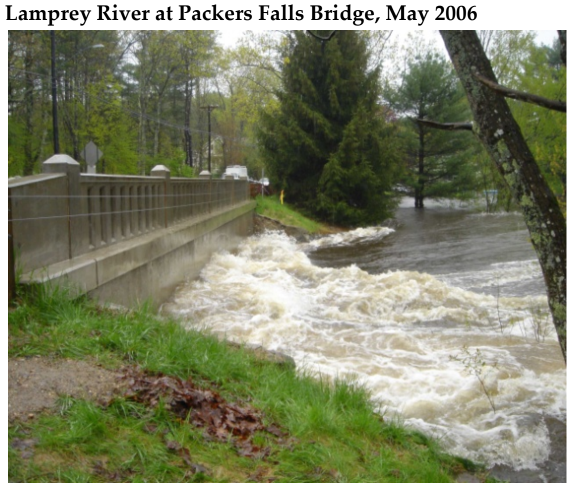


Photo credit: SRPC

Data on the condition of New Hampshire's bridges illustrate the extent of vulnerability in our region's transportation infrastructure. Many of the region's bridges are in a critical state and climate change increases the vulnerability of these structures. Bridges can be the critical factor for timely evacuation during emergencies. A recent example is Tropical Storm Irene in 2011, which caused significant damage to roads and bridges in the White Mountains region of New Hampshire, as well as Northern Vermont. According to 2013 data from NHDOT's "red list,"[88] there are several bridges on state-owned roads in Strafford region communities (including Farmington, Dover, Lee, and Nottingham) which require immediate attention.[89] These bridges have serious structural issues like rust, weakened piles, and deteriorating decks, or are at risk from erosion and riverbank scouring. There are even more bridges under municipal jurisdiction. The municipal red list includes 19 bridges in 12 communities, many of which are described as "structurally deficient."[90]

Changes in temperature will have variable impacts on road infrastructure. Higher temperatures are likely to result in higher costs to build and maintain roadways. Higher temperatures can cause pavement to soften and expand, creating rutting and potholes that require attention. In addition, heat waves can limit construction activities. Milder winters and reduced snowfall may result in reduced plowing and salting needs.[91]

The Federal Highway Administration developed a conceptual Risk Assessment Model to assist with identifying which assets are most exposed to the threats from climate change and/or associated with the most serious potential consequences of those climate change threats. For more information see:
http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/vulnerability_assessment_pilots/conceptual_model62410.cfm .

Water Utilities

Critical infrastructure including pump stations and waste water treatment facilities (WWTFs) may be flooded from both surface water flooding and from excessive infiltration and inflow.[92] Severe flooding can reduce a WWTF's capacity to manage floodwaters, and as a result, water quality may deteriorate.

NHDES recommends facility managers consider:

1. *What critical elements at the WWTF may be without power after severe storms*
2. *How long can the WWTF operate on generator power during high flow conditions and maintain adequate treatment to protect public health and the environment*
3. *How will facilities continue to operate your WWTF and collection system if critical infrastructure (pump stations, outfalls, process equipment and tankage, pipes, and buildings) are flooded*

To date, flooding has occurred at pump station and WWTFs in the region but has not impacted treatment processes at WWTFs. Flooding did occur at the Rollinsford WWTF in May 2006, but treatment was not impacted. Pump stations in Dover, Durham, Rochester, and Somersworth have flooded. Flood damage from the May 2006 flooding did not impact pumping at the Durham pump station and resulted in less than $10,000 in monetary damage. April 2007 floods impacted pumping at the Newmarket pump station and resulted in less than $10,000 in monetary damage. Rochester pump stations experienced $20,000-$50,000 in damage from the May 2006 floods that impacted pumping at the pump station.

Communities in the region including Dover, Durham, Newmarket, Rochester, and Somersworth have included flood preparedness plans in their WWTF Emergency Response Plans. Rollinsford has included a WWTF flood preparedness plan in its town-wide Emergency Response Plan. Farmington and Milton have a flood preparedness plan for their WWTF. The projected risk for flooding for WWTFs in the region is displayed in the table below. Figure 6 lists strategies WWTFs can implement to address climate change.

Table 4. Projected risk of flooding at WWTFs and Wastewater (WW) collection system infrastructure in region.

Facility	Projected risk to the WWTF for flooding	Projected risk to the WW collection system infrastructure for flooding
Dover Wastewater	Low	Medium
Durham Wastewater	Low	Low
Farmington Wastewater	Low	Low
Milton Wastewater	Low	Low
Newmarket Wastewater	Low	High
Rochester Wastewater	Low	High
Rollinsford Wastewater	Medium	Medium
Somersworth Wastewater	Medium	Low

[Source: NHDES - 2014]

Figure 6. Strategies to address climate change at waste water treatment facilities.

What can WWTFs do about climate change?

WWTFs and communities can integrate climate change into asset management, effective utility management, capacity building, security and emergency preparedness. There are six basic elements of becoming Climate Ready:

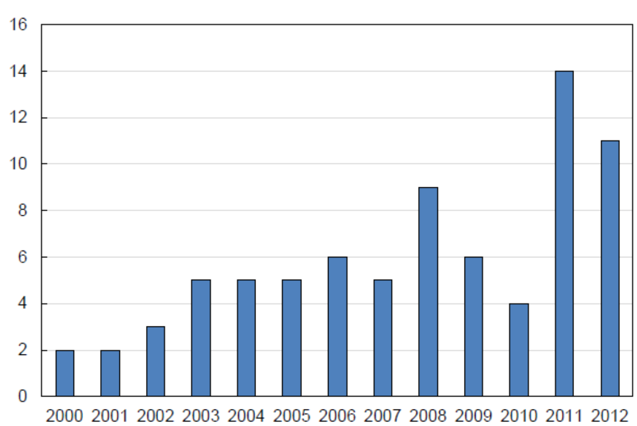
1. Climate Impact Awareness – learn and educate yourself, your staff and your management. Understand how climate change impacts your WWTF and collection system. Ask questions.
2. Adaptation Strategies – evaluate your system and find your weak points. Develop plans to strengthen your weaknesses. Adaptation is an iterative process, be flexible.
3. Mitigation Strategies – reduce your energy consumption to reduce your carbon footprint and your contribution to climate change. Start with conservation and energy efficiency, and then add alternative green power generation. Mitigation can save money while you are also positively impacting climate change!
4. Federal and State Policies and Programs – be aware of regulations and policies that must be met and maintained as the climate changes. Communicate regularly with regulators relative to issues or concerns relative to climate change impacts at your WWTF or collection system. Ask for assistance.
5. Community Interest and Support – educate your community and your users. Develop an outreach strategy with tools appropriate to the audience. You need your community's support.
6. Partnerships Outside of the Utility – critical to the long-term success of your Climate Readiness. Forge partnerships with key stakeholders such as: watershed and environmental organizations, land use planners, regional planning commissions, other utilities and water associations.

[Source: NHDES]

Community Water Systems (CWS)

Factors including proximity to the coast and Great Bay, location in relation to fresh water bodies, elevation of system components, size of contributing watershed to a surface water sources, and geologic settings of groundwater sources will affect the impact of climate change on water systems.[93] Impacts of flooding, wind, seal level rise may include damage to infrastructure, water quality impairment, and water availability. NHDES Drinking Water & Groundwater Bureau developed a draft Climate Change Resilience Plan in June 2014 provides information and resources about CWS and climate change including a summary of resilience measures taken to date, strategies water systems can use to become more resilient, and actions NHDES can take to promote resiliency of these important systems.

Figure 7. Number of storms costing $1 Billion or more.



[Source: NOAA- 2013 in Economic Benefits of Increasing Electric Grid Resilience to Weather Outages]

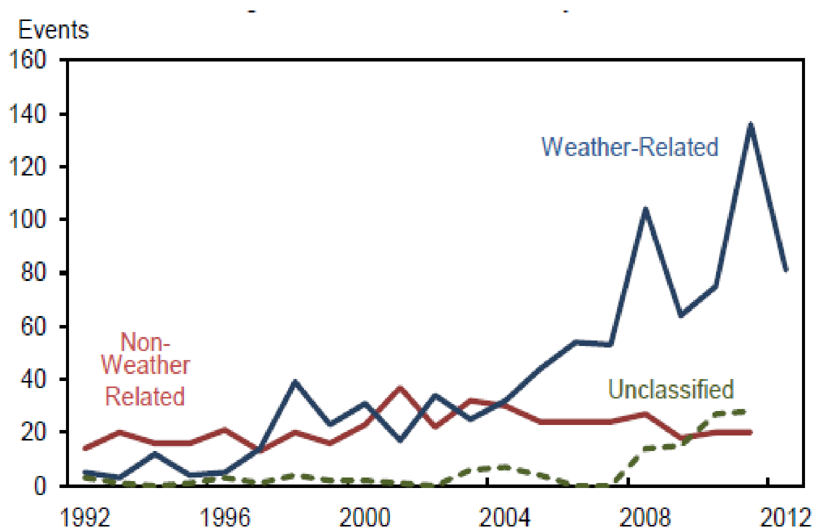
Potential Future Costs

Large, damaging weather events are becoming more frequent, and the direct costs from weather-related damage follow a disturbing trend. The number of weather events causing $1 billion or more has increased dramatically (see Figure 7).[94] Even more dramatic is that fact that seven of the ten costliest storms in U.S. history occurred between 2004 and 2012.[95] In the past, when extreme weather events were less frequent, perhaps economic excuses could be made for recovery over investing in adaptation. Under the current conditions, a reactive approach is not feasible. The economic cost of recovering from multiple severe weather events is now far greater than that of preparing for the worst. With high-intensity storms becoming more frequent, there is risk that municipal rainy day funds will be depleted on the first rainy day every year. The priority should be investing in adaptation now to protect financial and physical capital in the future. Budgets will suffer if they're spent recovering from "extreme" weather every year.

The priority should be investing in adaptation now to protect financial and physical capital in the future.

Climate change will bring more intense, damaging storms; however, the other primary danger is unpredictability. Climate change means greater variability in weather patterns, and it increases the chances that "unusual" events will happen. This has dire implications for vulnerable infrastructure. The poles and wires that deliver electricity to our homes and businesses offer a critical example. Increases in extreme weather across the nation have had an easily observable impact on electricity transmission systems (Figure 8).[96] New Hampshire has seen similar trends, and several regional examples present a stark picture.

Figure 8. Observed outages to the bulk electric system (1992-2012).



[Source: Energy Information Administration – 2013]

October 2011 Nor'easter

Between October 29 and 30th, 2011 an unexpected and unprecedented Nor'easter dumped record-breaking levels of snow (up to 2.5 feet) along the east coast, wreaking havoc from Pennsylvania to Maine. A combination of heavy, wet snow, and soft, un-frozen ground caused thousands of otherwise healthy trees to uproot or break branches which damaged power lines, distribution stations, and businesses.[97] Official reports from the National Oceanographic and Atmospheric Administration estimate a total cost of nearly $1 billion, while other estimates put the total cost at $3 billion.[98] The majority of damage was on widespread, lower voltage power lines and many thousands of utility customers were without power for more than a week. Utility providers in New Hampshire reported a peak of approximately 386,780 power outages.[99]

2008 Ice Storm

The 2008 ice storm is another example of the damaging, extreme events that will become more frequent under climate change. Starting at 4am on December 11th, 2008, a winter storm deposited up to an inch of ice on surfaces across New England. Ice accumulation caused tree branches to fall on power lines, or simply brought down the lines themselves, resulting in widespread outages. During the storm, major power providers in New Hampshire reported outages for at least 50% of their customers, with Public Service of New Hampshire (PSNH) reporting 65% (Table 5), and significant numbers of outages were sustained over more than five days.[100] The economic costs associated with the damage were significant, and affected numerous sectors (Table 6). Total costs for PSNH – the state's largest supplier – reached $75 million.

Table 5. 2008 ice storm impacts: number and percentage of customers without power, by major utility.

Utility	PSNH	Until	National Grid	NHEC	Totals
Total # of Customers as of December 2008	492,803	74,115	40,470	78,424	685,812
Maximum # of customers without power	332,438	37,800	24,164	48,230	432,632
Percent of customers without power	65%	51%	60%	61%	63%

[Source: New Hampshire Public Utilities Commission – 2009]

Table 6. The economic impact of the 2008 ice storm as reported for the State of New Hampshire

Entity Reporting Loss	Value
NHEC	$2,126,000
National Grid	$2,565,000
PSNH	$75,000,000
Unitil	$3,196,665
FairPoint	$4,788,090
TDS Communications	$272,180
Division of Resources and Economic Development (DRED) (Private business losses)	$11,370,000
FEMA Assistance to towns, municipal organizations, and non-profit organizations	$17,874,000
Personal Insurance Claims	$32,411,901
Commercial Insurance Claims	$4,057,292
Cable TV Companies	$1,633,900
Total Reported Losses	$155,295,028

[Source: NEI Engineering – 2009]

All communities rely on services from infrastructure components that are intimately linked. This interdependency presents a risk of cascading impacts. The effects of damage to one piece of infrastructure do not stay isolated; physical, economic, and social, impacts will ripple throughout the community. In fact, long-term costs from secondary impacts may be greater than initial cost of damages.[101] The cost of damage or loss of infrastructure will be high (especially if loss is repeated due to lack of adaptation), but impact of lost services will be greater.

Community Connectivity: Broadband as a tool for increasing community resilience

With the growing threat of extreme weather, resilience is a critical factor in community preparedness, emergency response, and recovery from disasters. A central factor of resilience is community connectivity. Any system – a forest, a city, or a small business – can be envisioned as a web or interconnected parts and relationships. The strength of the web depends of the strength of the connections between and among components of the system. A system with strong connections between its components will be more resilient to shocks. Strong connections among elements of a community – the businesses, public services, individual citizens – are important for day-to-day activity, but critical in emergencies.

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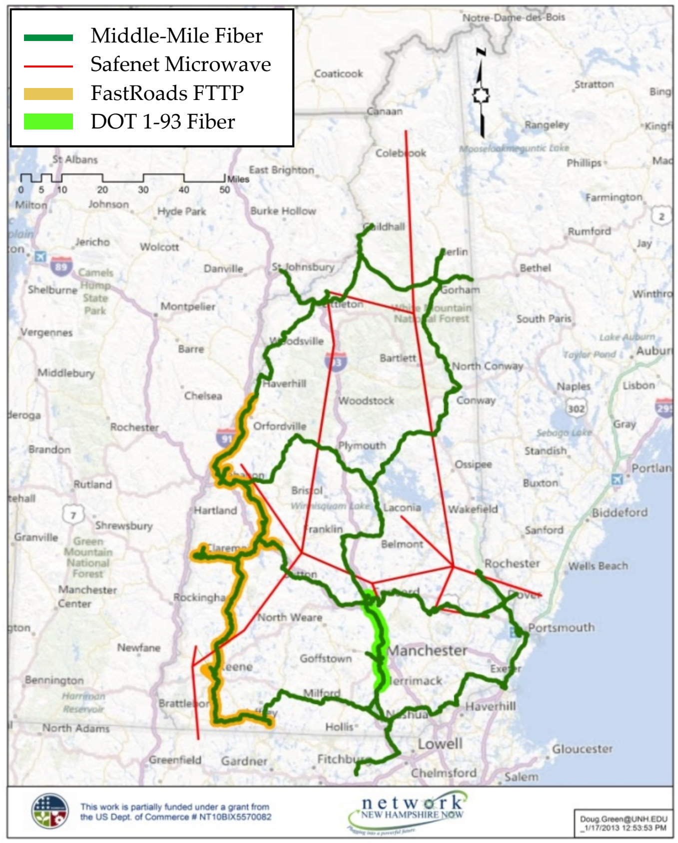
High-speed internet represents a new way to increase community connectivity and resilience. Today's towns and cities could not function without access to public services like electricity, and access to broadband internet is quickly becoming as indispensable as public services that are more familiar. Broadband has huge capacity for increasing connectivity between individuals and institutes. Besides its entertainment and media applications broadband: helps police and fire departments respond to emergencies faster; allows hospitals to provide treatment and care more effectively; provides greater access to educational materials and tools for both students and teachers; and connects citizens with opportunities to participate in community building.

Currently, broadband internet is available across most of the Strafford Region, but every community has areas where access is limited or unavailable.[102] Regional research results of the New Hampshire Broadband Mapping and Planning Program[103] suggest that increasing community-level access to high-speed internet should be a priority over increasing wide-scale individual access. Connecting local community anchor institutes (CAIs) with regional broadband networks will improve local services and increase connectivity between and among communities.

