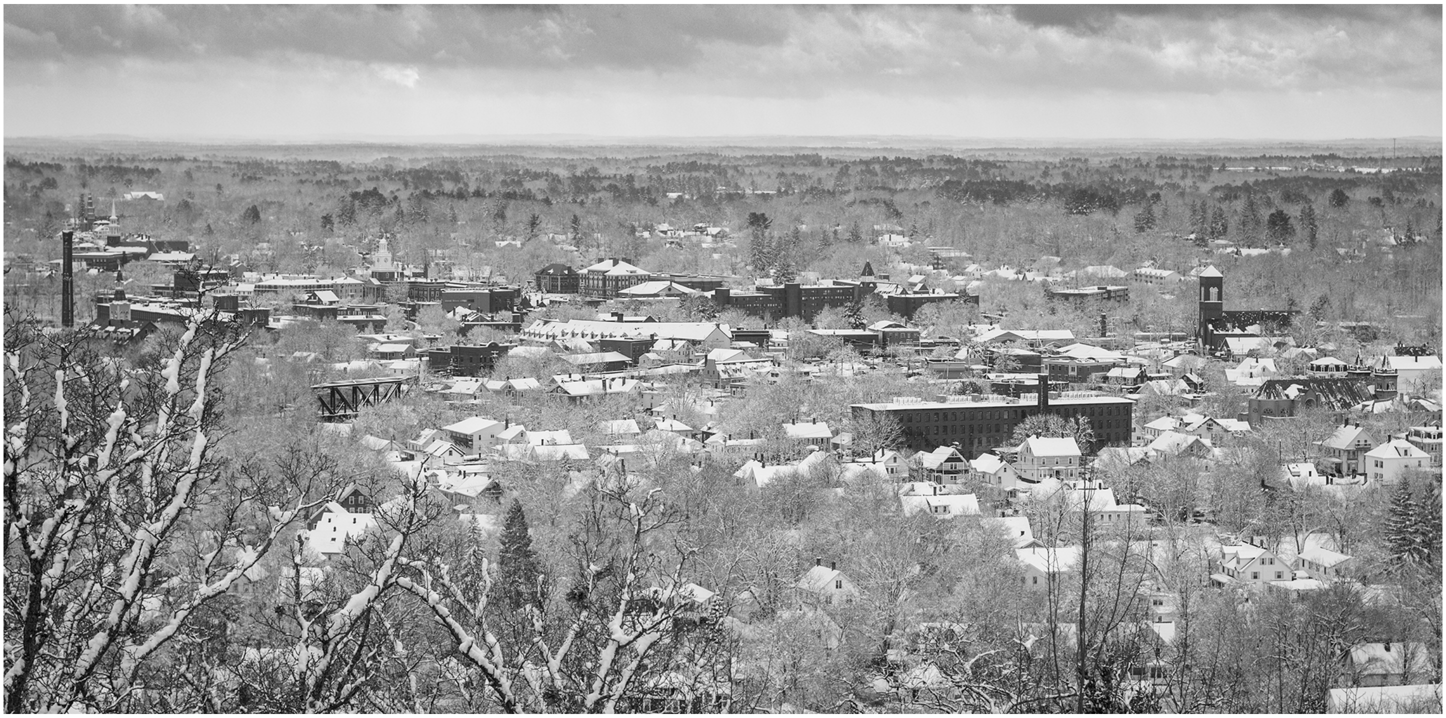
New England
Climate Adaptation
PROJECT



Summary Climate Change Risk Assessment
Dover, New Hampshire

March 2014

PRODUCED BY:
Massachusetts Institute of Technology Science Impact Collaborative
Consensus Building Institute
National Estuarine Research Reserve System

Acknowledgements

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About the MIT Science Impact Collaborative

The Massachusetts Institute of Technology Science Impact Collaborative (MIT SIC) is a research group focused on developing and testing new ways of harmonizing science, politics and public policy in the management of natural resources and resolution of environmental disputes. MIT SIC's tools and approaches include collaborative adaptive management, joint fact-finding, scenario planning, collaborative decision-making, multi-stakeholder engagement, and role-play simulation exercises.

MIT SIC was established in 2003 with initial support from the United States Geological Survey. Today, the research group has numerous partners and supporters, ranging from the U.S. National Estuarine Research Reserve System to the Dutch research organization TNO. By engaging in community-based action research projects, MIT SIC researchers—including doctoral students, masters students, and faculty from the MIT Department of Urban Studies and Planning—train emerging environmental professionals while simultaneously testing the latest environmental planning methods and providing assistance to communities and policy-makers who seek their help.

Visit the MIT Science Impact Collaborative website for more information:
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About the Consensus Building Institute

The Consensus Building Institute (CBI) is a not-for-profit organization founded in 1993 by leading practitioners and theory builders in the fields of negotiation and dispute resolution. CBI's experts bring decades of experience brokering agreements and building collaboration in complex, high-stakes environments — and possess the deep understanding required to tackle negotiation and collaboration challenges in their practice areas. CBI's founder, managing directors, and many of their board members are affiliated with the Program on Negotiation at Harvard Law School and the MIT-Harvard Public Disputes Program.

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About the Great Bay National Estuarine Research Reserve

The National Estuarine Research Reserve System (NERRS) is a network of 28 areas representing different biogeographic regions of the United States that are protected for long term research, water-quality monitoring, education, and coastal stewardship. The reserve system is a partnership program between the National Oceanic and Atmospheric Administration (NOAA) and the coastal states. Reserve staff work with local communities and regional groups to address natural resource management issues, such as climate change, non-point source pollution, habitat restoration, and invasive species. Through integrated research and education, the reserves help communities develop strategies to deal successfully with these coastal resource issues. Reserves provide adult audiences with training on coastal and estuarine issues of concern in their local communities. They offer educational programs for students, teachers, decision-makers, and community members. Reserves also provide long term weather, water quality, and biological monitoring as well as opportunities for scientists and graduate students to conduct research in a “living laboratory.”

The Great Bay National Estuarine Research Reserve in New Hampshire works to expand knowledge about coasts and estuaries, engage people in environmental learning, and involve communities in conserving natural resources, all with the goal of protecting and restoring coastal ecosystems around the New Hampshire coast. The Great Bay Reserve was established in 1989 and is managed by the New Hampshire Fish and Game Department. The Reserve is also supported by the Great Bay Stewards, a non-profit friends group. Visitors are encouraged to explore the natural beauty of the Great Bay Estuary and discover New Hampshire’s hidden coast.

Visit the Great Bay National Estuarine Research Reserve for more information:
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Executive Summary

Dover faces several climate-related risks, the most notable being the risk of increased flooding along the Bellamy and Cochecho Rivers stemming from more intense precipitation events and sea level rise. In addition to flooding, heat waves are also expected to become more frequent and severe, groundwater supplies may become less reliable, and changing temperatures and precipitation patterns may significantly impact local and regional ecosystems. These risks, if not managed and prepared for, could threaten Dover's population, buildings, infrastructure, landscapes, and ecosystem health. While Dover has improved its physical infrastructure and services in response to related historical climate events, there is much more that can and needs to be done.

This Summary Risk Assessment presents how the climate could change in Dover over the 21st century, and outlines the city's key climate change risks as well as possible adaptation options to address those risks. This assessment was developed by the New England Climate Adaptation Project with the primary objective of providing targeted content for a role-play simulation exercise for Dover residents. While the information gathered by this project alone is not sufficient to guide Dover's planning and adaptation efforts, it may begin to inform local officials and city residents about potential future climate risks and adaptation options. Dover could benefit from a more detailed vulnerability assessment.