New Hampshire FastRoads – Open-Access Network

The New Hampshire FastRoads project has begun connecting Western NH communities with fiber optic cable to create a region-wide, open-access network.[104] The project will connect CAIs throughout 22 Southwest NH communities – from Rindge and Fitzwilliam near the Massachusetts border, to Orford north of Hanover (Figure 9). Linking important local facilities and increasing their capacity for work benefits the entire community by increasing the efficacy and availability of public services. It also provides access for individuals who want to increase their at-home internet speeds. This effort is related to a large-scale project called Network New Hampshire Now, which is implementing local and regional fiber optic cable for broadband access, and a microwave network for television, and public safety and transportation communications.[105]

Figure 9. Map of broadband and public safety communication networks.



[Source: Network New Hampshire Now – 2014]

It is important to consider several factors for successful broadband expansion. It is easy to worry about initial costs associated with this new technology, but those costs will quickly be outweighed by the benefits. Expanding broadband at the regional level will increase the benefits felt at the local level. Such efforts will require long-term collaboration among municipalities and regional partners. In particular, collaborating to identify funding opportunities will be essential for reducing potential financial burden on any single entity. Several partners will be essential throughout the planning of any regional broadband project:

- Internet service providers (ISPs) - It is important to attract ISPs that can offer services through new high-speed delivery infrastructure.
- Utility companies - Early participation from utility companies is critical because they own and manage the existing infrastructure that can accommodate new high-speed cable.
- Potential Community Anchor Institutions (CAIs) should be part of early planning to ensure that implementation and services will fill their needs.

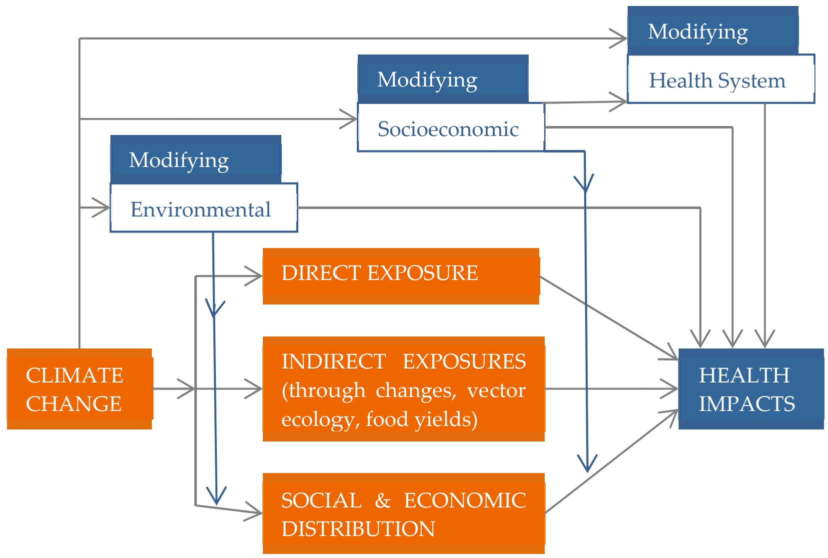
Adaptation Strategies | Infrastructure

- → Address planning, operational strategies, and capital/infrastructure adaptation
- → Collaborate across towns, power, and telecom supplies to assess vulnerability of local power distribution
- → Place transmission lines underground to increase the security of electricity and communications during emergencies
- → Collect and maintain up-to-date data on vulnerable infrastructure through a region-wide, collaborative effort between communities and partners
- → Base design standards on best available precipitation and floodplain data
- → Implement Low Impact Development (LID) techniques to increase on-site stormwater infiltration and reduce or eliminate stormwater loads on critical infrastructure
- → Ensure that vulnerable infrastructure is a critical component of community emergency response plans
- → Collaborate across municipalities to expand broadband at the regional level to increase benefits felt at the local level
- → Address flood risks outside of the 100 year floodplain
- → Update infrastructure and material design standards to reflect projected temperature changes
- → Incorporation adaptation into Capital Improvement Plans
- → Expand decentralized management of culverts to avoid mal-adaption that leads to downstream problems
- → Reduce energy demand to increase ability to meet peak summer electricity demands in a warmer climate
- → Utilize the Federal Highway Administration's conceptual model for assessing the vulnerability of transportation systems to climate change

Human Health

Climate change has a range of direct and indirect impacts on human health (Figure 10). Changes in temperature, extreme precipitation, and sea level will have varying impacts on the region's population. Vulnerability to climate change is dependent on factors including: underlying medical conditions such as heart or lung disease; demographics such as race, age, and education; housing conditions; local ecology and geography; and water supply. Young children, the elderly, people with pre-existing health conditions, and outdoor workers are more vulnerable to heat and poor air quality.[106] Within the SRPC region, 11.3% of the population are under age ten, and 11.9% of the population are seniors over age 65.[107] Additional factors that increase risk include access to air conditioning and adequate health care.[108]

Figure 10. Pathways by which climate change may affect human health.



[Source: adapted from American Public Health Association]

Exposure to warmer temperatures and extended heat waves can cause health effects ranging from heat rashes and dehydration[109] to heat stroke, and can aggravate chronic diseases such as cardiovascular and respiratory disease.[110] Nationally, heat related weather fatalities were 73% higher in 2011 than the ten year 2002-2011 average.[111]

In 2012, the New Hampshire Department of Health and Human Services and the Massachusetts Department of Health conducted a health-focused hazard vulnerability assessment for the Boston Metropolitan Statistical Area. The table to the right (Table 7) summarizes a vulnerability assessment prepared for Strafford County as part of this assessment.

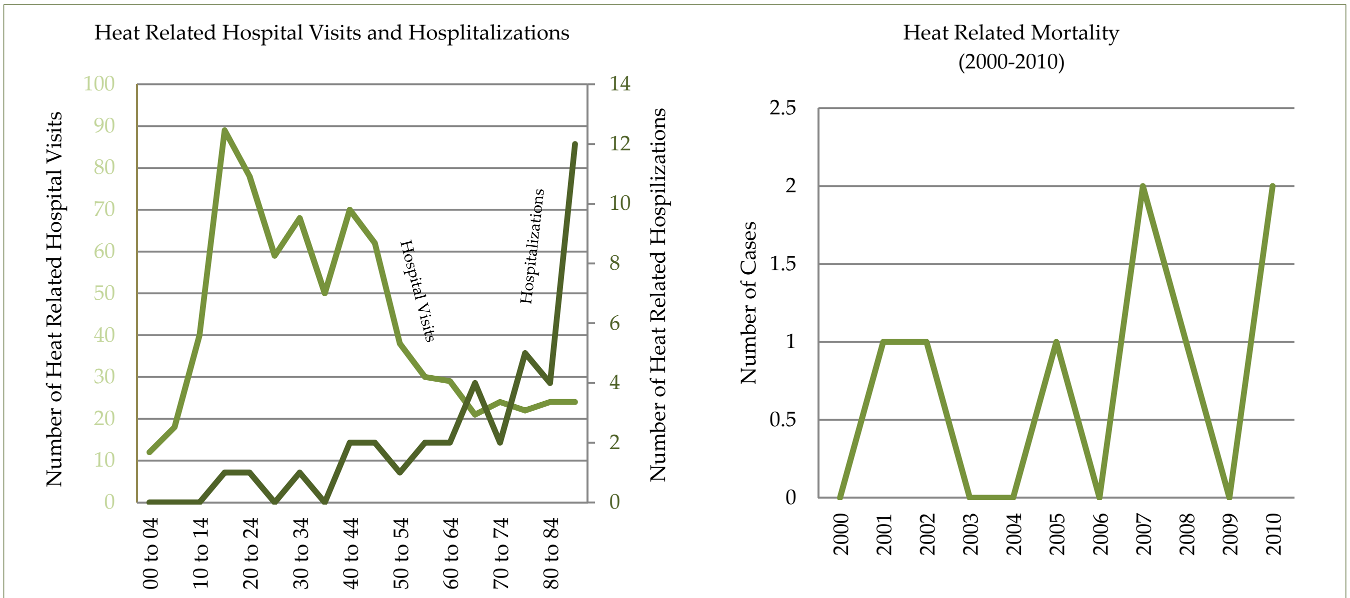
Strafford County Hazard Vulnerability Assessment

Hazard	Severity of Impact - Rank Order	Hazard Probability	Risk Score - Rank Order
Flood	2	4 (High)	5
Winter Storm	3	3 (Medium)	4
Hurricane	4	2 (Low)	3
Heat Wave	1	3 (Medium)	2
Earthquake	5	1 (Very Low)	2
Radiological Emergency	4	1 (Very Low)	1
Influenza Pandemic	4	1 (Very Low)	1

Table 7. Strafford County Hazard Vulnerability Assessment for the Public Health, Health Care, and Behavioral Health Systems. [Source: NHDHHS, MADH]

Data from New Hampshire' Environmental Health Data Portal shows that while individuals ages 15 to 45 dominated heat-related hospital visits, people over the age 65 incurred the most hospitalizations (Figure 11).[112] Heat-related mortality has fluctuated between 0 in 2000 and 2 in 2010 in New Hampshire (Figure 11).[113]

Figure 11. Heat related hospital visits and hospitalizations by age between 2005 and 2009 (left) and heat related mortality in New Hampshire between 2000 and 2010 by age.



[Source: NH Environmental Public Health Tracking Program]

Higher temperatures will lead to air quality degradation as smog caused by ground-level ozone and airborne particles released from fossil fuel burning air conditioners increases.[114,115] The number of days that fail to meet air quality standards is anticipated to increase as temperature rises.[116] Between 2001 and 2006 the particulate matter 2.5 level in New Hampshire exceeded the National Ambient Air Quality Standards 24-hour standard approximately seven days per year. From 2003 to 2006, ozone levels in Hampshire generally met the standard.[117] Poor air quality can cause direct lung damage as well as exacerbate existing conditions.[118] As a result of warmer winter temperatures, illness and death associated with exposure to cold will likely decrease over the next century.[119] Additional indirect health effects associated with higher carbon dioxide levels and longer growing seasons may include increased allergies and respiratory disease. Higher carbon dioxide levels are also associated with greater toxicity in poison ivy.[120] Additionally, increased temperature and precipitation can enhance mold growth. Mold can cause coughing, wheezing, nasal and throat irritation, and is a greater threat to persons with asthma or weakened immune systems.[121]

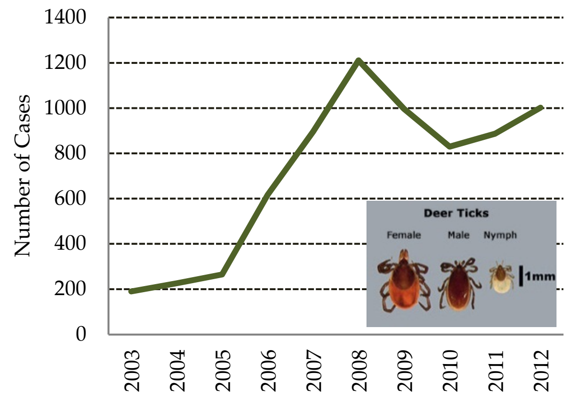
Extreme precipitation events and flooding can cause drowning, injury and structural collapse of dams, levees, and bridges.[122,123] Storms and flooding can interrupt communication, utilities, and health services and contribute to carbon monoxide poisoning from portable electric generators.[124] Individuals evacuated from homes are at greater risk of suffering from stomach and intestinal illness as well as depression and PTSD. [125] The number of fatalities caused by floods in the U.S. was 45% higher in 2011 than the 2002-2011 average.[126]

Temperature and extreme weather events will impact the supply and safety of food and water. Temperature and increased drought periods can strain agricultural production and result in food shortages.[127] Higher air temperatures can increase food-borne diseases such as salmonella and other bacteria related food poisoning, causing gastrointestinal distress and death.[128] Climate change increases the risk of crop contamination associated with sewage treatment overflows.[129] Exposure to and prevalence of water-borne parasites such as Cryptosoridum and Giardia is also expected to increase as heavy rainfall contaminates lakes and beaches and increases sewage and pollutants entering the water supply.[130]

Over time, increased temperature can cause ecosystem changes such as migration of vectors and animal hosts that carry disease.[131] In the Northeast, conditions will become more favorable for mosquitoes that carry West Nile Virus as well as ticks that carry Lyme disease. [132]

New Hampshire has one of the highest rates of Lyme disease in the U.S.[133] The number of New Hampshire residents diagnosed with Lyme disease has increased over the past 10 years, with significant increases occurring since 2005.[134] In 2009, the rate of cases of Lyme disease reported in New Hampshire residents was 108 cases per 100,000 persons, which is significantly higher than the Healthy People 2010 scince-based 10-year national objective for improving the health of all Americans objective of 9.7 cases per 100,000 persons.[135] Rockingham, Strafford, and Hillsborough counties had the highest rates of disease in 2008-2009.[136] In 2012, there were 172 reported cases of Lyme disease in Strafford County, 550 cases in Rockingham County, and 48 cases in Carroll County.[137] The number of reported and diagnosed cases of Lyme disease in New Hampshire reported by the Center for Disease Control is shown in Figure 12.

Figure 12. Reported cases of Lyme disease in New Hampshire.



[Source: Center for Disease Control and Prevention – 2014, Image credit: CDC]]

Adaptation Strategies | Human Health

- → Identify and support vulnerable populations including the elderly, children, individuals without access to adequate health care, and individuals with pre-existing conditions
- → Identify a basic set of core competencies for public health professionals responding to and preparing for the effects of climate change
- → Ensure that housing strategies include land use and transport planning for walking, cycling and rapid transit/public transport, as well as access to green areas to enhance health and climate benefits and reduce risks (i.e. urban heat island effects)
- → Ensure that appropriate standards and codes are in place, particularly to safeguard basic structural features such as access to electricity, safe drinking water, proper sanitation, natural ventilation and lighting, and to avoid use of materials with health hazards
- → Develop and implement healthy housing criteria, checklists, and good practice guidance

Heat-Related:

- → Promote individual behavior change through education about maintaining hydration and scheduling work breaks
- → Encourage building installation, installation of high-albedo (highly reflective) materials on roads and roofs, installation of green roofs, and planting trees in urban areas
- → Implement weather watch/warning systems
- → Identify suitable cooling centers

Extreme weather-related events:

- → Create disaster preparedness programs
- → Reduce flash floods through land use planning and reduction of impervious surfaces
- → Limit residential development in hazardous areas
- → Fortify sanitation systems and install green infrastructure to minimize the potential for sewage overflows
- → Encourage individuals to build disaster kits

Vector-borne diseases

- → Implement vaccination and education programs to reduce exposure and eliminate breeding sites
- → Develop long term policy for tracking the patterns of insects
- → Educate community members about vector-borne diseases

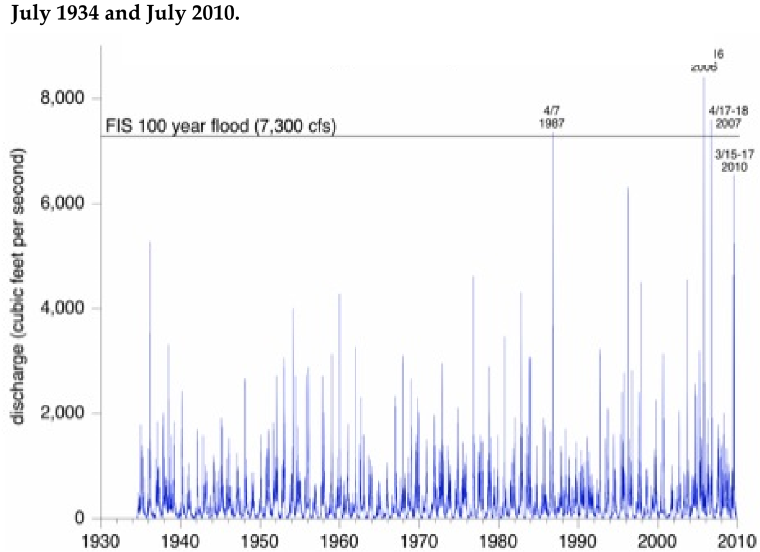
Water Resources

Climate change will impact the quantity and quality of water moving across the region's landscape. Flooding — already a significant problem in New Hampshire — will become a greater risk as extreme precipitation events, coastal storms, rapid snow and ice melt occur, and as more winter precipitation falls as rain.