This report consists of two sections. Section 1 outlines potential future climatic conditions of Dover based on climate change projections downscaled to the nearest meteorological station in Durham, New Hampshire, including historical and future trends for temperature and precipitation. Sea level rise projections are based upon the tidal gauge in Portsmouth, New Hampshire. Climate change projections are presented for two scenarios—a high emissions scenario and a low emissions scenario—which are used to represent uncertainty concerning the amount of future global greenhouse gas emissions. Projections are presented in terms of three time scales -- short term (2010-2039), medium term (2040-2069), and long term (2070-2099) -- to capture change over time. The historical baseline refers to the time period between 1980 and 2010.

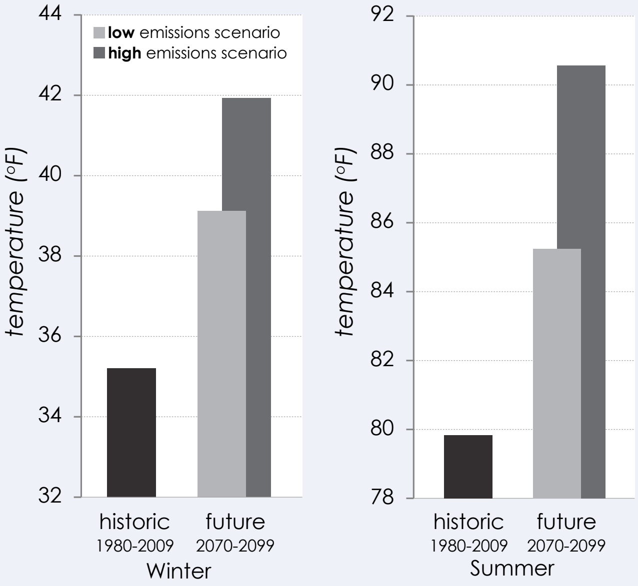
Section 2 discusses how future climatic changes (including those in temperature, precipitation, and sea level) combine with other factors (such as built environment, economics, demographics, and natural context) to create integrated risks and increased vulnerability for Dover. This section also provides a sample of adaptation methods that Dover might undertake to address each type of vulnerability. Vulnerabilities and adaptation options were developed based on input from city officials and the city's experience with past climate-related issues, as well as review of published documents, such as the Dover Hazard Mitigation Plan. Examples of adaptation options Dover might consider include moving residences and businesses out of floodplains, increasing flood insurance, protecting and enhancing natural areas, securing additional water supply sources, and investing in cooling centers.

Even though some climate change impacts seem to be a long way off, many adaptation measures may take years of planning, coordination, and investment in order to come to fruition. Additionally, the choices and investments Dover makes today will either increase or decrease the city's vulnerability to current and future climate-related risks. Dover can increase its resilience in the face of a changing climate, but doing so will require that residents, business owners, and local and regional agencies work together and begin preparing for a changing climate now rather than waiting to confront the challenge after the damage has been done.

What do climate projections tell us about Dover by the end of the century?

Hotter Annual Temperatures. In the long term, average annual maximum temperatures could increase between 4.6 and 9.0°F.

Average Daily Highs (*max temp*)

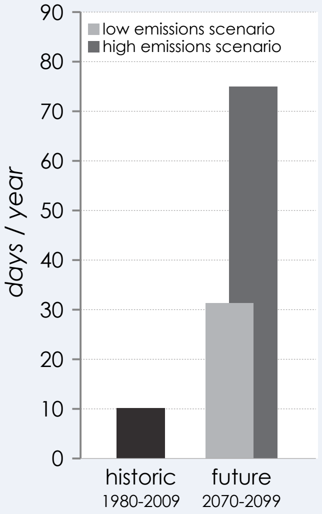


Warmer Summer Evenings. Climate change will have a greater warming influence on nighttime minimum temperatures than daytime maximum temperatures, both of which will increase. Especially in the long term, summer nights will not cool down as much as they did in the past.

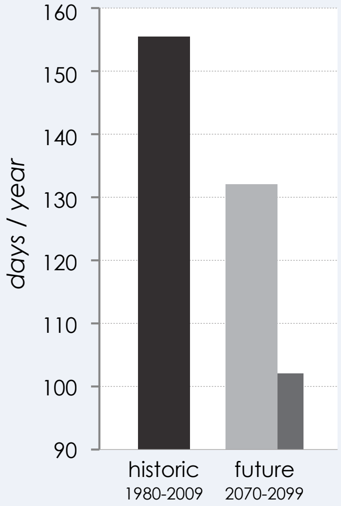
Outdoor summer movies

More Extreme Heat Events. Less Extreme Cold Events. Dover will likely experience more extreme heat events (days where temperatures rise above 90°F) and fewer extreme cold events (days where temperatures drop below 32°F). Under the high emissions scenario, Dover could experience over 6 times more extreme heat events per year than during the historical baseline period, increasing from 10 days to 65 days per year. High emission scenario projections further indicate that the city could experience one third fewer extreme cold events per year by the end of the century.

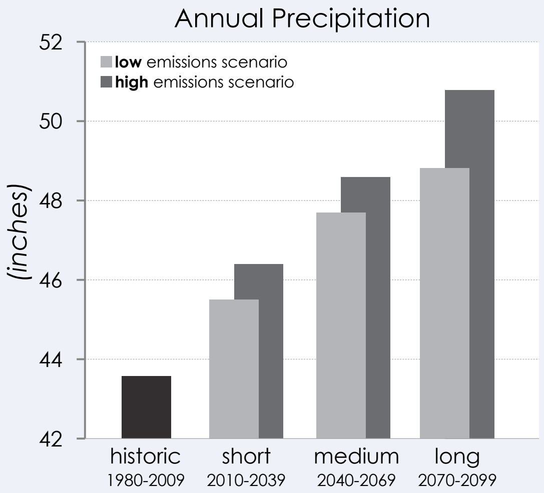
Days of Extreme Heat (>90°F)



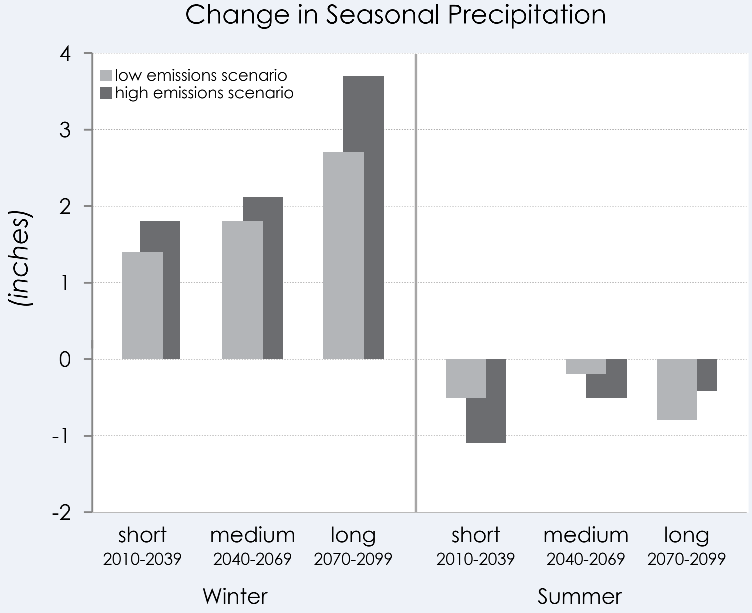
Days of Extreme Cold (<32°F)



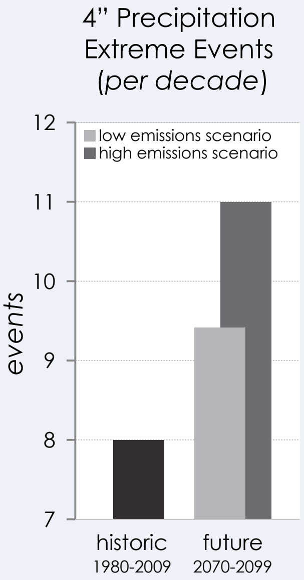
More Annual Precipitation. Over the long term, Dover may see as much as 7.2 additional inches of annual precipitation, on average.