Extreme precipitation events have intensified in recent decades in most U.S. regions. Reported flood frequency and severity increases are generally consistent with observed and projected water cycle changes in many U.S. regions. This trend, combined with the devastating toll of large floods (in human life, property, environment, and infrastructure) suggests that proactive management measures could minimize changing future flood risks and consequences.
[National Climate Assessment]

In recent years, flooding has caused road closures and resident evacuations, and flood damage has cost the state of New Hampshire tens of millions of dollars.[138] Total discharge for the Lamprey and Oyster Rivers increased between 1935 and 2009, with a significant increase occurring in both rivers in the fall.[139] Seasonally, peak flow date discharge also increased significantly in the Lamprey and Oyster River in the winter/spring period and decreased significantly in the Lamprey River in the fall.[140] The spring floods in 2006 and 2007 recorded the highest maximum discharge on the Lamprey River (see Figure 13).[141]

Figure 13. Daily discharge for the Lamprey River near Newmarket, NH between July 1934 and July 2010.



[Source: Carbon Solutions New England – 2013]

Within the SRPC region, there are approximately 2,400 miles of rivers and streams that flow into the Piscataqua-Salmon Falls, Merrimack, and Saco Rivers. Surface water accounts for 7.4% (or 26,088 acres) of the total area within the SPRC region.

There are a total of 296 dams in the region. As of 2010, there were 11 high hazard dams, 26 significant hazard dams, 41 low hazard dams, and 218 non-menace structure dams in the region. The high hazard designation refers to a dam that has a great hazard potential because of the size and location of the structure. The failure or misoperation of high hazard dams will result in the probable loss of human life.[142]

100-Year Event

A 100 -year flood is a flood that statistically has a 1% change of occurring in any given year. Likewise, a 100-year storm defines a rainfall event that can be expected to occur once every 100 years. The expected flood water level of a 100-year flood can be predicted and mapped out. This floodplain map is used for building permits, environmental regulations, and flood insurance. [NH Floodplain Learning on Demand – 2007]

Currently, 91% of New Hampshire's communities and all of the Strafford Regional Planning Commission's communities participate in the National Flood Insurance Program (NFIP), which is administered by the Office of Energy and Planning (OEP).[143] Flood Insurance Rate Maps (FIRM) are issued for most communities who participate in NFIP in New Hampshire. FIRMs identify Special Flood Hazard Areas or areas where there is a 1% chance of flooding in any year in a community (also known as the 100-year flood). It is important to recognize that although communities adopt the parameters NFIP places on development in the floodplain, these parameters are established for the purpose of enabling affordable insurance, not to keep the public safe from floods.[144] Development that is permitted to occur in the floodplain will result in an expansion of the floodplain over time.[145] FIRMs are currently being updated. Preliminary, revised FIRMs for Strafford and Rockingham Counties based on an updated methodology and 2-foot topographic data obtained through Light Detection and Ranging (LiDAR) were released in April 2014.[146] Maps in noncoastal communities will be updated subsequently.

A range of both structural and non-structural measures can protect individuals, property, and infrastructure from damage. Examples of different types of flood protection measures are show in Table 8.

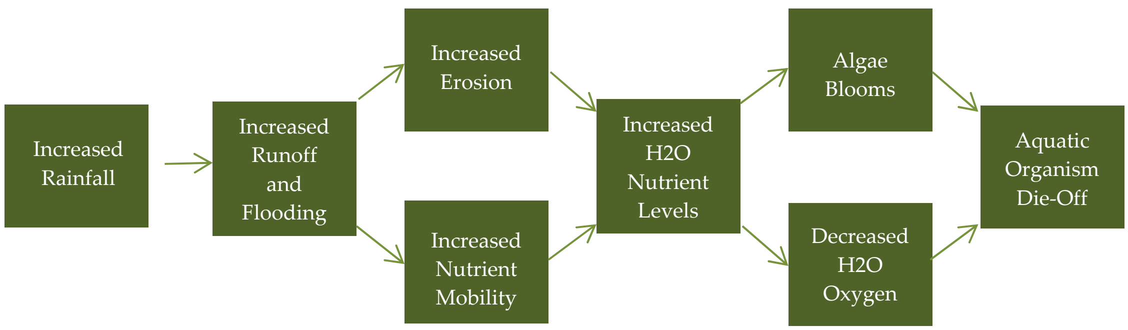
Table 8. Major flood protection measures.

	Structural Measures	Nonstructural Measures
	Measures in watersheds	Social measures
Dams	Increase natural water retention and water storage in watersheds by extending floodplains and creating	Flood mitigation systems including forecasting, warning, evacuation, and post flood recovery
Levees	Enhance infiltration and retardation of water by reducing impermeable areas, building groundwater cisterns, etc.	Land-use planning
Water storage reservoirs for flood control	Agriculture practices reducing runoff, e.g., catch crops, no black fallow in set-aside areas	Local and transboundary emergency committees
Flood retention ponds	Zoning to delineate floodplain, in which only low-value infrastructure is allowed	Household mitigation and preparedness actions
Dikes	Appropriate construction methods in flood-prone areas	Capacity building to improve flood awareness, understanding, and preparedness
River embankments and floodwalls		Risk spreading through flood insurance

[Source: Adapted from Krysanova et al., 2008]

Changes in precipitation and temperature will impact water quality. Heavy rainfalls will exacerbate existing pollution problems in Great Bay as runoff carries sediment, nutrients, pollutants, and waste downstream. This may in turn increase the risk of hypoxia or low oxygen levels in the bay (Figure 14).[147, 148] Earlier lake ice-out will effect organisms that inhabit the region's lakes. For example, earlier ice-out can increase phytoplankton productivity which will lead to lower summer oxygen levels.[149] In the southern part of the region, freshwater resources are at risk from sea level rise, saltwater inundation, and eutrophication associated with greater precipitation.[150]

Figure 14. Primary, secondary, and tertiary impacts on aquatic environments due to climate change effects on rainfall and runoff.



[Source: Adopted from Roseen et al., 2011]

The effects of climate change on water resources will also impact other sectors such as public health and recreation. For example, in Southern New Hampshire projected drought is a risk to the summertime drinking water supply.[151] In 2013, a record number of freshwater beach advisories (76) due to E. coli[1] were issued in New Hampshire, including one 5-day advisory at Camp Fireside Beach in Barrington and one 12-day advisory at Milton Recreation Area Beach.[152] The dramatic increase in bacteria violations was attributed to wet weather in June and July, when rainfall was almost double the normal monthly rainfall.[153]

While the impacts of climate change on groundwater storage or flow are not well understood, expected changes in precipitation and land use in aquifer recharge areas, coupled with changes in demand for groundwater, will affect the availability and quality of groundwater.[154]

LID in the Willow Brook Watershed – Rochester, NH

The UNH Stormwater Center, Rochester Department of Public Works, and Cocheco River Watershed Coalition partnered to:

- Install low impact development (LID) at two demonstration locations
- Evaluate opportunities within the Willow Brook Watershed
- Recommend strategies and realistic targets for impervious cover reductions.

The Willow Brook Watershed is a tributary to the Cocheco River located in the urban center of Rochester that is impaired for primary contact recreation due to bacteria. The project included installation of several LID BMPs to reduce runoff from impervious cover – which accounted for 16% of the area of the watershed - at 2 sites: the School Street School site and a new development of 15 homes built on a cul-de-sac. Three rain gardens, a rain barrel, an infiltration dry well, a pervious asphalt basketball court, and infiltration drain, and a pervious concrete sidewalk treat over 85% of the impervious cover at the School. Tree box filters, a bioretention systems and rain barrels were installed in the residential neighborhood. A comprehensive report identifying additional opportunities for the City of Rochester to promote innovative, cost-effective stormwater management was also produced as part of this project.

School Street School LID retrofits, Rochester, NH

Image credit: Lori Chase, Cocheco River Watershed Coalition

This project was funded in 2005 by the NH Department of Environmental Services.

[1] E.coli advisories are issued when a single sample was over 158 cts/100ml of water or two samples were over 88 cts/100ml of water.

- → Review and amend zoning and subdivision regulations to incorporate strong stormwater management provisions and consider ordinances that protect water quality
- → Install low impact development (LID) and green infrastructure (rain barrels, rain gardens, pervious pavement, sand box filters, green roofs, etc.) to mitigate impacts of increased precipitation by increasing infiltration, reducing runoff volumes, and delaying runoff peak as well as to reduce nonpoint source pollution
- → Prevent erosion and sedimentation during and after construction
- → Protect wetlands and install and maintain vegetated buffers to control and purify stormwater flows
- → Minimize the impact of impervious surfaces by:
  - Conducting an inventory to identify the best areas to develop and protect
  - Targeting conservation efforts near water bodies
  - Adopting conservation design alternatives to minimize the amount of land disturbed, maintain significant ecological areas in a natural state, and reduce the amount of impervious surface created
  - Managing existing impervious surfaces and stormwater drainage systems through measures such as vegetated buffers, keeping parking areas clean of debris, and capturing stormwater for treatment or groundwater recharge
  - Conducting outreach and education
  - Planting shrubs, groundcover, and trees; limiting impervious surfaces; directing rainwater from gutters to landscaped areas; and sweeping driveways and walkways instead of hosing them down in residential areas
- → Replace existing or newly constructed infrastructure with management practices that encourage groundwater infiltration to protect water supply and water quality during extreme precipitation or drought

Natural Systems

Stages of moose hair loss due to winter ticks

Photo credit: Dan Bergeron/NH Fish and Game

New Hampshire's diverse ecosystems are critical to maintaining a high quality of life in the state. Climate change will likely have direct physiological effects on plants, wildlife, and physical processes throughout the state.[155] Changes in seasonal precipitation and temperature, for example, will impact stream flow, summer drought, risk of wildfire, and water chemistry in Great bay.[156] While species that require cooler temperatures or specific water chemistry may be most influenced, a range of wildlife will face changes to their habitat.[157]

Climate change will influence ecosystems spatially and temporally and may result in changes in suitable habitat for many species and disrupt important individual and ecosystem functions such as interactions between plants and pollinators and plant productivity and reproductive success.[158] These changes in key life stages are largely unpredictable and will likely have very broad effects on ecosystems.[159] For example, the timing of migratory bird arrival and wildflower and woody perennial blooms may change. The range of many species may be extended.[160]

A total of 6.2% of the land area in the region is conserved, ranging from 3.5% in Wakefield to 39.2% in Durham.[161] Habitats within the boundaries of these conserved lands will likely change as species shift north due to increased temperature in the region.

Climate change will likely increase stress – including sea level rise, salt water inundation, and beach erosion -- on coastal ecosystems that are already stressed by human activity, pollution, invasive species, and storms.[162] Species that inhabit ocean and coastal waters will also face rising acid levels.[163] In addition, human responses to climate change – such as construction of dams, seawalls, and increased water withdrawal may further exacerbate stress on coastal ecosystems.[164]

Warmer temperature will increase the water temperature in streams, resulting in lower dissolved oxygen levels in bodies of water. One impact of lower oxygen levels is lower offspring production in fish.[165] Warmer water can also increase the range of non-native fish species that may outcompete native fish.[166]

Shorter winters have a negative, indirect impact on New Hampshire's moose population. Shorter, less snowy winters provide more optimal conditions for winter tick and brainworm, which impact moose health and mortality.[167]

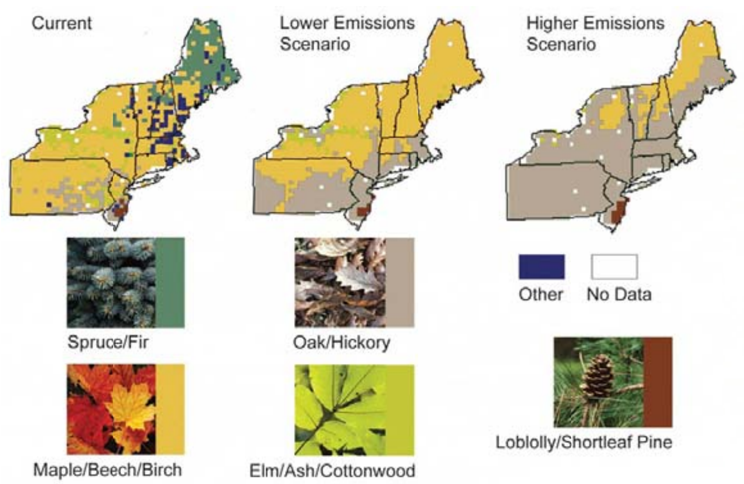
Forests

Forests play an important role in mitigating climate change and provide a range of benefits and services including: a renewable supply of fuel, lumber, and forest products; water cycle regulation; groundwater recharge; water quality protection; wildlife habitat; and opportunities for recreation.[168] U.S. forests absorb about 13% of all carbon dioxide emitted by fossil fuel burning in the U.S.[169]

There are approximately 42,750 acres of conserved forest land within SRPC's 18 communities. The percent of forest land conserved by town ranges from 3.1% in Rochester to 26.7 in Durham.[170] As temperature warms, species within this conserved land will likely shift northward. The result may be a disconnect between the geography or location of preserved land and the location of the forest.

Climate change is already affecting native ecosystems that are the foundation for New Hampshire's eco-tourism economy; the health of plant and wildlife species like sugar maple and moose is declining rapidly. Imagine New Hampshire without leaf peepers and maple syrup.

Figure 15. Current and future forest types under low and higher emissions scenarios in the Northeast.



[Source USGCPR – 2009]

Climate change in the Northeast may have positive and negative impacts on different species of trees and will likely change the composition of New Hampshire's forests[171] (see Figure 15). All species will not have the same ability to adapt. Species that are more sensitive to changes in temperature or drought may perish or migrate north, while others may thrive under warmer temperatures, wetter summers, and higher levels of carbon dioxide. By 2100, forest changes may include: a decline in the quality of spruce-fir forest; an increase in the productivity of northern hardwood-conifer forests; and a 20% decrease in abundance of hemlock.[172] Two profitable timber species that may respond well to climate change include white pine and red oak.

Impacts to New Hampshire's Forest Industry

- *Change in forest type to more southern species*
- *Reduced wood harvest volume due to longer mud seasons and fewer days with frozen ground*
- *Increased potential for ice damage*
- *Potential direct economic loss of $3.3 billion and total economic loss of $13 billion over the next century due to change in forest type*
- *Economic loss due to lengthening of the mud season including a potential total economic loss of $5.6 billion (10 day longer mud season) to $33.0 billion (60 day longer mud season)*
- *Potential elimination of the maple syrup industry within 50 years and with an economic loss of over $1.8 billion over the next century*

In general, climate change will likely have adverse impacts on forests. By the end of the next century, it is predicted that the optimal conditions for the growth of northern hardwood forest species would move at least 100 to 300 miles north. An increase in disturbances including pest and pathogen outbreaks, flooding, and wind damage will likely increase mortality in forests.[173] Heat stress and decreased soil moisture will result in a shrinking range and loss of habitat.[174] Extreme weather events will be particularly stressful for sensitive species such as sugar maple, ash, and yellow birch. Potential large-scale die-off of sugar maple will have a significant impact on the $3-$3.5 million maple syrup industry.[175] Dulling of fall foliage – which is important to the tourism and recreation industries – and decline of important forest product – which is the fourth largest employer in the state – species will impact New Hampshire's economy.[176] Finally, increased periods of drought may exacerbate the risk of wildfire.

Invasive species

Invasive species are a particular concern associated with climate change. Future climate change will likely increase both the likelihood of invasion of forests by nonnative plants and the damage caused by invasives.[177] Invasive species often have a strong ability to outcompete native species and as a result may be better able to cope with changes in temperature and precipitation. Climate change is expected to create more favorable conditions for some invasives. The range of the Hemlock Wooly Adelgid, for example, has already increased and it is expected to expand further as climate changes.[178] Privet and kudzu, two invasive plants, have also expanded north.[179] As insect pests, pathogens, and invasive plants increase, ecosystems will likely experience loss of biodiversity, function, and resilience.

Hemlock Wooly Adelgid Damage

Photo credit: National Parks Service

Two Countries One Forest (2C1Forest) – Northern Appalachian Acadian Ecoregion

2C1Forst is a Canadian-U.S. collaborative of 50 conservation organizations, researchers, and foundations working to conserve and restore 80 million acres of forests in the Northern Appalachian Acadian ecoregion. This ecoregion is defined by geography and ecology, not political boundaries, and includes forests in New York, Vermont, New Hampshire, Maine, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia. The project protects forest ecosystems threatened by climate change and human activity through a regional approach that crosses political boundaries. 2C1Forest works to build a science-based understanding of the ecoregion and develop a set of values and threats maps to guide conservation efforts in the protection of critical linkages that allow for the movement of individual plants and animals across the landscape and enable healthy populations and genetic diversity. This effort takes a regional, ecosystem-centric approach to protecting habitat. For more information see: http://www.2c1forest.org/atlas/.