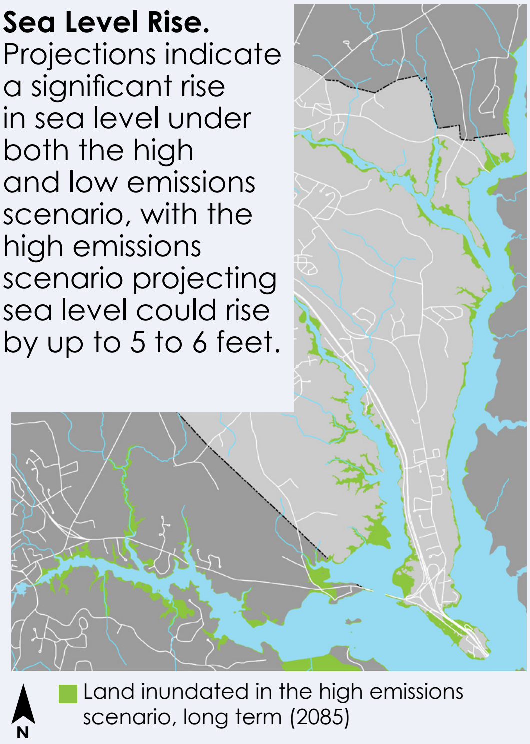
Wetter Winters. Drier Summers. Winters in Dover are expected to become much wetter. Over the long term, Dover may see a 44% increase in precipitation during the winter season under the high emissions scenario. Conversely, summers are projected to become slightly drier.



More Extreme Precipitation Events. The number of events where 4" of precipitation falls in 48 hours is projected to increase by 3 additional events per decade under the high emissions scenario, for a total of 11 events per decade.



Sea Level Rise. Projections indicate a significant rise in sea level under both the high and low emissions scenario, with the high emissions scenario projecting sea level could rise by up to 5 to 6 feet.



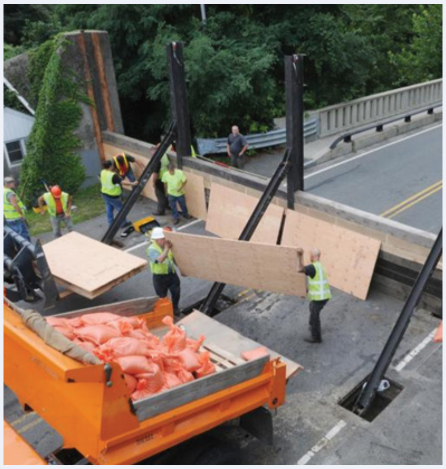
🟩 Land inundated in the high emissions scenario, long term (2085)

What are the major risks for Dover and what can be done?

Flooding

Increased riverine flooding is expected to be the greatest climate change risk in Dover. The probability of flooding along Dover's Bellamy and Cochecho Rivers will likely increase in the future with increased frequency of extreme precipitation events, reduced winter snowpack, and wetter winters. Most of Dover lies 80 feet above sea level, which means it is not directly at risk from sea level rise. However, higher sea levels and storm surge may increase flooding because they can block drainage from the rivers into the ocean, thus causing the rivers to rise. These effects would take place along the Bellamy and downstream from the Central Ave dam on the Cochecho River. In addition, sea level rise is projected to increase the coastal hurricane inundation area, as the storm surge would arrive above elevated sea levels. The risk of river flooding may be further heightened by an increase in development and related increase in impermeable surfaces, which would lead to additional stormwater runoff.

Examples of Adaptation Options



Floodwalls
ex: New Hampshire

Flood Resilient Building Design
ex: Providence, RI

Wetland Restoration
ex: Woonasquatucket,RI

Heat Waves

Dover is likely to see a rise in public health problems associated with heat-related illnesses and invasion of pests as year round temperatures rise and Dover experiences more frequent heat waves. More frequent and prolonged heat waves can also damage electrical equipment and create additional pressures on sensitive ecosystems. While warmer winter temperatures may result in less snow accumulation, which could reduce winter maintenance costs, the overall negative impacts of increased temperatures are likely to outweigh the benefits.

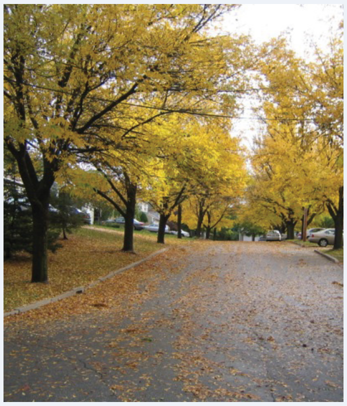
Water Supply

Dover's supply of water comes from eight city wells that draw on four aquifers (City of Dover, 2013). Projected climate changes, including warmer summer temperature, reduced summer precipitation, reduced snowpack accumulation, and rising groundwater levels due to sea level rise may make Dover's water supply unreliable in the future. Warmer summer temperatures may lead to higher rates of evapotranspiration reducing the amount of water that is available to recharge Dover's aquifers. Reduced summer precipitation and snowpack accumulation can further stress spring and summertime inputs, reducing aquifer recharge. When combined over several years, these conditions may result in a decrease in Dover's water supply. In addition, sea level rise may function to raise groundwater levels, particularly if there is less recharge. The intrusion of seawater into Dover's aquifers may change the water quality by, for example, increasing the salinity of the water.

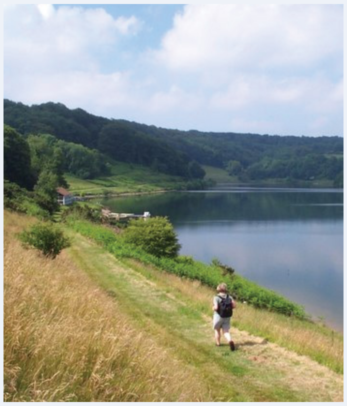
Ecosystem Impacts

Dover is home to diverse habitats within its rivers, forests, and estuaries. Warmer temperatures could affect the wildlife in the waterways and upland areas of Dover. For example, streams and ponds could become too warm to support native fish species. Increased climatic pressures could also increase many species' susceptibility to disease, such as forests that could become move vulnerable to pest outbreaks. Increased flooding along the Bellamy and Cochecho may inundate conservation areas including the Bellamy River Wildlife Management Area and Bellamy Preserve. Further, rising sea waters may change the biochemistry of waters, altering coastal habitat conditions.

Examples of Adaptation Options



Tree Canopy
ex: Providence, RI



Additional Reservoir
ex: West Hartford, CT

Vegetated Waterways
ex: Barnstable, MA

Section 1: Future Climate in Dover

This section highlights temperature and precipitation projections that have been downscaled for Dover, NH, from the nearest meteorological station in Durham, NH. Statistical downscaling translates coarse global climate model projections to the spatial scale of local weather station observations (Stoner et al., 2012). This is done by quantifying historical relationships[1] between large-scale weather features and local patterns. Two irreducible uncertainties govern the use of multiple projections in estimating future change. The first is the sensitivity of the climate to increased atmospheric concentration of CO_2, which is addressed through the use of multiple computational models. The second is predicting how much CO_2 and other greenhouse gases will be emitted over the next century, which is addressed through using multiple emissions scenarios. In order to capture the full range of future climate changes that Dover might experience during the 21st century, this project looks at the projections of four global climate models (GFDL, HdCM3, PCM and CCSM3) and two Intergovernmental Panel on Climate Change (IPCC) emissions scenarios (A1fi reflecting the highest projections of emissions and B1 reflecting the lowest projections of emissions) (Figure 1). Projections are presented in

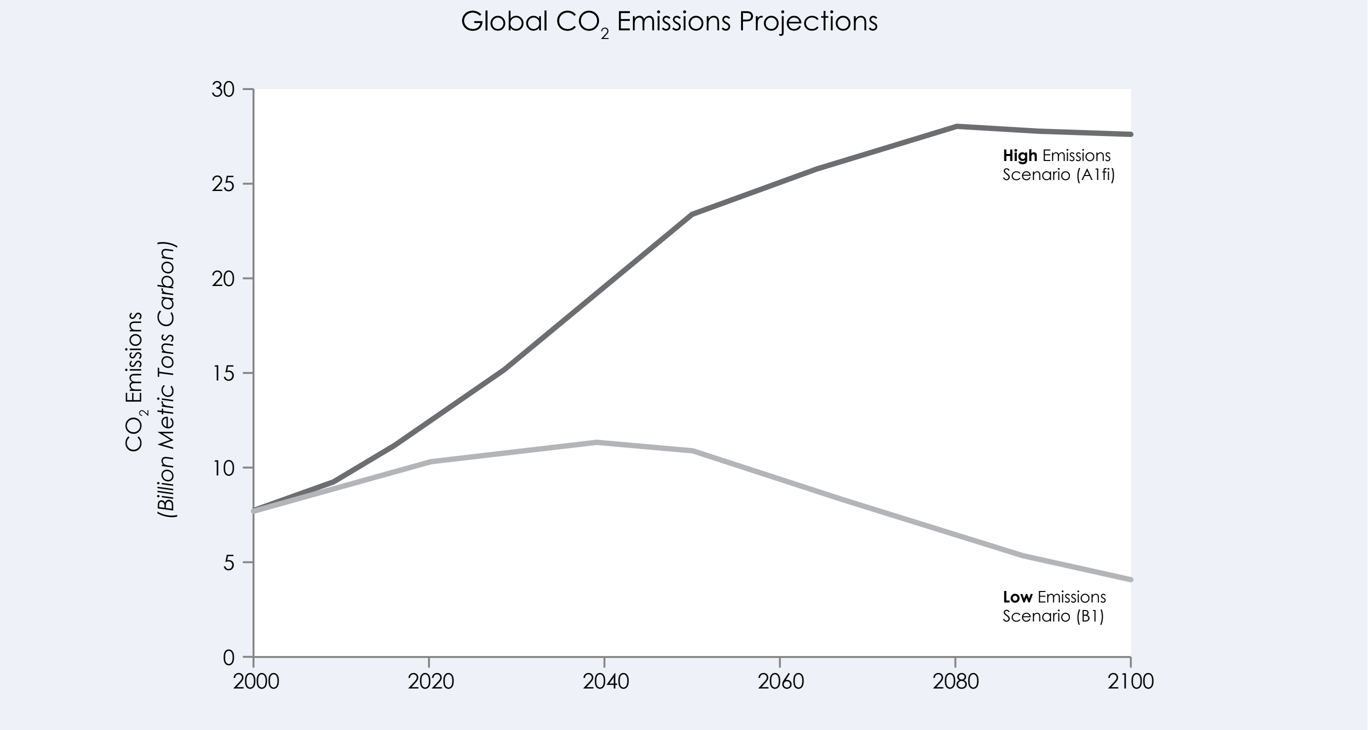


Figure 1. Global CO_2 Emissions Projected over a Century for High and Low IPCC Scenarios

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[1] It is worth noting that the historical period represents a relatively short and recent series of data relative to the period of anthropogenic greenhouse gas emissions – namely 1980-2009. That is, the historical period does not represent an era "pre-climate change," but is instead a baseline created due to available record-keeping. As an example, the New York Panel on Climate Change 2013 report states that for each decade between 1900 and 2011, the annual mean temperature rose by 0.4° Fahrenheit, precipitation increased by 0.7 inches, and sea level rose by 1.2 inches.

terms of three time scales—a short term (2010-2039), medium term (2040-2069), and long term (2070-2099)—to capture change over time. A full description of the statistical downscaling methodology used for this report is provided in Appendix 1. Sea level projections are produced through statistical analysis of the relationship between global temperatures and sea level rise.

Temperature

Average Daily Temperatures

The average temperature in Dover is projected to increase over the next century (Figure 2). This change is exhibited through increases in both the daily low temperatures (minimum) and daily high temperatures (maximum). The high emissions scenario (A1fi) corresponds with larger and faster temperature increases as compared to the low emissions scenario (B1). Average daily lows are expected to increase between 3.6 to 5.6°F by midcentury (2040-2069) based on the low and high emissions scenarios, respectively (Figure 3a). By the end of the century (2070-2099), average daily lows may increase by as much as 9.0°F under the high emissions scenario—a 25% increase. Under the high emissions scenarios, daily maximum temperatures are expected to increase by nearly identical values: 3.8 to 5.8°F in the medium term and up to 9.0°F in the long term (Figure 3a).

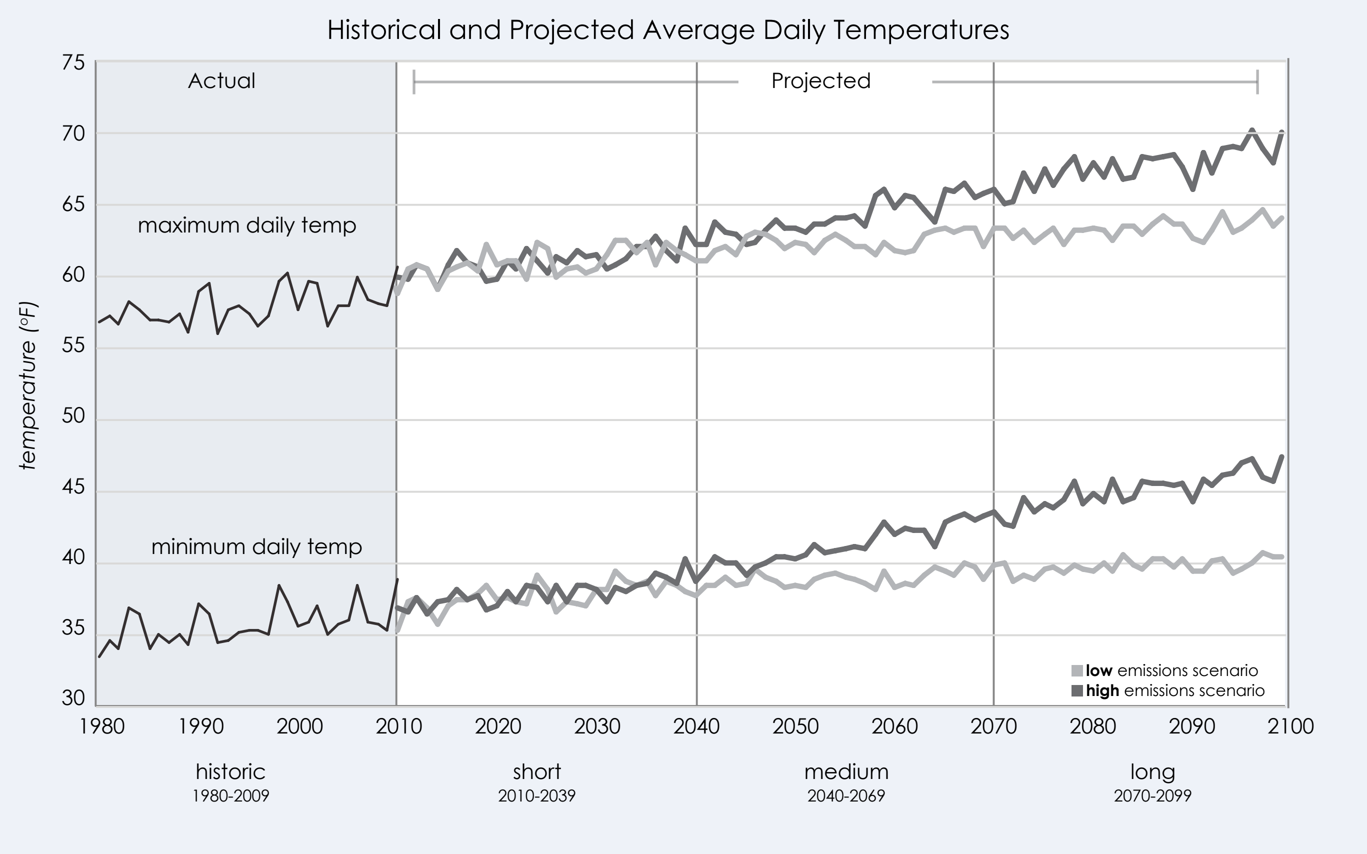
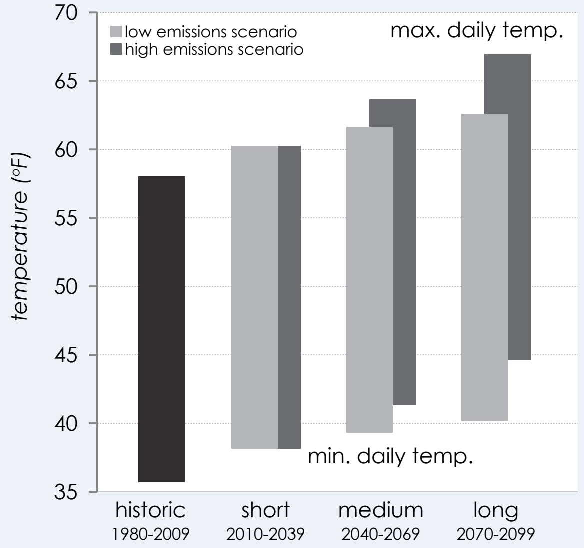