Adaptation Strategies | Natural Systems

- → Protect sensitive and vulnerable species and habitats and conserve areas for habitat expansion
- → Identify management strategies to facilitate species' ability to migrate to suitable habitat using wildlife corridors; encourage the use of wildlife habitat connectivity maps in conservation land planning and infrastructure
- → Manage forests as carbon sinks; management practices that increase forest growth include fertilization, irrigation, switching to fast-growing planting stock, shorter rotations, and weed, disease and insect control
- → Increase removal and eradication efforts of pests and diseases and education to reduce transmission of invasive species; increase surveillance and early detection for cost effective and successful responses to plant invasions; evaluate the level of risk of invasives and the future effectiveness of management actions to control invasives
- → Encourage development and growth in existing urban areas while avoiding natural areas. Develop a system of intact protected natural areas to foster resiliency and to allow for species movement
- → Ensure that all replaced culverts are sized properly to accommodate fish passage and increased flows
- → Incorporate consideration of ecological services into land use planning, municipal and regional master plans, hazard mitigation, and transportation plans
- → Develop guidelines and provide incentives for communities to incorporate wildlife-friendly and climate-smart actions into master plans, hazard mitigation plans, adaptation plans, and town ordinances

Climate change will impact the state's economy. One industry likely to be significantly impacted by climate change is the forest industry. Businesses that utilize timber products will be impacted by reduced wood harvest. Farms that sell maple syrup – a culturally significant product that generates tourism - will also be affected. Potential economic losses will likely result in job loss.

Agriculture

Warmer temperatures, changes in precipitation, and increased growing season will impact agriculture in a variety of ways.

The growing season in Southern New Hampshire is projected to lengthen by 20 days under low emissions and 49 days (30%) under higher emissions by the end of the century. Near term, the growing season is expected to increase by 7% or 11 to 12 days.[180] With a longer growing season, there is potential to diversify typical Northeast crops.[181] A longer growing season may also increase transpiration and decrease soil moisture. This could result in increased irrigation needs.[182]

Winter Farmer's Market in Rollinsford

Photo credit: Seacoast Eat Local

Extreme precipitation events may damage crops, reduce yields and will increase soil erosion.[183,184] Crops may be at greater risk to drought, which has a major impact on plant productivity and reproductive success.

Warmer temperatures have direct and indirect effects on crops. Heat stress may reduce yields and negatively impact sugar maple and dairy cow milk production.[185,186] Warmer winters may result in inadequate winter chill period for optimum fruiting. Crops will likely also face increased pressure from invasive weeds, insects, and disease associated with warmer winters.[187] Increased pressure from new and existing pests will potentially drive farmers to increase pesticide and herbicide applications.[188] In addition, there is potential for crops to become more resistant to herbicide control.

Change in atmospheric carbon dioxide will also impact agriculture. With adequate nutrient levels, soil moisture, water availability, many crops may benefit from increased carbon dioxide levels.[189] However, weeds that benefit from higher carbon dioxide level may have a greater advantage over crops.

Farm land accounted for 4.6% (15,276 acres) of total land area within the region in 2011.[190]

Adaptation Strategies | Agriculture

- → Modify farming practices including crop varieties and timing of field operations to cope with changes in temperature and precipitation
- → Alter local topography of land
- → Utilize artificial systems to improve water use and availability and protect against soil erosion
- → Build resilience by diversifying crop rotations, integrating livestock with crop production systems, improving soil quality, and minimizing off-farm flows of nutrients and pesticides
- → Adopt soil and water moisture conservation measures that minimize the impact of potential seasonal water shortages
- → Change livestock breeding practices and shift grazing patterns
- → Develop disease-resistant crop and livestock species

While climate change has negative impacts for native species, it often helps introduced or invasive species get a stronger foothold, helping them spread and accelerating their impacts. For more information about invasive species in the region, see the Environment, Land Use, and Recreation Appendix (page 97).

Society

Heat waves and coastal and river flooding associated with more extreme precipitation events and sea level rise will increasingly challenge environmental, social, and economic systems in the Northeast.[191]

Adapting to changing environmental conditions will involve both regulatory and non-regulatory measures. Communities will likely need to reconsider zoning, site plan and subdivision regulations and identify innovative land use controls to increase local resilience to change. 36 Land use planning that incorporates strong environmental protection and open space to allow filtration and absorb floodwater will also become more important. In coastal areas, communities will need to address challenges such as issues of social equity associated with managed coastal retreat and potential changes in jurisdiction associated with changing shorelines and rising water levels.

Projected climate change will have a range of impacts that influence how and where people in Southern New Hampshire live, work and play. Depending on proximity to flood hazards, for example, communities may be forced to reconsider where development is permitted, modify building codes, and relocate critical infrastructure. Decision makers will have to address challenges such as the disproportionate impacts climate change will have on different community members and to identify where to best invest resources to minimize risk.

Communities will face potential damage to personal property, businesses, and public infrastructure[192] and the costs associated with this damage. Communities will also likely have to cope with more frequent road closures and power outages, which have impacts ranging in magnitude from inconvenience to life threatening. Hurricane Sandy, for example, left 210,000 people without power and closed 32 state roads in New Hampshire.[193] Extreme precipitation events and heat related health impacts will likely increase the burden on Frisbie Memorial, Wentworth Douglas and other area hospitals and medical facilities. More frequent extreme precipitation may also result in increased school closures and disruption to school schedules.

Climate change threatens the livelihood of individuals who make a living in professions and industries linked to weather who depend on access to and the integrity of natural resources, such individuals in the agricultural, recreation, and tourism industries.[194]

Family Skiing at Mount Sunapee

Photo credit: Liftopia

Warmer winters will negatively impact snow and ice-related recreation[195] and the winter recreation industry, a $7.6 billion annual industry in the Northeast.[196] New Hampshire's ski and snowmobile industries have already been affected by warming winters.[197] Smaller, more southern ski areas are at the greatest risk to warmer temperatures. Less snowfall will impact recreational facilities in the region, as well as impact reduce recreational opportunities in New Hampshire and throughout the Northeast. Anticipated earlier lake ice-out will shorten the ice-fishing and snowmobiling seasons.[198] The estimated total economic contributions from winter tourism (including over 2.2 million skier visits and half a million snowmobile days) in the 2009/2010 season in New Hampshire was $451 million.[199] Winter tourism supported 7,819 employees and provided $258.5 million in labor income in New Hampshire.[200] The amount of snowfall greatly impacts the number of skier visits: between 1999 and 2010, there were 17% fewer skier visits during lower snowfall years compared to higher snowfall years in New Hampshire.[201] According the NH Department of Environmental Services, a loss of 10 to 20% of ski season days could result in a loss of $42 million to $84 million in direct and indirect spending in New Hampshire (in 2008).[202]

Climate change will impact the economic viability of businesses that rely on cold winter temperatures and snowfall. As a result, residents and visitors may face decreased opportunities to ski and communities may face declining tourism revenues.

Under a higher emissions scenario, one study estimated that only four of 14 major ski resorts in the Northeast will remain profitable by 2100.[203]

Climate change may also impact summer recreation. An increase in extreme precipitation events and stormwater runoff, for example may lead to the need to close beaches due to water quality impairment. Warmer temperatures will also impact cold water fish and may result in as much as a 50 to 100% eradication of rainbow, brook, and brown trout fishing, a $150 million industry in the state.

Flooding and environmental degradation associated with climate change impacts will impact on New Hampshire's $484 million coastal tourism industry.[204] The fall foliage tourism industry, which draws travelers that spend an average of $292 million annually, will also likely suffer impacts associate with climate change as the vibrancy of fall color diminishes.

Leaf-peepers taking in fall color in the White Mountains

Photo credit: AP File

Regional and Local Implementation

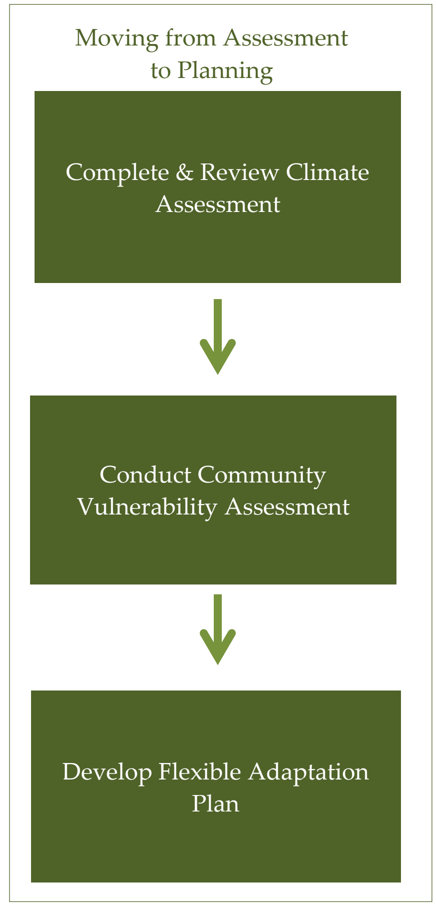
Overview

Because anticipated changes in climate vary by region and the impacts of those changes are dependent on the vulnerability and specific character of the population, built environment, and ecosystem of a place, adaptation strategies are inherently local or regional in nature. Communities in New Hampshire have the opportunity and authority to adopt local action plans and adaptation measures to address issues that are of particular local concern.

Adaptation strategies are inherently local or regional in nature.

In nine regional planning documents and 18 community plans reviewed by SRPC in 2013, mitigating climate change impacts was mentioned in one regional plan and in none of the community plans. While a number of master plans contain provisions related to climate adaptation and mitigation – such as increasing open space protection, encouraging sustainable growth that is sensitive to environmental issues and minimizes energy consumption, and building sustainable communities for current and future generations – an explicit reference to climate change and recognition of the need to incorporate adaptation and hazard mitigation into local planning is lacking.

However, more recent extreme weather events including the 2001-2002 drought, 2006 and 2007 spring floods, and ice storms including those in 2008, 2010, and 2013 have shaped new views on the importance and value of planning for new climate trends. In addition, each municipality in New Hampshire has adopted an All Hazards Mitigation Plan that includes strategies to prepare for environmental hazards including: flood, drought, extreme heat and wildfire; geological hazards; severe wind; and winter weather. Implementation strategies of these plans include components such as emergency action plans, dam inundation plans, floodplain map updates mobile home tie down requirements, and compliance with earthquake standards.



[Adapted from Wake et al., 2014]

Relevant Federal and State Programs and Initiatives

There are a number of federal and state programs and initiatives that can guide local adaptation. At the federal level, the President's 2013 Climate Action Plan builds on progress made in reducing pollution from the energy sector and addresses climate mitigation, preparedness, and leadership. Agencies including the Environmental Protection Agency, Department of Transportation, Department of Homeland Security, and Department of Health and Human Services provide resources, funding, and technical assistance for climate adaptation through a number of programs (see Table 8). At the state level, the Department of Environmental Services, Department of Health and Human Services, Fish and Game Department, Department of Transportation, and Office of Energy and Planning provide assistance in areas including emergency preparedness, flood hazard mitigation, wildlife planning, and resiliency (Table 7). In addition, New Hampshire's Climate Action Plan lays out a path for reducing greenhouse gas emissions while maintaining economic growth.

Table 8. Federal and state programs and initiatives with climate change adaptation, impacts, and mitigation components.

	Federal Programs & Initiatives	
The President's Climate Action Plan, June 2013	A broad-based plan to cut the carbon pollution that causes climate change and affects public health. Three key pillars of the plan include: 1) Cut Carbon Pollution in the U.S. 2) Prepare the United States for the Impacts of Climate Change 3) Lead International Efforts to Combat Global Climate Change and Prepare for its Impacts The plan directs EPA to work with states and industry to establish carbon pollution standards, supports energy efficiency and renewables projects; sets a carbon pollution reduction goal for the energy sector; commits partnering with industry and stakeholder to develop fuel economy standards; and leverages opportunities to reduce hydroflourocarbons, address methane, and protect forests and critical landscapes. The plan directs agencies to support local climate resilient investment; provides tools and information through a new Climate Data Initiative; and commits to strengthening global resilience by expanding government and local community planning and response capacities.	http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf http://www.data.gov/climate/
U.S. Global Change Research Program	Federal program that coordinates and integrates global change research across 13 government agencies to ensure that it most effectively and efficiently serves the Nation and the world. Mandated by Congress in the Global Change Research Act of 1990. The program advances climate science and understanding current and future global change impacts through the establishment of interagency partnerships, working groups, and collaborations with leading experts.	http://www.globalchange.gov/
Environmental Protection Agency Adaptation Programs	17 Draft Program and Regional Adaptation Implementation Plans (released for comment November 2013) , including a Region 1 New England Climate Adaptation Plan Draft Climate Change Adaptation Plan (February 2013) Climate Ready Estuaries Partnership between EPA and the National Estuary program National Water Program Climate Change Strategy Smart Growth and Partnership for Sustainable Communities	http://www.epa.gov/climatechange/impacts-adaptation/fed-programs.html
Council on Climate Preparedness and Resilience 2013	Established to advise the Obama Administration on how the federal government can respond to the needs of communities nationwide that are dealing with the impacts of climate change. Replaces the Interagency Climate Change Adaptation Task Force formed in 2009. 2010 Progress report has 3 cross-cutting national strategies:	http://www.whitehouse.gov/the-press-office/2013/11/01/fact-sheet-executive-order-climate-preparedness

Federal Programs & Initiatives		
	-National Action Plan for Managing Freshwater Resources -National Ocean Policy Implementation Plan -National Fish, Wildlife and Plants Climate Adaptation Strategy 2011 Progress Report focuses on: -Building resilience in local communities -Safeguarding critical natural resources -Providing accessible climate information and tools to help decision-makers manage climate risks	
Department of Health and Human Services Centers for Disease Control and Prevention's Climate-Ready State and Cities Initiative	Helps states and cities: -develop ways to anticipate health effects by applying climate science, predicting health impacts, and preparing flexible programs. -understand potential climate changes in their areas -develop and use models to predict health impacts, monitor health effects, and identify vulnerable areas	http://www.cdc.gov/climateandhealth/climate_ready.htm
Department of Transportation Climate Action Plan, 2012	Prepared under Executive Order No. 13514, Federal Leadership in Environmental, Energy, and Economic Performance, and Council on Environmental Quality Implementing instructions. Lays out steps DOT will take to fully integrate considerations of climate change and variability in DOT policies, programs, and operations.	http://www.dot.gov/sites/dot.dev/files/docs/DOT%20Adaptation%20Plan.pdf
Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program	Provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. State, local governments, Indian tribes or other tribal organizations, and private non-profit organizations are eligible applicants.	http://www.fema.gov/hazard-mitigation-grant-program

State Programs & Initiatives		
Department of Environmental Services Climate Change Program New Hampshire Climate Action Plan, 2008	Aims to achieve the greatest feasible reductions in greenhouse gas emissions while also providing the greatest possible long-term economic benefits to the citizens of the state. Recommends actions to: -Reduce greenhouse gas emissions from buildings, electric generation, and transportation -Protect natural resources to maintain the amount of carbon sequestered -Support regional and national initiative to reduce greenhouse gases -Develop and integrated education, outreach and workforce training program -Adapt to existing and potential climate change impacts	http://des.nh.gov/organization/divisions/air/tsb/tps/climate/index.htm http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/nh_climate_action_plan.htm
Homeland Security and Emergency Management Multi-Hazard Mitigation Plan, 2013 Update	Provides an overview of the natural and human-caused hazards that impact the State and outlines the State's plan for mitigating damages associated with these events. Prepared pursuant to Section 332, Mitigation Planning, of the Robert T. Strafford Disaster Relief and Emergency Assistance Act.	http://www.nh.gov/safety/divisions/hsem/HazardMitigation/planning.html
Fish and Game Department Wildlife Action Plan, Ecosystems and Wildlife: Climate Change Adaptation Plan 2013 amendment	Addresses how climate change will affect wildlife and their habitats through a series of vulnerability assessments of critical habitat and development of a broad set of strategies to address those vulnerabilities.	http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm http://www.wildlife.state.nh.us/Wildlife/Wildlife_Plan/climate.html
Department of Health and	Supports NH and its local communities to identify, prevent, prepare for, and	http://www.dhhs.nh.gov/d

State Programs & Initiatives		
Human Services	respond to health hazards associated with changing climate through organized, coordinated, and effective systems in place. Part of Climate Ready States and Cities Initiative, a CDC funded national collaboration to help local communities prepare for public health impacts.	phs/climate/index.htm
Climate and Health Program		http://www.dhhs.nh.gov/dphs/climate/documents/nh-excessive-heat-plan.pdf
Excessive Heat Emergency Response Plan, 2011	Provides information and identifies DHHS's role in response to excessive heat emergencies in NH in collaboration with the NH Public Health Regions and with other State agencies and in accordance with the National Incident Management System	
Department of Transportation	Currently developing a Resilience and Preparedness Action Plan that will identify NHDOT programs, policies, and activities that impact or are impacted by changing weather trends and identify opportunities to increase the resilience of existing infrastructure and future investments	
Department of Energy and Planning Floodplain Management Program	Provides technical assistance to communities and the public on floodplain management and helps to promote sound land use planning techniques that will reduce flood losses.	http://www.nh.gov/oep/planning/programs/fmp/index.htm

Vulnerability of Critical Assets

Vulnerability mapping is part of the process of developing climate-resilient communities and regions. Spatial mapping is a tool that can assist decision makers and stakeholders with identifying at risk populations, infrastructure, and areas within a community or region using variables such as hazards and exposure. Vulnerability maps can highlight priority areas where adaptation is most necessary with regard to current and future risks posed by climate change, as well as areas to target investment in adaptation projects.