Figure 2. Historical (Actual) and Future (Projected) Daily Temperatures for Dover Based on Different CO_2 Emissions Scenarios and Timeframes

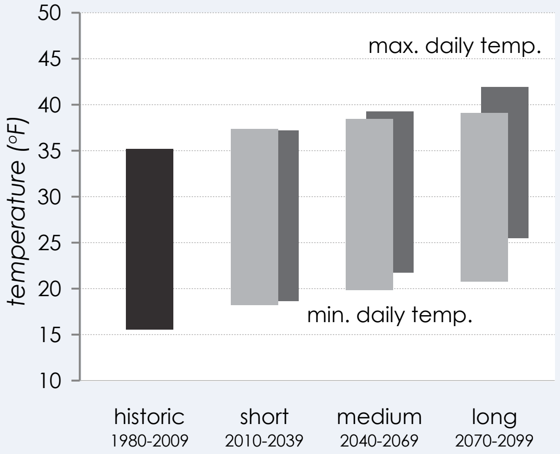
Seasonal Highs and Lows

Both summer and winter average daily temperatures are projected to increase over the next century. This includes both minimum and maximum temperatures. The projections indicate that climate change is likey to have the greatest influence on minimum winter temperatures, meaning that, especially in the long term, winters may not be as cold as they were in the past. This change is expected to result in fewer very cold nights and less snow accumulation. In the long term (2070-2099), winter minimum temperatures may increase by between 5.3 and 9.9°F, a 63% increase from a historical baseline of 15.6°F (Figure 3b). Winter maximum daily temperatures are also projected to increase from a historical baseline of 35.2°F to as much as 42°F under the high emissions scenario by the end of the century. Projections indicate that summer nights may similarly not cool down as much as they have in the past. By the end of the century, summer minimum daily averages in Dover will potentially increase by 4.7 to 9.0°F (Figure 3c). Summer maximum daily averages may increase by 5.4 to 10.7°F, raising the average daily high in the summertime to nearly 90.5°F under the high emissions scenario (Figure 3c).

a) Average Daily Temperature Range



b) Average Winter Daily Temp. Range



c) Average Summer Daily Temp. Range

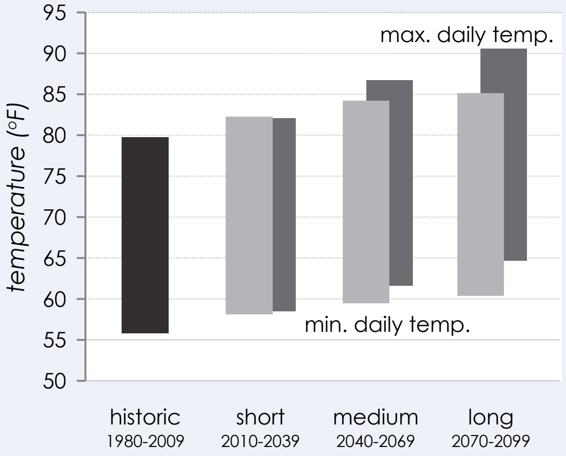


Figure 3. Future Average Daily Lows and Highs as Compared to Historical Baseline

Extreme Temperature

The most dramatic change in temperature likely to occur in Dover over the next century is an increase in the number of extreme heat events where daily temperatures rise above 90°F. Historically (1980-2009), Dover experienced an average of 10 extreme heat days a year. By the end of the century, under the high emissions scenario, Dover may see as many as 72 days a year where temperatures exceed 90°F. Under the low emissions scenario this number might be as high as 31 days (Figure 4a). In addition, in the long term, Dover is projected to see a reduction in the number of extreme cold events (below 32°F) from 155 to 102 days per year under the high emissions scenario (Figure 4b).