The maps included in this section are intended to serve as a general assessment of areas in the region where climate change may pose a greater threat to people and infrastructure. The maps are intended for planning purposes at a regional and community level scale. More comprehensive vulnerability mapping should assess risk associated with factors including but not limited to:

- Sea level rise
- Floodplains
- Soil type
- Demographics
- Transportation systems
- Precipitation projections
- Projected population
- Population density
- Urbanized areas
- Impervious surfaces
- Health indicators
- Temperature projections
- Infrastructure
- Critical community assets
- Housing type and location
- Emergency services
- Conservation land
- Sensitive or threatened species

Summary of maps:

Map 1: Social vulnerability

This map displays the Social Vulnerability Index (SoVI) 2006-2010, which measures the social vulnerability to environmental hazards, for the region. The index is a comparative metric that facilitates the examination of the differences in social vulnerability among counties. SoVI graphically illustrates the geographic variation in social vulnerability. It shows where there is uneven capacity for preparedness and response and where resources might be used most efficiently to reduce the pre-existing vulnerability. SoVI also is useful as an indicator in determining the differential recovery from disasters. The index synthesizes 30 socioeconomic variables, which the research literature suggests contribute to reduction in a community's ability to prepare for, respond to, and recover from hazards. SoVI data sources include primarily those from the United States Census Bureau. In SoVI 2006-2010, seven significant components explain 72% of the variance in the data. These components include: race and class; wealth; elderly residents; Hispanic ethnicity; special needs individuals; Native American ethnicity; and service industry employment. For more information see: http://webra.cas.sc.edu/hvri/products/sovi.aspx.

Map 2: Vulnerable community assets

This map displays key community assets and infrastructure and highlights assets and infrastructure that is vulnerable due to proximity to the 100 and 500year floodplains. This map was generated using community anchor institution data from the New Hampshire Broadband Mapping and Planning Program (NHBMPP).

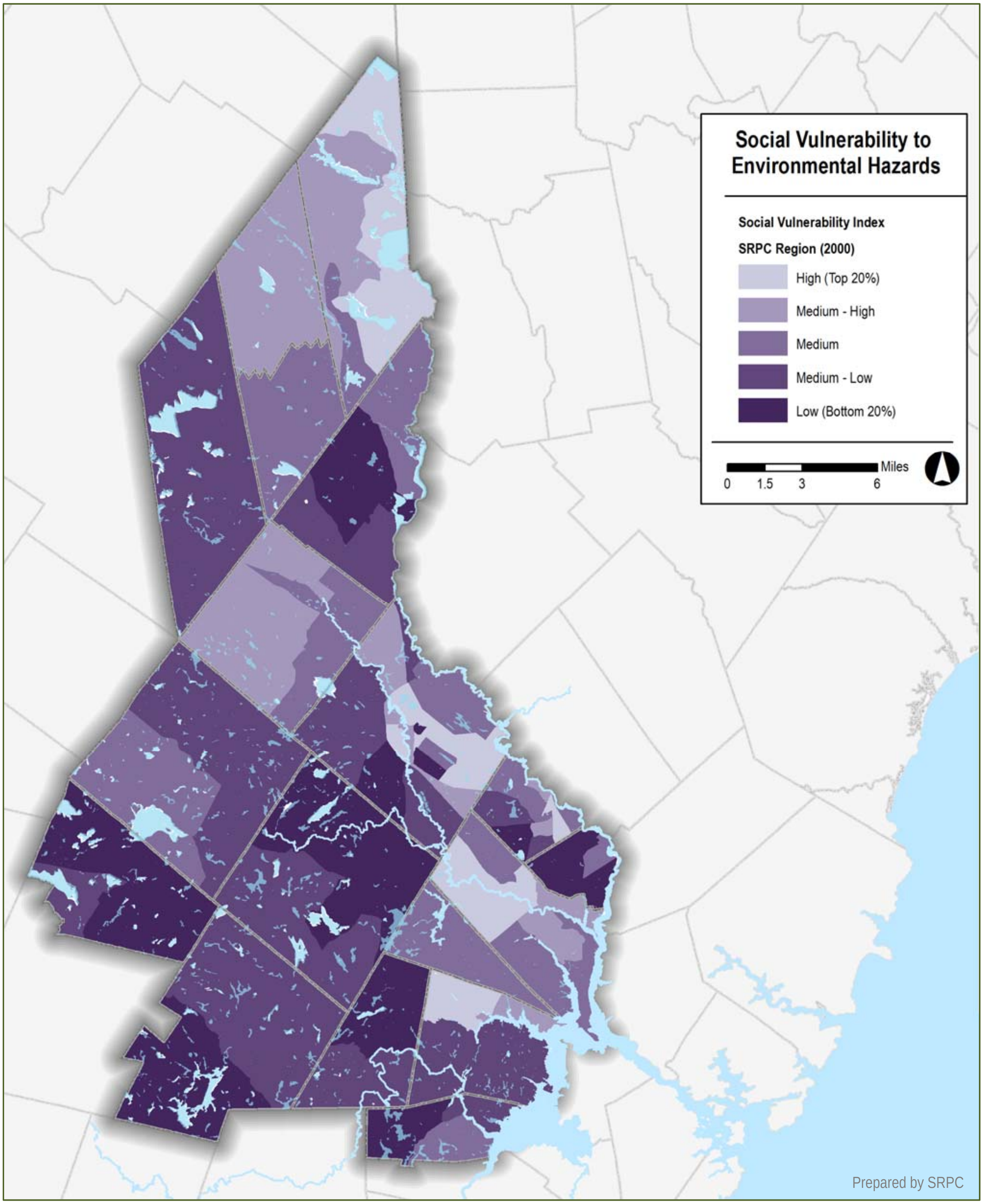
Map 3: Flood risk due to stream – road crossings

This heat map highlights regions with a high prevalence of stream and road crossings where culverts, bridges, and or roads – as well as the surrounding population that relies on this transportation network - are at risk of flooding due to location within the 100-year floodplain.

Maps 4-8: Sea level rise and flood elevation

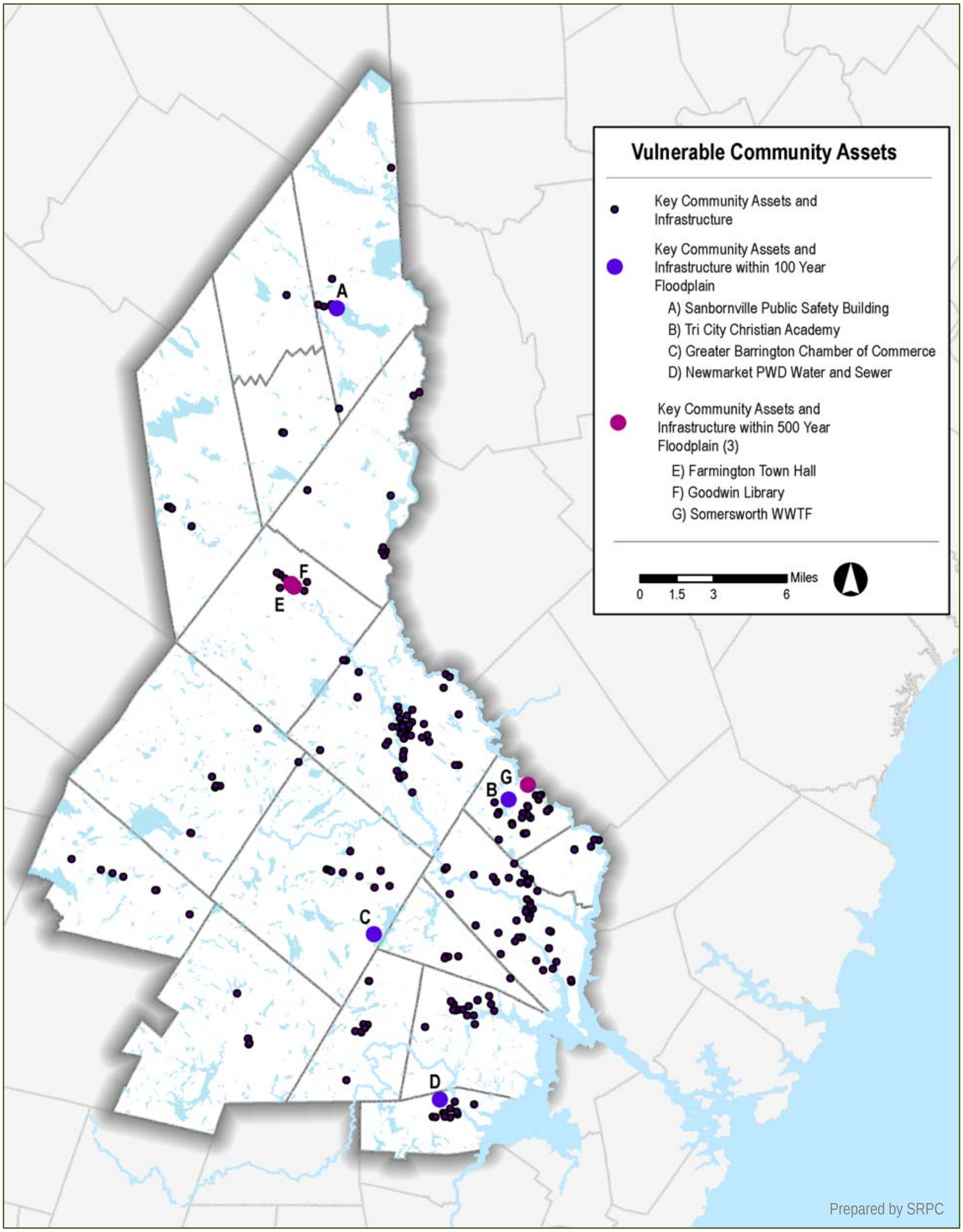
The projected flood level displayed in these sea level rise maps reflects the projected 75 inch increase in 100-year flood elevation at Fort Point in New Castle, NH from the current elevation of 11.2 feet to 17.8 feet by 2100 under a high emissions scenario. These maps were generated from data produced by GRANIT and the UNH Earth Systems Research Center using results from Wake et al. 2014. These maps are based on detailed LiDAR (Light Detection and Ranging) topographic data that was collected during the spring of 2011. Note that the maps are provided for discussion and research purposes only. It is not appropriate to use the maps for detailed analysis.

Map 1. Social vulnerability to environmental hazards.



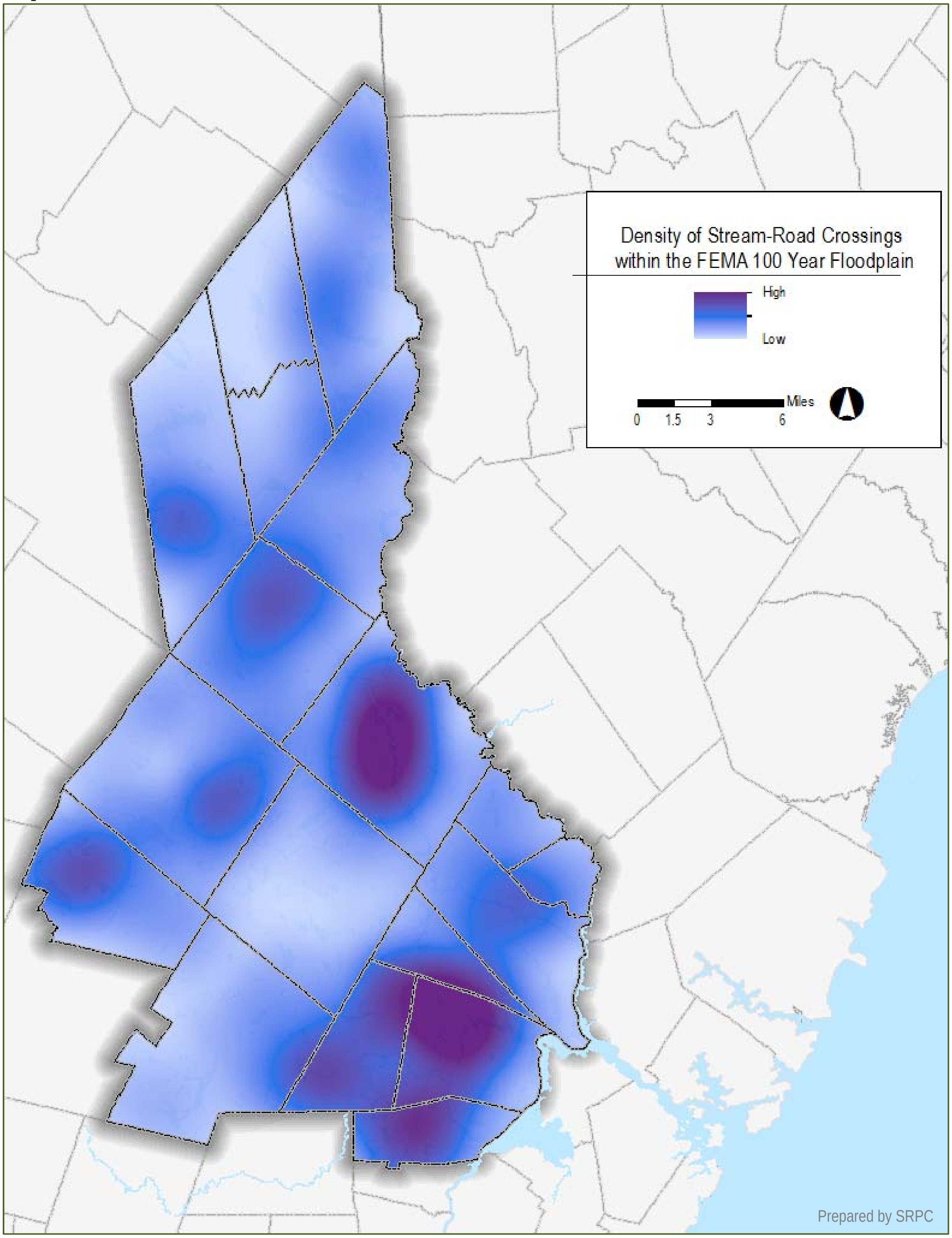
[Source: University of South Carolina, NOAA]

Map 2. Vulnerable community assets within the 100 year floodplain.