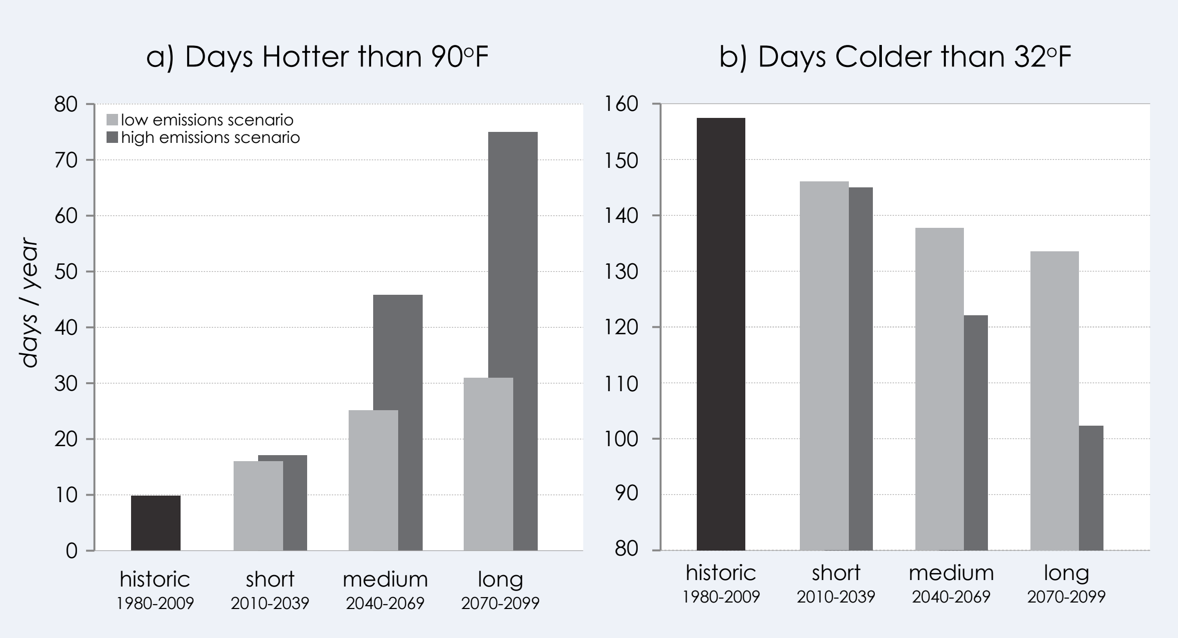


Figure 4. Extreme Temperature Events

Table 1. Potential Impacts of Higher Temperatures

Change	Potential Impacts of Higher Temperatures
↑	**Health impacts:** Extended and magnified heat events will increase risk of heat strokes, air pollution, and vector borne diseases.
↑	**Infrastructure damages:** Extreme heat and heat waves may damage roads and electricity transformers.
↓	**Water supply:** Higher temperatures will result in more precipitation falling as rain rather than snow. Snowpack functions as a natural reservoir to store water outside of manmade reservoirs for drinking water supply. The reduction of snowpack may reduce spring and early summer supplies. Higher average temperatures can also be associated with increased evaporation and transpiration which could further reduce water availability.
↓/↑	**Agriculture productivity:** Higher temperatures may cause a longer growing season, supporting agricultural benefits in crop production. Higher temperatures could also harm agricultural crops that are not suited for higher temperatures.
↑	**Ecosystem stress:** Higher temperatures can cause populations and habitats to migrate to lower temperature areas (high elevation or higher latitude), where possible. Ecosystems that cannot migrate or adapt to changing climatic conditions may degrade or collapse.
↓	**Snow removal costs:** Governments and property managers may be able to reduce their budgets for snow removal due to fewer extreme cold days.
↓/↑	**Heating and air conditioning bills:** People may save money if the warmer winter temperatures enable them to reduce the amount of energy needed to heat buildings. Conversely, higher summer temperatures may lead to higher air conditioning costs.

Precipitation

Average Daily Precipitation

There is high variability in average annual precipitation, both historically and in future projections (Figure 5). Comparing an average historic baseline (1980-2009) to short term, medium term, and long term averages more clearly reflects precipitation trends (Figure 6). The projections show little change in average annual precipitation in the short term (Figure 6). In the medium and long term, however, both the low and high emissions scenarios show an increase in precipitation (Figure 6). In the long term, the high emissions projections indicate average annual rainfall could increase by 7.2 inches annually, a 17% increase over the baseline.

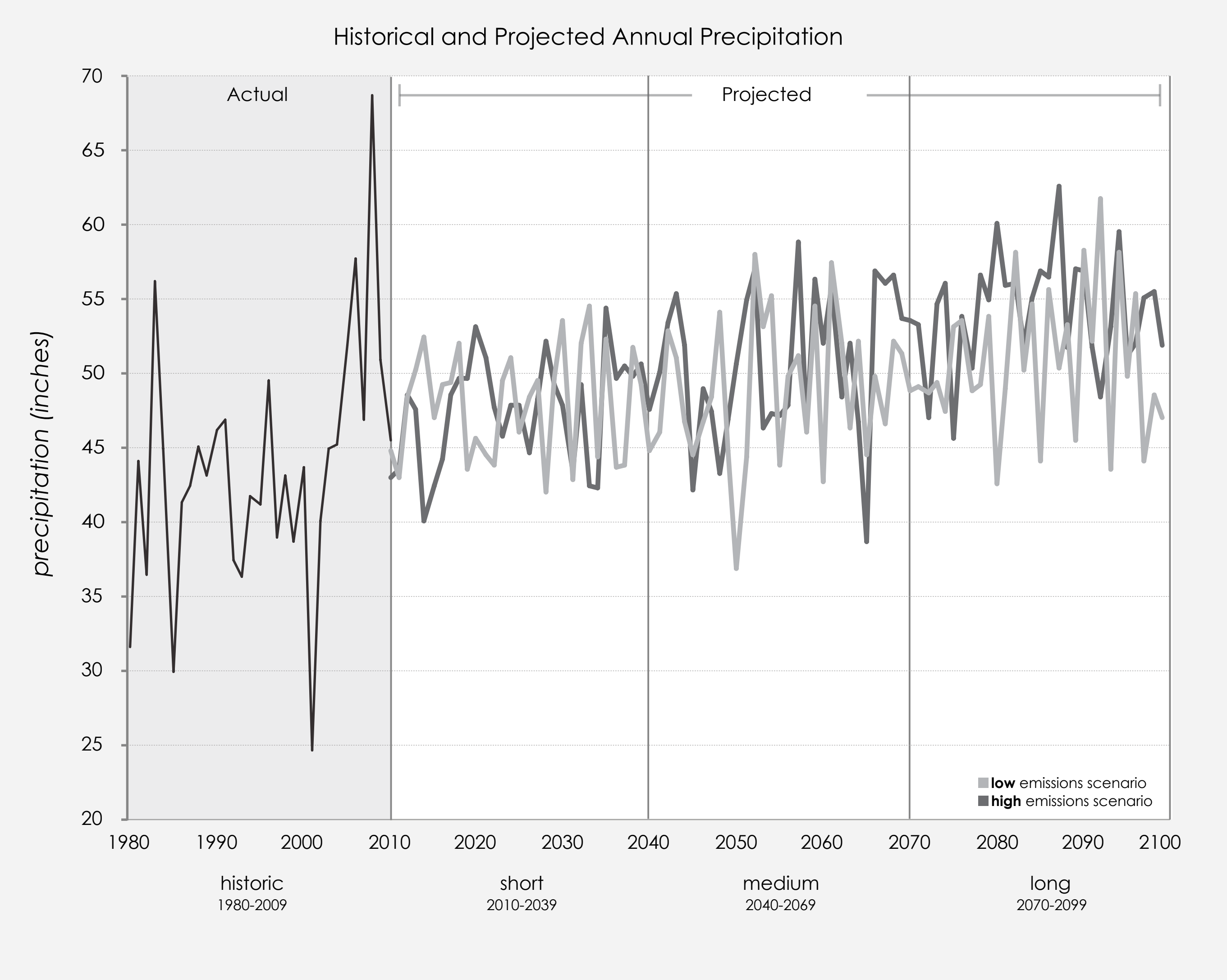


Figure 5. Historical and Future Average Annual Precipitation Trends

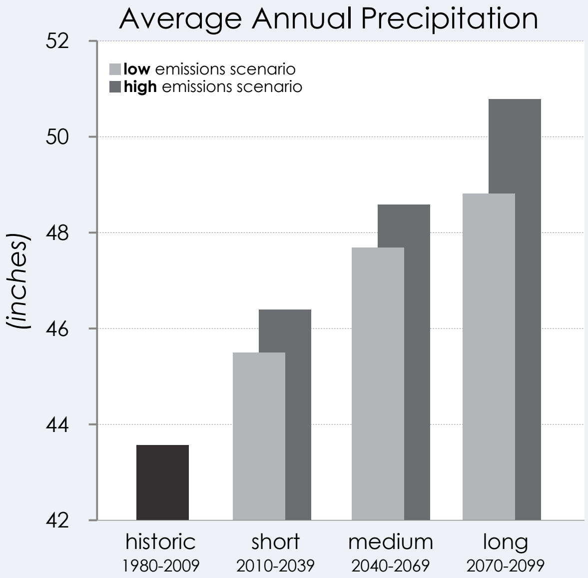
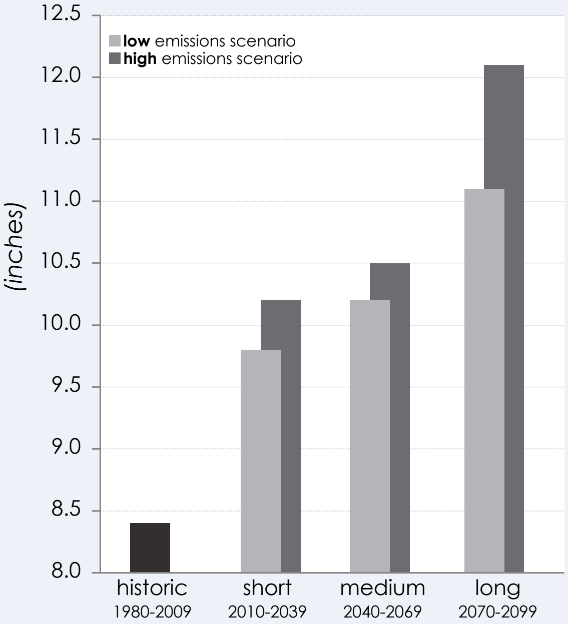
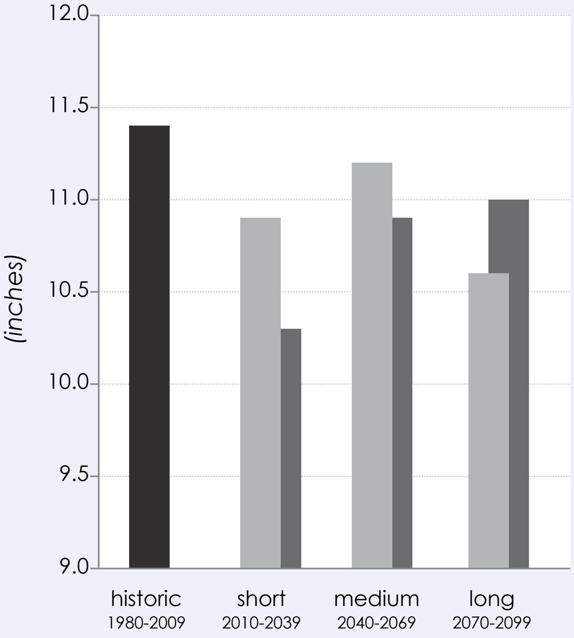