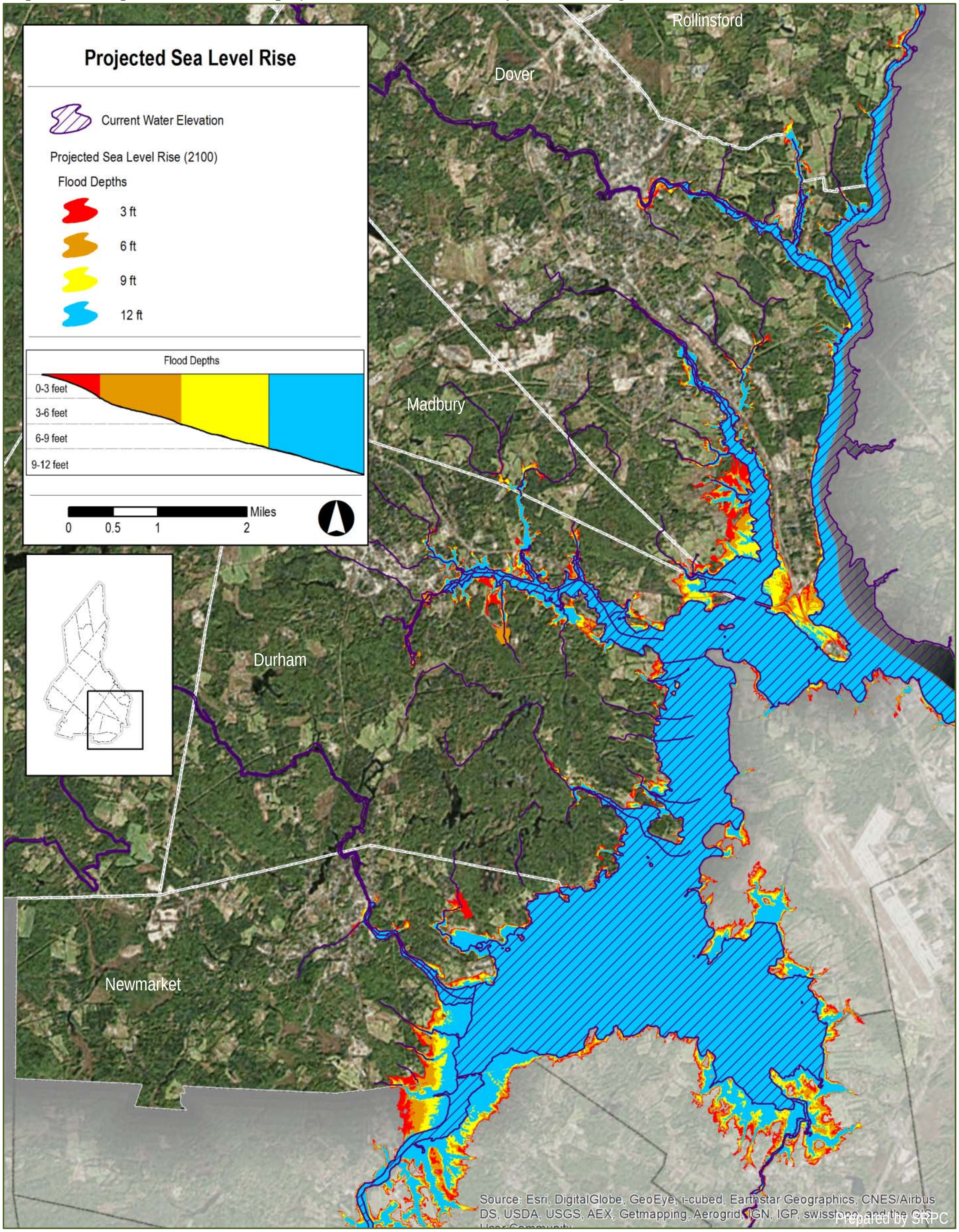
[Source: NHDES, NHBMPP]

Map 3. Areas with greater vulnerability to flooding due to the presence of stream – road crossings within the 100-year floodplain.



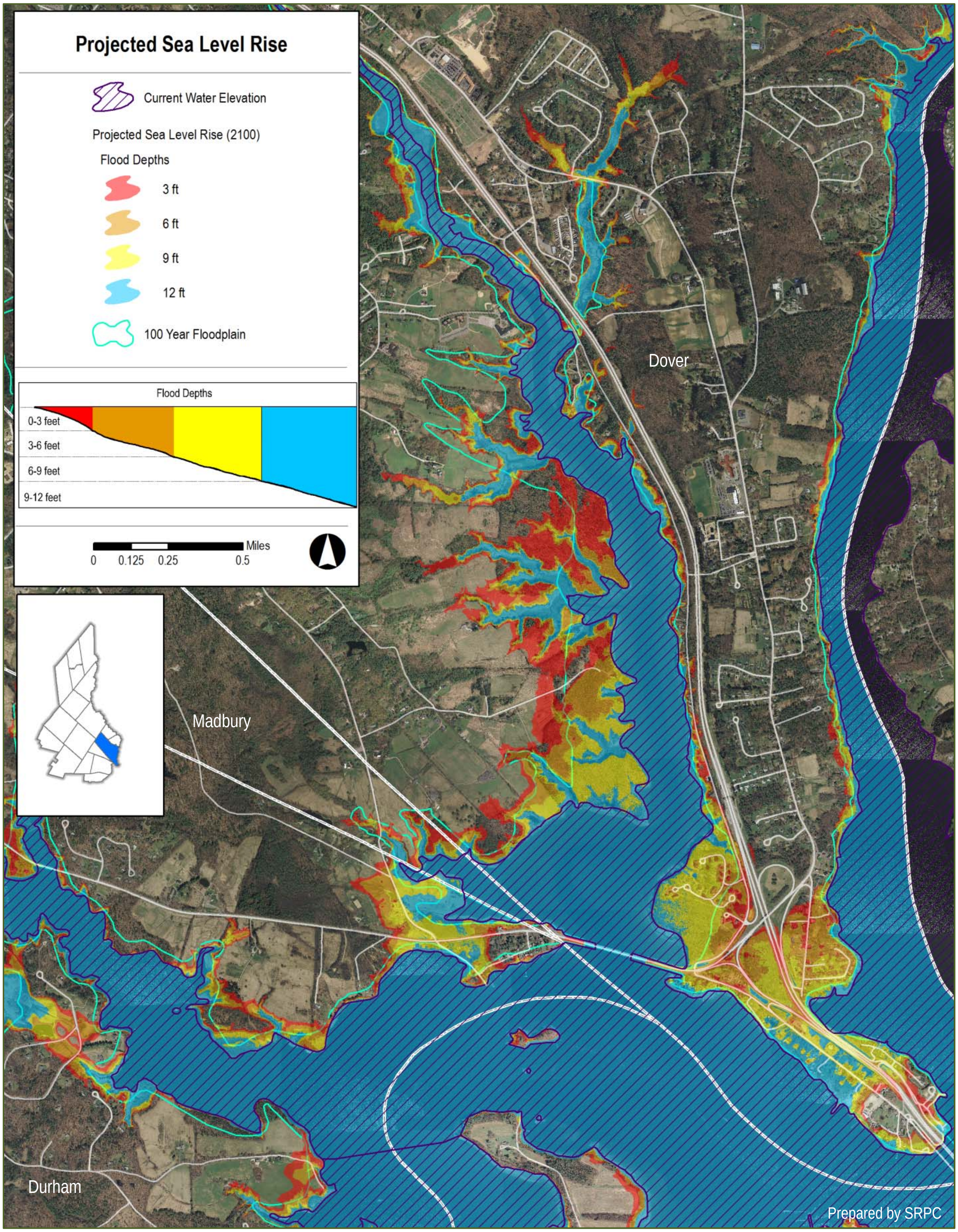
[Source: NHDES]

Map 4. Flood depths associated with projected sea level rise of 75" by 2100 in the region.



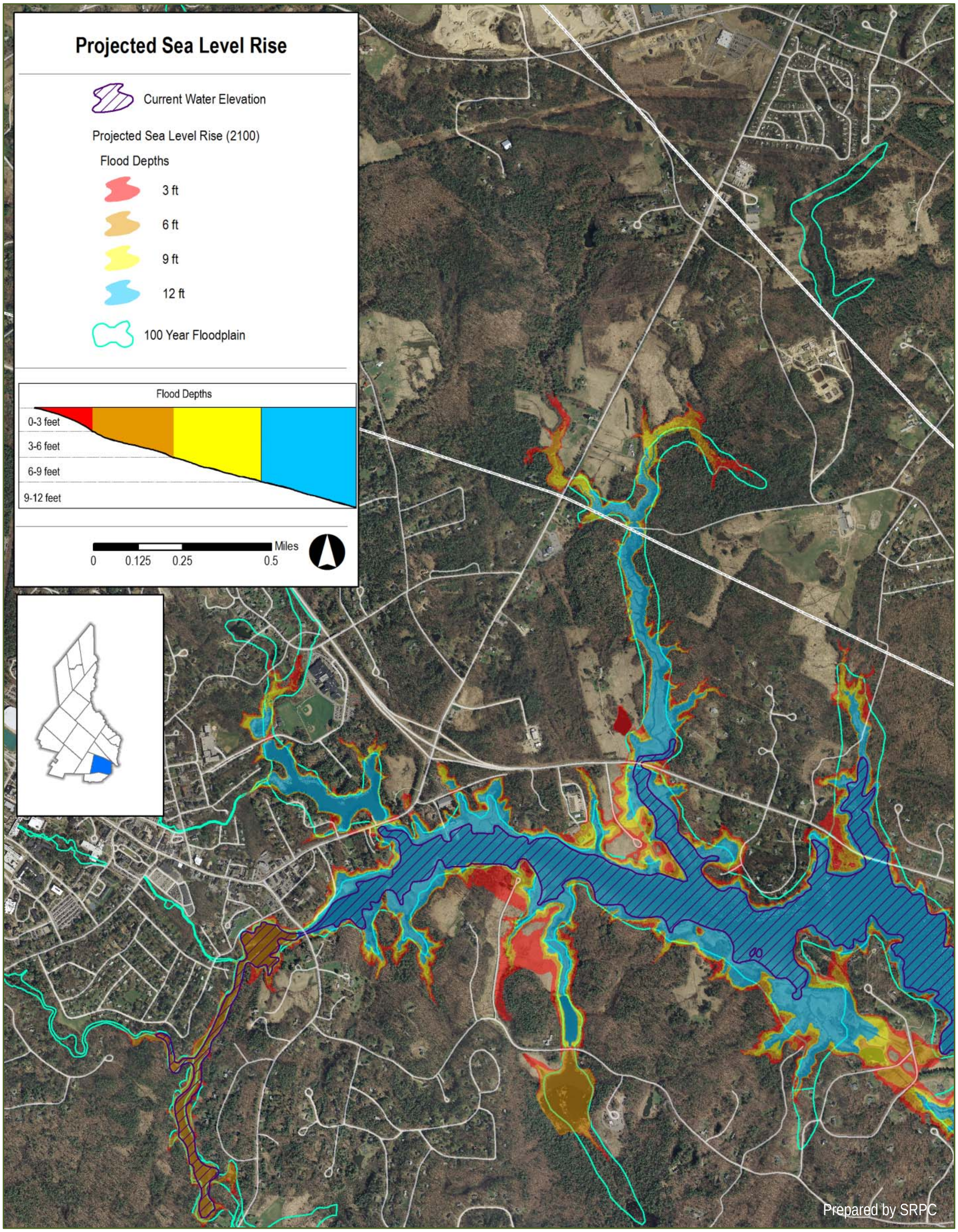
[Source: NHDES, UNH Earth Systems Research Center, GRANIT, aerial imagery: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community]

Map 5. Flood depths associated with projected sea level rise of 75" by 2100 in Dover, Madbury, and Durham.



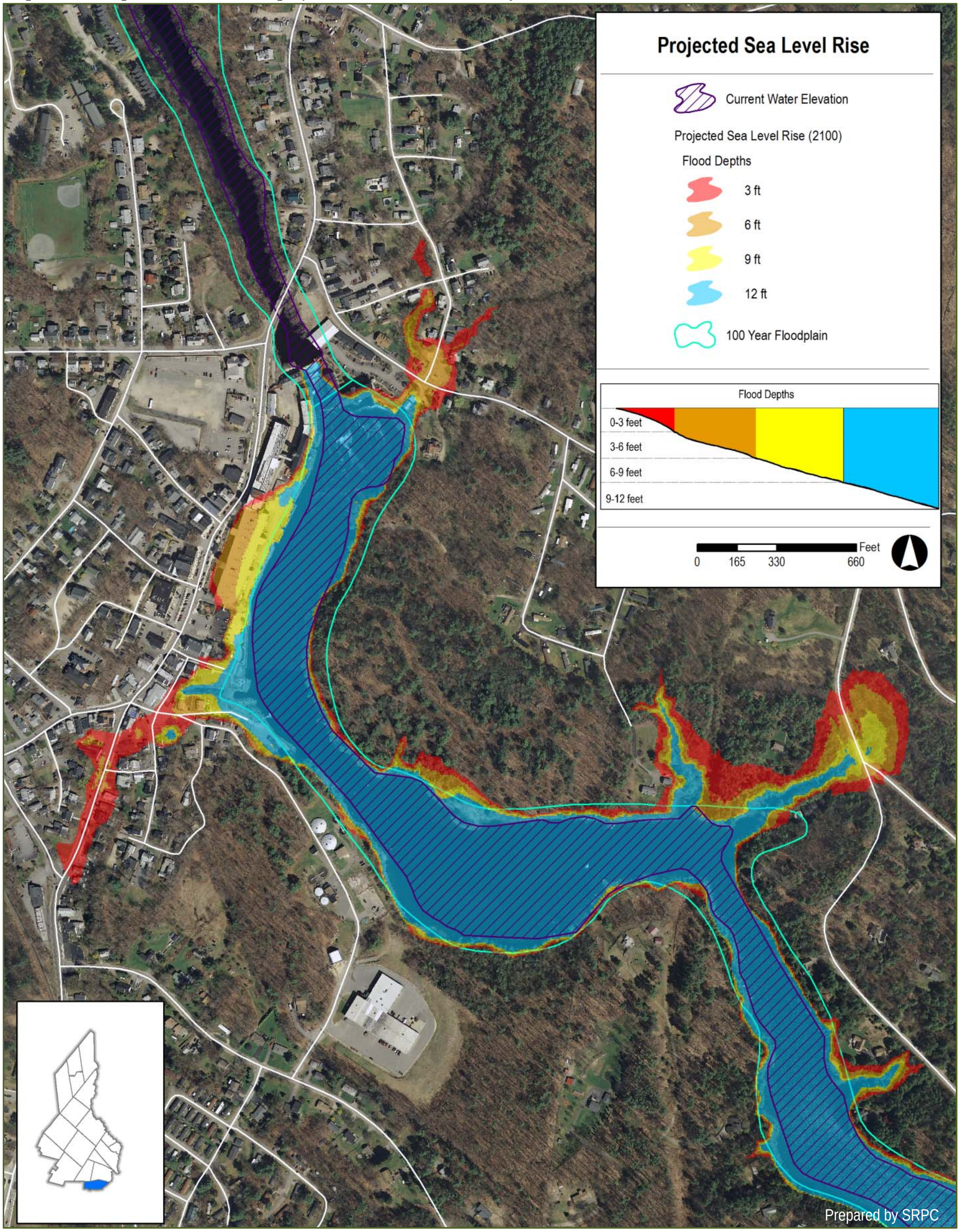
[Source: NHDES, UNH Earth Systems Research Center, GRANIT, NHDOT]

Map 6. Flood depths associated with projected sea level rise of 75" by 2100 in Durham and Madbury.



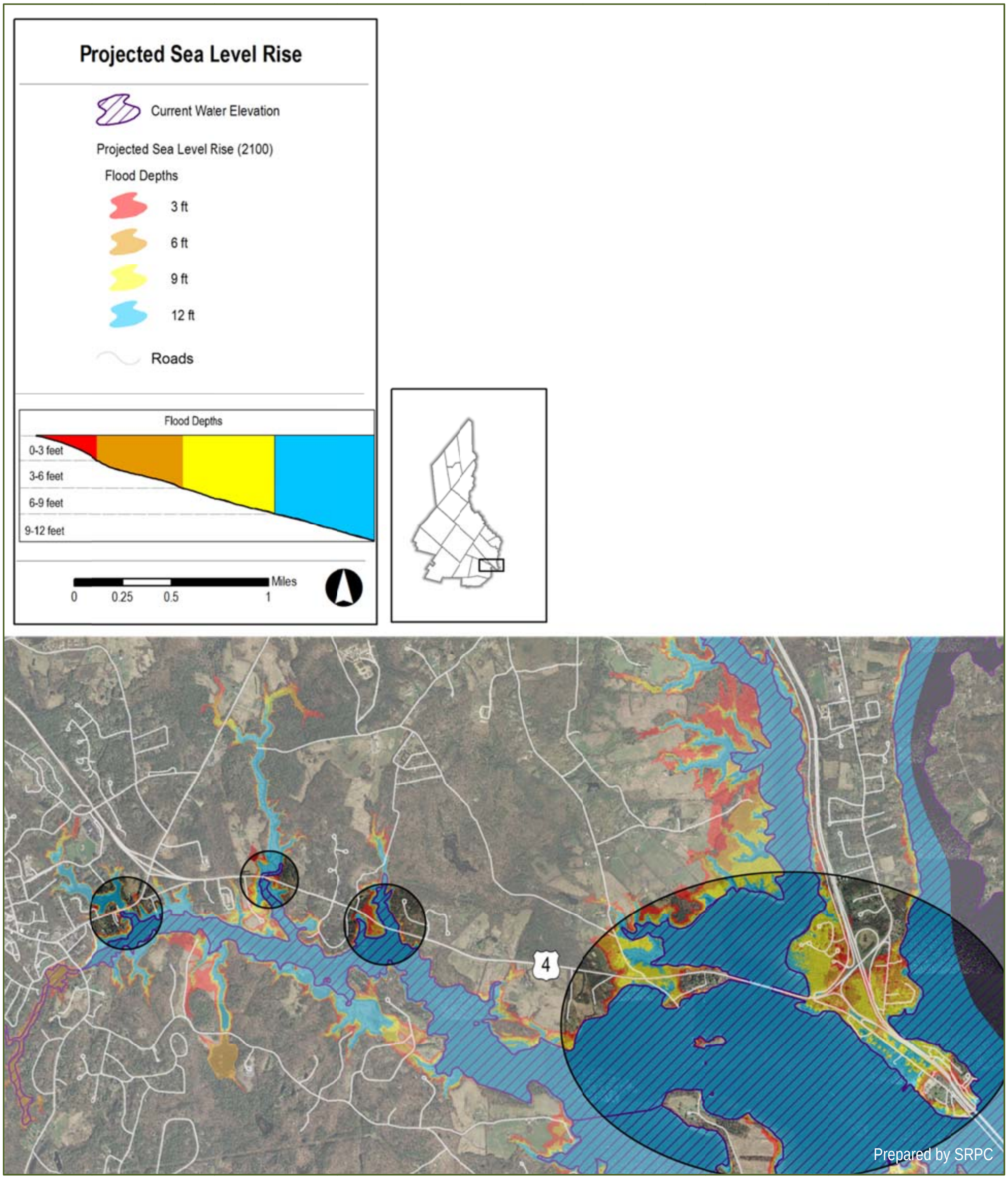
[Source: NHDES, UNH Earth Systems Research Center, GRANIT, NHDOT]

Map 7. Flood depths associated with projected sea level rise of 75" by 2100 in Newmarket.