Figure 6. Comparison of Historical to Short, Medium, and Long Term Average Annual Precipitation Projections



a) Winter Average Precipitation



b) Summer Average Precipitation

Figure 7. Seasonal Precipitation Pattern

Seasonal Precipitation

Seasonal projections show that, while winters may become significantly wetter, summers may actually become drier. In Dover, there is more precipitation in the summer than in the winter. However, winter precipitation is predicted to increase by 2.7 to 3.7 inches– as much as a 44% increase over the historical average of 8.4 inches (Figure 7a). Summer precipitation is projected to decrease in the short, medium, and long term under both scenarios. Over the next century, summer precipitation may decrease between 0.2 to 1.0 inches from a historic baseline of 11.4 inches (Figure 7b).

Extreme Precipitation Events

Dover is expected to see more extreme precipitation events, which are characterized by storms with heavy precipitation falling within a short time interval. Extreme precipitation events are a key driver of flooding in Dover, so this projected increase could have significant impacts on flooding risk in the area. Dover is projected to double the number of annual events where 2" of precipitation falls within 24 hours, from a historic value of 4.4 events to between 7.7 and 9.3 events in the long term. Dover is also projected to increase the number of events where 4" of precipitation falls in 48 hours. Historically, Dover experienced 8 of these events per decade. In the short term, the number of these events may actually decline, but in the long term Dover is projected to see an increase of 3 additional events per decade under the high emissions scenario, for a total of 11 events per decade (Figure 8).

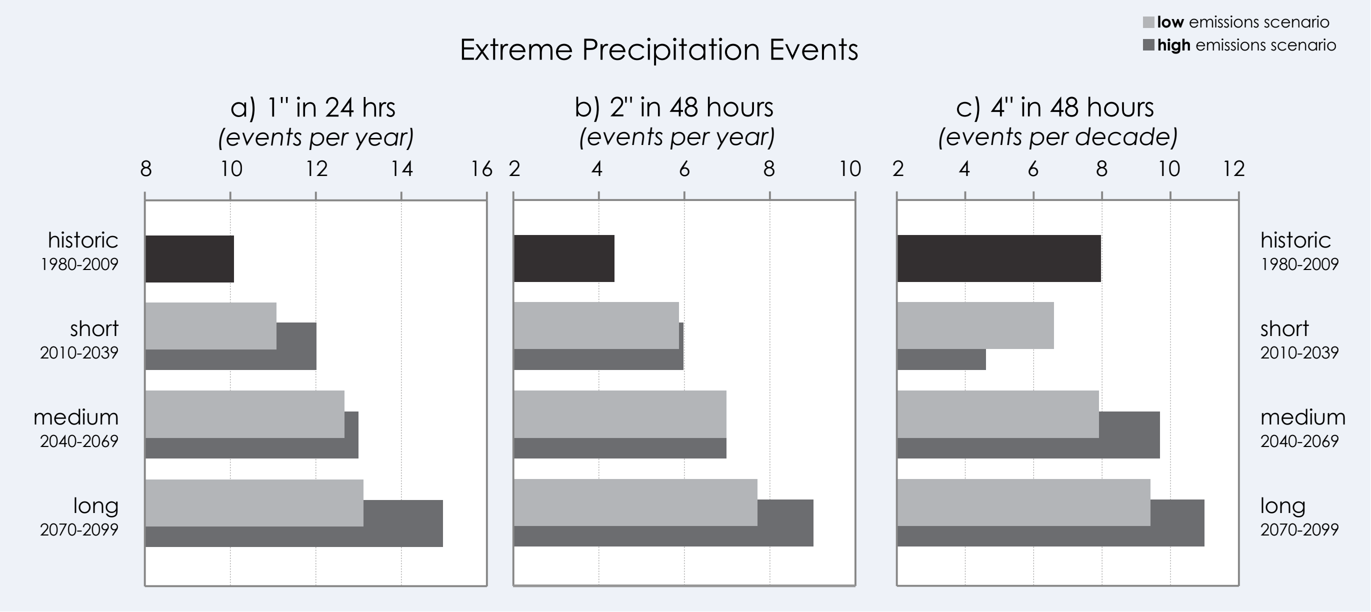


Figure 8. Extreme Precipitation Events

Table 2. Potential Impacts of Precipitation Changes

Change	Potential Impacts of Precipitation Changes
↑	**Flooding:** One of the key impacts associated with higher precipitation and more extreme precipitation events is increased flooding risk, which can potentially damage houses, businesses, and infrastructure and disrupt livelihoods.
↑	**Erosion:** Flash flooding and storm surges associated with extreme precipitation events may lead to increased erosion, especially along steep slopes and non-vegetated soil.
↓	**Water quality:** Increased stormwater runoff associated with precipitation events could increase the concentration of water-borne pollutants in urban streams.
↑	**Vector borne disease:** An increase in the amount and duration of standing water may lead to an increase in pests and vector borne diseases such as West Nile Virus.

Figure 9. Watson Waldron Dam on the Cochecho River

Sea Level Rise

In the long term, Dover's sea level is projected to rise by up to 5 to 6 additional feet from 2000 levels under the high emissions scenario. The low emissions scenario projects a more modest increase, indicating a 6 inch rise in sea level in the short term (2025) and a 2 foot rise in the long term (2085)(Figures 10 and 11).