[Source: NHDES, UNH Earth Systems Research Center, GRANIT, NHDOT]

Map 8. Flood depths associated with projected sea level rise of 75" by 2100 along NH Route 4.



[Source: NHDES, UNH Earth Systems Research Center, GRANIT, NHDOT]

Incorporating Climate Adaptation into Local and Regional Planning

Climate adaptation strategies must be tailored to address exposure and sensitivity to climate change impacts at the local level. In addition to minimizing or preventing vulnerability and preserving quality of life, adaptation planning can result in significant cost savings for individuals and municipalities. This is particularly true because the cost of inaction or delaying adaptation is potentially very high. In addition, failure to address how climate change will exacerbate many existing challenges in the region - such as managing stormwater runoff to protecting property and the ecological integrity of water bodies in an increasingly impervious landscape – will likely result in the need to modify policies, regulations, and infrastructure in the future.

Planning for climate change involves consideration of a number of tradeoffs. For examples, economic conditions may constrain implementation of the numerous flood risk reduction measures such as land use zoning, flood insurance, and restoration of natural flood plain retention capacity.[205] Evaluating tradeoffs – such as when to invest in an adaptation strategy, who will benefit from an adaptation strategy and when they will benefit, and whether to invest in an adaptation strategy when future conditions may change -- can help prioritize the implementation of adaptation strategies.

Changes in demographics, economies, and policies related to development, economy, and climate contribute to uncertainty about climate change impacts in the Northeast.[206] The complexity of natural and human systems makes it challenging to predict the positive and negative synergies and impacts that future change will have on climate, ecosystems, the built environment, and people. There is also uncertainty about the ability of adaptation strategies to reduce vulnerabilities.[207]

Adoption of no-regrets adaptation measures that yield benefits even in the absence of climate change is one strategy to help decision-makers act given these uncertainties.[208] For example, from a cost-benefit analysis point-of view, maintaining culverts or drainage channels is a good investment even in the changes if extreme precipitation events do not occur.

Adoption of no-regrets adaptation measures that yield benefits even in the absence of climate change is one strategy to help decision-makers act given these uncertainties.

Given that resources to address climate change are not unlimited, it is advantageous to consider opportunities to pair mitigation and adaptation efforts. For example, the New Hampshire Climate Action Plan (CAP) recommends reducing greenhouse gas emissions from buildings, electric generation, and transportation.[209] One method to address this mitigation objective and climate adaptation, is by installing a green roof, which would serve to regulate building temperature and reduce demand for electricity. Additionally, a green roof reduces runoff and the urban heat island effect. A second recommendation included in the CAP is to protect natural resources in order to maintain the amount of carbon that is sequestered through the landscape.[210] Conserving and protecting forests maintains carbon sinks and the ability to store and filter surface water. As a result, this action addresses increasing challenge of reducing runoff and protecting water quality under the heavy precipitation events expected to occur as climate changes.

Strategies to integrate climate change adaptation planning into local planning are included in the box below. Communities in New Hampshire are already implementing many of these planning strategies. The case studies that follow highlight examples of local climate adaptation planning in and around the region.

Integrating Climate Change Adaptation Planning

- → Integrate planning for transportation, facilities, land use, human health, natural resources, and ecosystem services
- → Integrate zoning, land use, and resource conservation—environmental and floodplain regulation, conservation subdivision incentives in high-risk areas, village center zoning, transfer of development rights, open space, and land preservation
- → Encourage sustainability and Smart Growth planning (mixed use development and village development, conservation/open space subdivision, alternative transportation access, and preservation of agricultural lands)
- → Conduct a municipal audit to identify barriers and incentives to implement climate change planning and adaptation at the local level (zoning, regulations, and master plan)
- → Encourage integration of climate change into local plans—master plans, hazard mitigation plans, open space/land conservation plans, and regional health assessments
- → Adopt long-range infrastructure investments and improvements into capital improvement plans (CIPs) and maintenance plans and link adaptation strategies with CIP cycles
- → Encourage municipal participation in the FEMA Community Rating System to reduce flood insurance premiums
- → Encourage cooperative agreements among municipalities (for water and sewer services; equipment and inspectional staff/consultants; and integrated transportation, land use, and environment planning)
- → Build community participation and support (warrant articles, budget, and voluntary stewardship)
- → Develop an action plan for regional implementation of recommended actions from the NH Climate Action Plan

[Source: Wake et al., 2014]

Hazard Mitigation Plan Climate Adaptation Chapter – Durham, NH

With assistance from SRPC, the Town of Durham developed a climate adaptation chapter for its Hazard Mitigation Plan to increase the Town's resiliency against coastal hazards and flooding due to sea level rise. The chapter addresses potential impacts and develops options to help protect the Town from risks associated with climate change. The purpose of this project was to conduct research on regional climate change; review how other states and communities are responding to sea level rise; develop maps identifies flood risk areas; develop strategies to protect at risk areas; and identify regulatory and non-regulatory options that can be considered by the Town.

The plan is available at:
http://www.ci.durham.nh.us/sites/default/files/fileattachments/administration/climate_adaption_proposed_plan.doc.pdf

This project was funded in 2013 through the New Hampshire Coastal Program.

Local Climate Action Plan & Climate Resilient Communities Program – Keene, NH

The City of Keene developed and published a Local Climate Action Plan (CAP) in 2004 with goals to lower greenhouse gas emissions by 10% community wide and 20% internally by the year 2015. In 2007, in recognition of the need to develop an adaptation and resiliency planning process, the City participated in a Climate Resilient Communities Program to analyze how the city could adapt to change. This included: conducting a local resiliency study; setting preparedness goals; prioritizing preparedness actions and creating a preparedness plan; implementing the preparedness plan; and monitoring, evaluating, and re-assessing. The City developed a comprehensive list of vulnerabilities to climate change and identified 35 priority measures for inclusion in the City's Preparedness Plan. A key outcome of these efforts was the integration of climate adaptation and climate mitigation into the City's Community Vision and Comprehensive Plan. Lessons learned from undergoing an adaptation analysis include: allow adequate time for development of adaptation plan; work with a climate scientist; utilize local data to the extent possible; reach out to university staff, state planning or department of energy staff, non-profit science organizations, and other organizations with an understanding of climate science; and remember that climate adaptation and climate mitigation are not mutually exclusive.

Remember that climate adaptation and climate mitigation are not mutually exclusive.

For more information see:
http://www.ci.keene.nh.us/sites/default/files/Keene%20Report_ICLEI_FINAL_v2_1.pdf
http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance/climate-resilient-communities-program

Coastal Resilience Initiative - Climate Change Vulnerability Assessment and Adaptation Plan – Portsmouth, NH

In 2005, the City of Portsmouth received $30,000 in funding from the Gulf of Maine Council to conduct a Coastal Resilience Initiative research study led by a team of researchers from the University of New Hampshire and the Rockingham Planning Commission. The team produced a Climate Change Vulnerability Assessment and Adaptation Plan describing the impacts of climate change and sea level rise and possible adaptation measures with associated costs the City can take over to time protect private property and public infrastructure. This report represents a starting point for the City to identify options to implement adaptation measures to increase resiliency in the build environment and protect natural systems. The project integrates adaptation strategies into to the city Master Plan, building codes, and the city's capital improvement plan and other plans, regulations, and policies. Seventeen flood elevation scenario maps were produced as part of this project.

Downtown Portsmouth 18' Flood Elevation Scenario

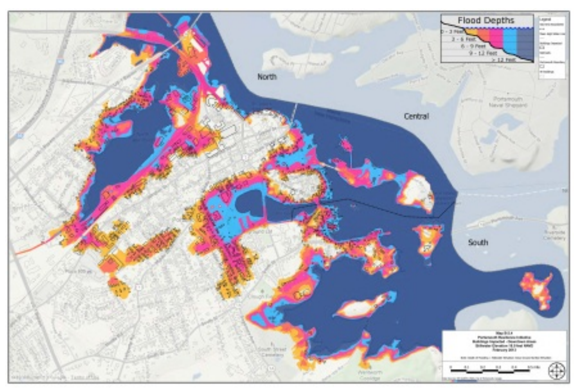


Image credit: Prepare.Protect.Portsmouth.

The plan is available at: http://www.planportsmouth.com/cri/CRI-Report.pdf

This project was funded by the Gulf of Maine Council on the Marine Environment through a grant from the National Oceanic and Atmospheric Administration.

Climate Change Role Play Simulation – Dover, NH

In partnership with the Great Bay National Estuarine Research Reserve Systems and Massachusetts Institute of Technology, the City of Dover hosted a series of events to get Dover residents talking about how the City should respond to risks from climate change. Participants role-played as a city official or resident and negotiated through climate change planning. The goal of this effort was to assess local climate change risks, identify key challenges and opportunities for adaptation, and to test the use of role-play simulations as a means to engage the community about climate change threats while exploring ways of decreasing its vulnerability to climate change impacts.

This project was funded in 2013 by the National Oceanic and Atmospheric Administration through the New England Climate Adaptation Network.

Role Play Simulation, Dover, NH

Image credit: The Crow's Nest

Resources for Communities

Resources, Organizations, and Tools in the Region

A host of regional resources, organizations, and tools are available to guide and support adaptation planning and are identified in Table 9, below. For communities and individuals who seek general information about climate change and adaptation in New Hampshire, guidance on topics including hazard identification, preparedness, and mitigation, current activities and case studies, and more, StormSmartCoasts (nh.stormsmart.org) is an excellent resource and first stop.

Table 9. Resources, organizations and tools to support climate adaptation in the region.

	Organizations & Groups	
Regional Climate Hubs	Announced in early 2014, 7 Regional Climate Hubs will help farmers adapt to climate change while making the case for broader climate regulations. One hub is located at the Northern Research Station of the Forest Service in Durham.	http://www.usda.gov/oce/climate_change/regional_hubs.htm
Capital Area Public Health Network	Information and resources for emergency preparedness and planning. Links to additional resources such as disasterprepped.com.	http://www.capitalareaprepares.com/prepare.html
Center for Climate Preparedness and Community Resilience	Based on experience in research, education, and community engagement in climate-change preparedness and adaptation and in support of the President's Climate Data initiative.	http://www.antiochne.edu/aunenews/new-aune-center-support-new-white-house-climate-data-initiative/
Clean Air Cool Planet/UNH Sustainable Institute	Works collaboratively with campuses, communities and corporations to pioneer and scale-up innovative solutions aimed at reducing carbon emissions and preparing for climate change and works to build support for environmentally effective and economically efficient national policies.	http://cleanair-coolplanet.org/ http://www.sustainableunh.unh.edu/
Climate Adaptation Working Group	A collaboration of nineteen organizations working to help communities in New Hampshire's Seacoast area prepare for the effects of extreme weather events and other effects of long-term climate change. NHCAW provides communities with education, facilitation, and guidance.	http://nh.stormsmart.org/
Climate Solutions New England	An affiliate of the University of New Hampshire Sustainability Institute that promotes regional collaboration toward the goal of greater energy self-reliance and weather resilience that contribute to healthy, prosperous, and sustainable communities across New England. The CSNE Network is organized around four integrated activities: shared vision; research, analysis, communication; planning and implementation efforts; and convening workshops and summits with five core roles: Network, Vision, Analysis, Planning, and Convening.	http://climatesolutionsne.org/
Great Bay National Estuarine Research Reserve	Managed by NH Fish and Game and support by the Great Bay Stewards and part of a national network of protected areas established for long-term research, education and stewardship. Created under the Coastal Zone Management Act, this partnership program between the National Oceanic and Atmospheric Administration (NOAA) and the coastal states protects more than one million acres of the nation's most important coastal resources.	http://www.greatbay.org/

Organizations & Groups		
Keene Cities for Climate Protection Committee	Created in 2000 by the Keene City Council to aid in the reduction of greenhouse gas emissions by assisting the city to implement the adopted climate action plans within the community, as well as to provide public education and outreach and advocate for changes in climate change policy at the State level.	www.ci.keene.nh.us/sustainability/climate-change
NH Sea Grant	A partnership between the University of New Hampshire and NOAA that works to create and maintain a healthy coastal environment and economy. NH Sea Grant connects community leaders to the science-based information, tools and resources they need to reduce vulnerability and increase the resilience of their environmental, social, and economic systems as they are impacted by climate change.	http://www.seagrant.unh.edu/
Ready Strafford Public Health Emergency Preparedness	Provides leadership and coordination to improve the readiness to respond to public health emergencies and threats.	http://nhphn.org/strafford-county-regional-public-health-network/
The Georgetown Climate Center	Provides resources to help communities prepare for climate change, including the Adaptation Clearinghouse, Adaptation Tool Kits, lessons learned, and case Studies.	www.georgetownclimate.org/adaptation/overview
The Infrastructure and Climate Network	Dedicated to accelerating climate science and engineering research in the Northeastern United States. It focuses on climate change and sea level rise impacts and adaptation for sustainable bridges, roads, and transportation networks.	http://theicnet.org
UNH Cooperative Extension	UNH Cooperative Extension brings information and education into the communities of the Granite State to help make New Hampshire's individuals, businesses, and communities more successful and its natural resources healthy and productive. Focus areas include: food and agriculture, community and economic development, natural resources, 4-H youth and families.	http://extension.unh.edu/About-UNH-Cooperative-Extension
Upper Valley Adaptation Workgroup	Building climate resilient communities in the Upper Valley through research, information sharing, and education.	www.uvlsrpc.org/resources/uvaw/

Resources		
American Public Health Association – Climate Change: Mastering the Public Health Role	A guidebook that addresses the challenge of communicating the health impacts of climate change and enhances public readiness to take actions that limit further warming. The guidebook brings together a diverse set of experts to bridge the gap between climate change science and the public health response.	http://www.apha.org/NR/rdonlyres/6B7B9486-E485-4473-8992-B42A73DF95BF/0/ClimateChgGuidebookApril11.pdf
APA Policy Guide on Smart Growth	Describes the benefits of Smart Growth and provides economic benefits, planning structure and process, transportation and land use, fiscal efficiency, social equity and community building, and farmland protection and land conservation outcomes of Smart Growth policies.	https://www.planning.org/policy/guides/pdf/smartgrowth.pdf
City of Portsmouth –	Detailed report that provides the starting point for understanding	http://www.planportsmouth.com/cri/

Resources		
Coastal Resiliency Initiative	the impacts of climate change and offers a number of possible adaptation measures that the City can take over time to protect private property and public infrastructure.	
Climate Adaptation Knowledge Exchange	Aims to build a shared knowledge base for managing natural and built systems in the face of rapid climate change. Features a vast library of concise case studies of climate adaptation from around the country and the world. It also provides links to funding sources for adaptation.	www.cakex.org
Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future Climate Change in Southern New Hampshire: Past, Present, and Future	Carbon Solutions New England report on climate change trends, projects and impacts in the Piscataqua/Great Bay Region and in Southern New Hampshire	http://climatesolutionsne.org/
Cornell Northeast Regional Climate Center Database	Database including a complete collection of historical data for the northeastern U.S. as well as continually updated National Weather Service weather observations and forecasts. Extreme precipitation analysis tool also available.	http://www.nrcc.cornell.edu/ http://precip.eas.cornell.edu/
Climate Data Initiative	Portal for data related to climate change that can help inform and prepare communities, businesses, and citizen. Includes data and resources related to coastal flooding, sea level rise, and their impacts. Overtime this database will be expanded and you will find additional data and tools relevant to other important climate-related impacts, including risks to human health, the food supply, and energy infrastructure.	http://www.data.gov/climate/
EPA Adaptation Strategies Guide for Water Utilities	A guide with climate information drawn primary from the U.S. Global Change Research Program 2009 Report that provides adaptation options for drinking water, wastewater, and stormwater utilities based on the region and projected climate impacts.	http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k13001.pdf
EPA Low Impact Development (LID)	Information about LID, its application and development, and links to fact sheets and reports on LID.	http://water.epa.gov/polwaste/green/
EPA Vulnerability Assessment	Links to reports and assessment on climate change vulnerability assessments case studies of water utility practices, climate estuaries vulnerability assessments, and general information about vulnerability assessments	http://www.epa.gov/ncea/global/vulnerability.html
Extreme Precipitation in New York and New England	Provides an updated extreme precipitation analysis via an interactive web tool.	http://precip.eas.cornell.edu
Federal Highway Administration Integrating Climate Change into the Transportation Planning Process	Design guidelines for assessing risk and vulnerability from climate change effects on transportation infrastructure FHWA Role in Climate Change, including mitigation, adaptation, sustainability, and energy	http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/vulnerability_assessment_pilots/conceptual_model62410.cfm http://www.fhwa.dot.gov/environment/climate_change/

Resources		
Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions	Provides an updated extreme precipitation analysis via an interactive web tool.	www.unh.edu/unhsc/forgingthelink
HomeGrown: The economic impact of local food systems in New Hampshire	Seeks to provide an answer to the question: What are local, healthy foods, and the food system that supports them, worth?	http://foodsolutionsne.org/sites/foodsolutionsne.org/ files/HomeGrownReport_final.pdf
New Hampshire Building Energy Code Compliance Roadmap Report	Maps out New Hampshire's existing energy code landscape, identifies barriers to energy code compliance across the state's residential and commercial building sectors, and presents a plan outlining New Hampshire-specific recommendations for achieving 90 percent energy code compliance by 2017.	www.nhenergycode.com/live/index.php?go=roadmap
New Hampshire Lives on Water	Final report of the New Hampshire Water Sustainability Commission and makes recommendations to ensure that the quality and quantity of New Hampshire's water in twenty-five years is as good as or better than it is today.	www.nh.gov/water-sustainability/publications/ documents/wsc-final-report.pdf
New Hampshire Local Energy Solutions	Provides a gateway to information and resources that promote local energy solutions in New Hampshire. It is intended to empower those on energy committees, in municipalities, and schools to tackle the complexities of reducing our reliance on fossil fuel energy.	www.nhenergy.org
New Hampshire Storm Smart Coast	Provides a well-developed example of a web resource dedicated to helping community decision makers address the challenges of storms, flooding, sea level rise, and climate change. The website also features efforts by the NH Coastal Adaptation Workgroup (NHCAW), a collaboration of nineteen organizations working to help communities in New Hampshire's Seacoast area prepare for the effects of extreme weather events and other effects of long-term climate change. NHCAW provides communities with education, facilitation, and guidance.	http://nh.stormsmart.org
New Hampshire's Changing Landscape	Explores the relationships between population growth, land use change, and the impact of development upon the state's natural resources, including our forest and agricultural lands, critical water supply resources, and biodiversity.	http://clca.forestsociety.org/nhcl/
NH Granit	New Hampshire's Statewide Geographic Information System Clearinghouse. It offers an array of geospatial services, including: data development and distribution, spatial analysis, online mapping (including 100-year flood plain maps), cartography, and related technical services.	http://www.granit.unh.edu
NOAA Coastal Services Center	Social science, geospatial, and training related to coastal issues including the economy, people and resources, climate change and sea level rise, and more. Includes GIS data and online mapping viewer.	http://www.csc.noaa.gov/regions/northeast/

Resources		
Northeast Climate Change Adaptation	Local impacts and adaptation stories	http://nh-journalists.stormsmart.org/local-stories/
US DOT Transportation and Climate Change Clearinghouse	U.S. Department of Transportation website that provides information on transportation and climate change including transportation's role in climate change.	http://climate.dot.gov/about/index.html

Tools		
Adaptation Toolkit for New Hampshire Communities	Provides communities with a path to plan for future extreme weather events.	http://des.nh.gov/organization/divisions/air/tsb/tps/climate/toolkit/index.htm
FEMA Community Rating System	The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.	www.fema.gov/national-flood-insurance-program/national-flood insurance-program-community-rating-system
FEMA National Flood Hazard	National Flood Hazard Layer visible in Google Earth	http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=cbe088e7c8704464aa0fc34eb99e7f30
New Hampshire Office of Energy and Planning-Cost of Sprawl Tool	Has been designed as a decision-support tool for New Hampshire's local and regional planners to evaluate the financial impact on local governments related to new development.	www.costofsprawl.org
ICLEI Climate Pathways	A comprehensive program of tools, training, technical support, and leadership recognition designed to help local governments measure and reduce GHG emissions and energy use	http://www.icleiusa.org/main-page/mount_iclei/iclei/blog/archive/2014/03/19/iclei-launches-climate-pathways-to-help-cities-tackle-carbon-pollution

Implementation

Implementation Process

Local Solutions is a vision and resource for the eighteen communities within the Strafford region. The findings of this plan reflect the 'advisory only' role of Regional Planning Commissions under RSA 36:45, which outlines the Purpose of Commissions and specifically the preparation of a "coordinated plan for the development of the region, taking into account the present and future needs with a view towards encouraging the most appropriate use of land". The RSA further defines the role of the comprehensive plan as that which promotes the "health, safety, morals, and general welfare of the region and its inhabitants" Regional Planning Commissions are also asked to "render assistance on local planning problems" and "make recommendations on the basis of…plans and studies to any planning board." This Plan represents not only a consultative resource for local-decision making, but also a foundation for the future work-planning of Strafford Regional Planning Commission and Strafford Metropolitan Planning Organization. Findings within each appendix shall shape the priorities and goals of this organization. The first step in this process is the identification of specific strategies, extracted from each appendix that fit within the goals created by the Strafford Regional Planning Commission, the Strafford Metropolitan Planning Organization, and Executive Director.

Strafford Regional Planning Commission staff, with the support of the Regional Master Plan Advisory Team, have compiled an comprehensive list of high, medium, and low priority implementation strategies within the following implementation table. These strategies are designed to carry forward the findings and conclusions of this Master Plan and its appendices, as well as provide support functions and build capacity of our regional communities and stakeholders. Each strategy identified in the table below was extracted from a larger list of strategies within each appendix. Thus, these represent the most important (but not always those with the highest priority rating) implementation strategies from each plan appendix. It is important to note that for each strategy identified, Strafford Regional Planning Commission or Metropolitan Planning Organization is the acting or responsible body.

On the following page, please find the implementation table key. This key is intended to provide important information about each field within the table. Such information includes a list of possible values for the field, additional formatting elements, and a description of the field's contents.

Implementation Table Key

Priority Rating

Field Values: *High, Medium, Low*

Field Description: *Represents a qualitative ranking by SRPC staff based on the following weighted factors (weighted as ordered below):*

1. Need
   How great is the need for the strategy

2. Impact
   How large of an impact with the strategy have on stakeholders

3. Feasibility
   How feasible is the strategy from a budgetary and staffing perspective

4. Term
   How long will the strategy take to complete and is the strategy a long, mid, or short term effort

Strategy

Field Values: *(Open Response)*

Field Description: *Includes narrative of the action to be taken by SRPC/SMPO.*

Stakeholder Level

Field Values: *Local, Regional, State*

Field Formatting: **Bold** or *Italic*

Field Description: *Who will a strategy impact.. Primary stakeholder level shall be in bold font, while secondary level(s) shall be italicized.*

Functional Areas

Field Values: *Land Use, Housing, Transportation, Economic, Water Infrastructure, Environment, Climate, Energy, Engagement*

Field Formatting:

● *Primary Functional Area Affected*

○ *Secondary Functional Area(s) Affected*

Field Description: *Strategies may bridge multiple planning areas. The Functional Areas field is an opportunity to identify those connections on both a primary and secondary level. Each strategy shall have only one primary functional area, but may have secondary functionality in multiple appendices.*

Potential Partners

Field Values: *(Open Response) Listed by acronyms, please see Partner Acronym List on following page.*

Field Description: *Identifies a list of potential partners.*

Organizational Capacity

Field Values: *Support the Development of Statewide and Regional Data Systems, Align Data Collection, Performance Measures, and Outcomes with Policy Making, Incorporate Consistency into Plans and Processes, Modernize Planning and Development Tools, Improve Capacity to Use Decision Making and Planning Tools*

Field Description: *SRPC Organizational Goals were drafted by the Strafford Regional Planning Commission Executive Director with guidance from the Strafford Regional Planning Commission Executive Committee. These values represent long term organizational goals.*

Table 10: Partner Acronym List

Partner Acronym	Full Partner Name
CAW	Climate Adaptation Workgroup
CEDS Committee	Comprehensive Economic Development Strategy Committee
CSNE	Carbon Solutions New England
DRED	New Hampshire Department of Resources Economic Development
EDA	Economic Development Administration
EMD	Emergency Management Director
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
ICNET	Infrastructure and Climate Network
GBNERR	Great Bay National Estuarine Research Reserve
GRANIT	Geographically Referenced Analysis and Information Transfer System
HEAL	Healthy Eating Active Living
NHDA	New Hampshire Department of Agriculture
NHDES	New Hampshire Department of Environmental Services
NHDOT	New Hampshire Department of Transportation
NHDPS	New Hampshire Department of Safety
NHEDA	New Hampshire Economic Development Association
NHFG	New Hampshire Fish and Game
NHHFA	New Hampshire Housing Finance Authority
NHHSEM	New Hampshire Homeland Security and Emergency Management
NHOEP	New Hampshire Office of Energy and Planning
NOAA	Nation Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Services
PREP	Piscataqua Region Estuaries Partnership
RPC	Regional Planning Commission
SAU	School Administrative Unit
SPNHF	Society for the Protection of New Hampshire's Forests
SWA	Southeast Watershed Alliance
TNC	The Nature Conservancy
UNH	University of New Hampshire
UNH T2	University of New Hampshire Technology Transfer Center
UNHCE	University of New Hampshire Cooperative Extension
UNHSC	University of New Hampshire Stormwater Center
USACE	United States Army Corps of Engineers
VHB	Vanasse Hangen Brustlin
WHCGS	Workforce Housing Coalition of the Greater Seacoast

Priority Rating*	Strategy	Stakeholder Level	Functional Areas*									Potential Partners					
			Land Use*	Housing	Transportation	Economic	Water Infrastructure	Environment	Climate	Energy	Engagement		Support the Development of Statewide and Regional Data Systems	Align Data Collection, Performance Measures, and Outcomes with Policy Making	Incorporate Consistency into Plans and Processes	Modernize Planning and Development Tools	Improve Capacity to Use Decision Making and Planning Tools
High	Integrate climate change adaptation planning into master plans and existing planning documents such as hazard mitigation plans and capital improvement plans.	**Local** *Regional*	◦	◦	◦	◦	◦	◦	•	◦	◦	Planning Board, NHOEP, NHDES, NHHSEM, EMDs		x	x	x	x
High	Provide technical guidance for assessing vulnerability and assistance with developing vulnerability maps.	**Local**	◦	◦	◦		◦	◦	•	◦		Municipalities, NHOEP, NHDES, NHHSEM, Climate Solutions New England, NOAA	x	x	x	x	x
High	Collaborate with county public health departments to increase community awareness of the health impacts of climate change.	**Local** **Regional** **State**							•		◦	County Health Departments, HEAL, Schools Districts, NHDPS	x				
High	Integrate climate change adaptation and mitigation into projects and planning.	**Local** *Regional*	◦	◦	◦	◦	◦	◦	•	◦	◦	Planning Department	x	x	x	x	x
High	Ensure communities have access to resources, tools, information, and support.	**Local** *Regional*							•		◦	Municipalities, UNH Cooperative Extension, County Health Departments, School Districts, Libraries, community groups and organizations, NH Listens, Rotary Clubs	x				x
High	Develop a regional, watershed wide strategy for upgrading and adapting culverts to future flood level risk.	**Regional** *Local*	◦				◦	◦	•			Municipalities, PREP, NHDES, EMDs	x	x	x	x	x

Priority Rating*	Strategy	Stakeholder Level	Functional Areas*: Land Use*	Housing	Transportation	Economic	Water Infrastructure	Environment	Climate	Energy	Engagement	Potential Partners	Support the Development of Statewide and Regional Data Systems	Align Data Collection, Performance Measures, and Outcomes with Policy Making	Incorporate Consistency into Plans and Processes	Modernize Planning and Development Tools	Improve Capacity to Use Decision Making and Planning Tools
High	Use best available data (FIRMs, precipitation data, climate science, local projections, etc.).	**Local** **Regional** *State*	○	○	○	○	○	○	●	○	○	Climate Solutions New England, FEMA, NOAA, EPA, PREP, GRANIT	x	x		x	x
Medium	Assist communities with identifying opportunities to increase resilience to change and 'no-regrets' projects and that enable decision making, action, and rationalization of investment given the range of uncertainties. Encourage communities to identify projects and policies that address both climate change adaptation and mitigation.	**Local**				○	○	○	●	○	○	Municipalities, UNH Stormwater Center, NHOEP, NHHSEM, EMDs		x	x	x	x
Medium	Identify projects and funding for projects that increase communities' resilience to climate change.	**Local** *Regional*							●			Municipalities, NHDES, Rotary Clubs					
Medium	Convene a panel of experts and host an educational workshop for public works facility managers and municipal staff on potential climate change impacts to infrastructure and key facilities, and identify opportunities to collaborate across the region.	**Local** *Regional* *State*			○		○	○	●	○		Public Works Departments, NHDES, NHOPE, NHDOT, Climate Solutions New England, ICNET	x	x		x	x
Medium	Work with regional and local partners to identify key land conservation priorities that will increase local resilience, increase carbon sequestration, and protect vulnerable flora and fauna	**Regional** *State*	○			○		○	●		○	NH Fish and Game, NH Forest Service, NH Society for the Protection of Forests, Conservation Commissions, TNC, GBNEER, land	x		x		x

Priority Rating*	Strategy	Stakeholder Level	Functional Areas*									Potential Partners					
			Land Use*	Housing	Transportation	Economic	Water Infrastructure	Environment	Climate	Energy	Engagement		Support the Development of Statewide and Regional Data Systems	Align Data Collection, Performance Measures, and Outcomes with Policy Making	Incorporate Consistency into Plans and Processes	Modernize Planning and Development Tools	Improve Capacity to Use Decision Making and Planning Tools
												conservancies					
Low	Increase online outreach and climate change education. Add climate change impacts and adaptation information to SRPC website and feature articles in newsletter.	**Local** **Regional**							•		○	Climate Adaptation Workgroup, NH Listens, Municipalities					x
Low	Develop guidance for incorporating the concept of ecosystem services into municipal education to workshops to increase resiliency.	**Local** *Regional* *State*				○		○	•		○	PREP, GBNEER, UNH Cooperative Extension, NHDES, Conservation Commissions		x	x	x	x
Low	Host a workshop to educate municipalities about FEMA's Community Rating System	**Local**		○		○	○	○	•		○	NHOEP, Planning Department, EMDs					
Low	Create a GIS-based flood impacts database to document and track: vulnerable and under capacity culverts; dam breaches or failure; flood damage to infrastructure.	**Local** **Regional**					○	○	•			Municipalities, PREP, UNH students, GRANIT	x	x	x	x	x
Low	Coordinate with OEP and RPCs to develop model decision trees to guide infrastructure management decisions under climate change (tools may include abandonment, insurance cost increases, altering culvert sizes, financial incentives, etc.).	**Local** *Regional*	○	○	○	○	○	○	•	○	○	RPCs, Public Works Departments, NHOEP, NHHSEM, NOAA, FEMA, EMDs		x	x	x	x

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