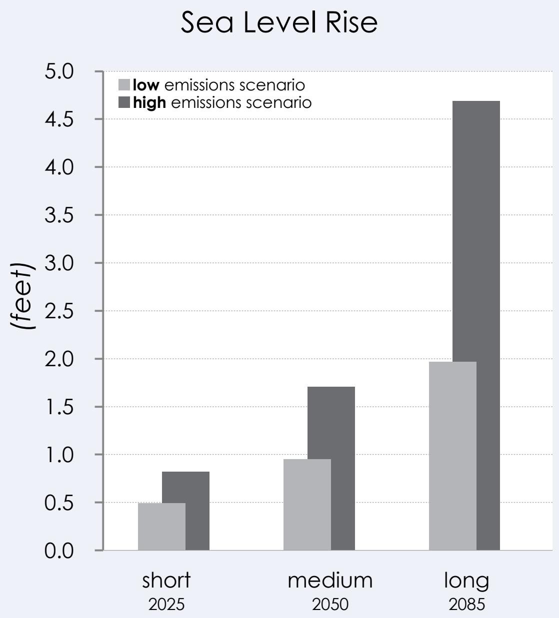


Figure 10. Sea Level Rise Projections

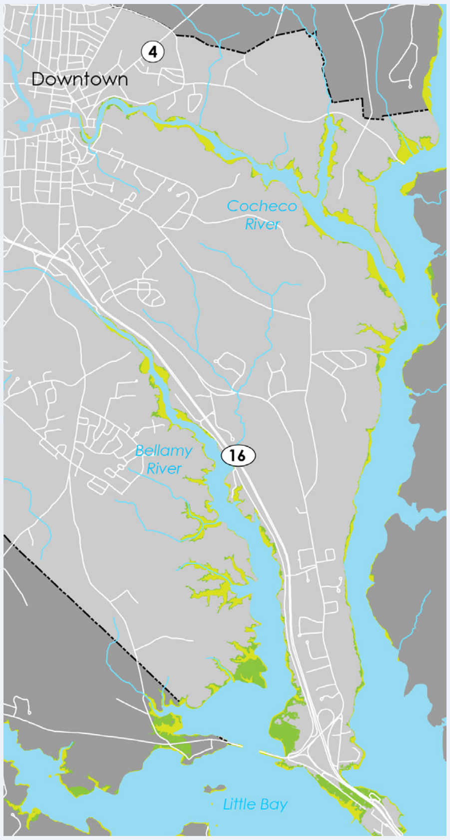


Figure 11. Sea Level Rise. Mean Daily Tidal Level

🟨 High emissions scenario - medium term *(2050)*

🟩 High emissions scenario - long term *(2085)*
(additional area flooded)

Table 3. Potential Impacts of Sea Level Rise

Change	Potential Impacts of Sea Level Rise
↑	**Daily tidal inundation:** Sea level rise will likely increase the extent of daily tidal inundation with social, economic, and ecological implications.
↑	**Groundwater levels:** Rising groundwater levels may damage infrastructure and damage property along the coast. Rising water may mean that Dover's aquifers become contaminated with salt ocean water.

Section 2: Integrated Risks and Adaptation Options

This section of the report builds on the climate change projections and possible impacts from Section 1, and applies them to community systems and assets in Dover to examine some of Dover's key climate change risks, vulnerabilities, and adaptation options. Figure 12 represents the approach we used to understand and assess risk. This approach is based on the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Extreme Events (IPCC, 2012). Risk (white circle) is the likelihood of impact resulting from the interaction of:

- a ***threat,*** an event caused by natural variability and/or anthropogenic climate change, and
- ***vulnerability,*** the sensitivity, exposure, and adaptive capacity of a place and its likelihood to be adversely affected.

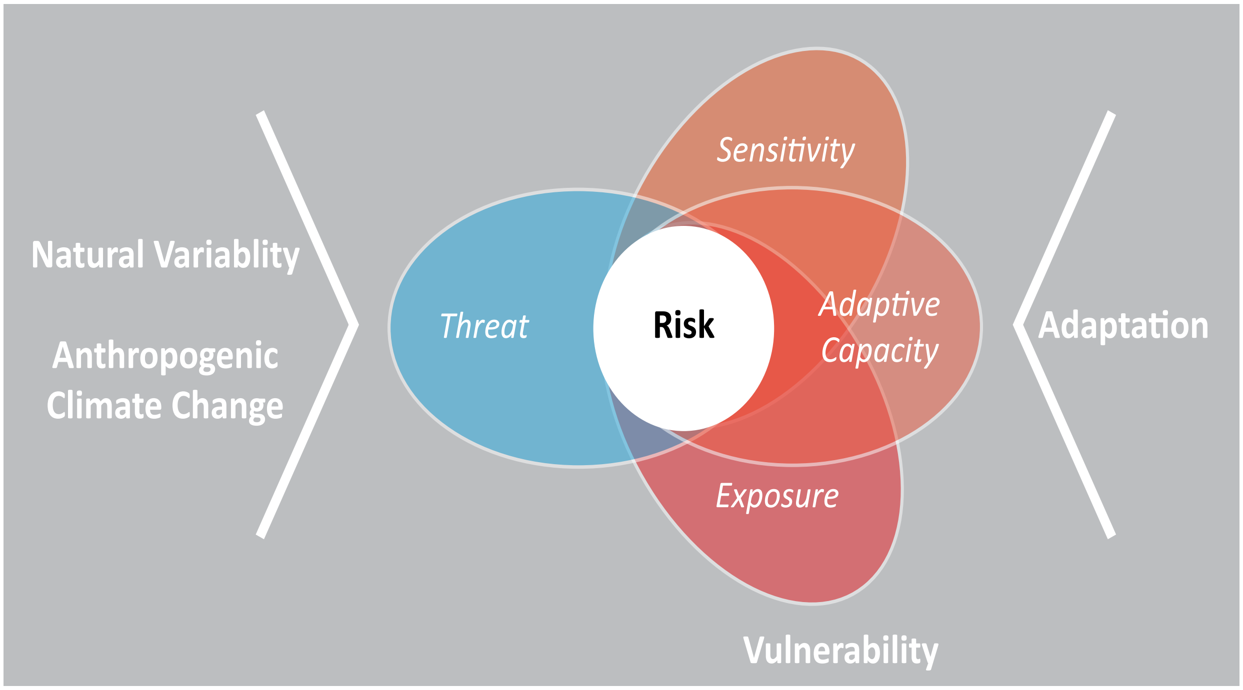


Figure 12. Integrated Risks (Adapted from IPCC SREX Report)

Climate adaptation focuses on reducing local and regional vulnerability. Adaptation options (right side of the diagram) reflect alternative mechanisms that can be used to reduce Dover's risk to a given climatic threat through minimizing exposure (e.g. moving out of harm's way), reducing sensitivity (e.g. implementing storm-resistant building techniques), and increasing adaptive capacity (e.g. putting in place wide vegetative buffers). Adaptation options can be broadly grouped under four categories: 1) no action, 2) accommodation, 3) protection, and 4) retreat. The type of adaptation options that are most appropriate in a given situation and time will depend on a number of factors, including, but not limited to, the magnitude of the threat, the timeframe and probability of the threat, the associated economic, social and ecological cost of the risk, and availability of resources and knowledge at the time. Accommodation options focus on increasing preparedness and reducing sensitivity in case a threat occurs. Such approaches may include early warning systems, the modification of ground floors of buildings to decrease damage when flooding occurs, and/or removal of critical infrastructure from ground floors. Protection options seek to reduce risk through preventing a threat from occurring. These measures could include things such as seawalls and restoring or creating wetlands to prevent flooding. Lastly, retreat options reduce exposure by moving the population away from the threat, such as through relocation, setback requirements, and phasing out development in high-risk areas. In contrast to climate change adaptation, climate change mitigation practices that reduce global greenhouse gas emissions aim to lessen the speed and severity with which regional climates are changing and, as a result, minimize climate change risks globally and in the long term by reducing threats.

This section highlights several climate change risks facing Dover, including coastal, riverine, and runoff-related **flooding; heat waves; water supply;** and **ecosystem changes**. Specific vulnerabilities for Dover were identified through consultation with key individuals from the city and climate change experts, as well as through reviewing published documents, including the Dover Hazard Mitigation Plan. See Additional Resources in Appendix 2 for more in-depth narratives and diverse examples of adaptation options.

Figure 13. Dover City Hall

Figure 14. Central Avenue Dam on the Cochecho River

Flooding

Risks

Dover has experienced numerous disastrous floods in the past (Dover Public Library; City of Dover, 2012). Climate projections indicate that the frequency and magnitude of floods will likely increase in the future. Future flooding will be exacerbated by more extreme precipitation events, warmer winter temperatures resulting in precipitation falling as rain instead of snow, sea level rise, and higher storm surges during extreme precipitation events. Snow functions as a natural reservoir, holding back precipitation. Reduced snowpack may increase streamflows when the watershed is already saturated. Dover may also see increased flooding associated with more development and the resultant expansion of impervious surfaces. The impact of development on flooding depends on many factors, such as the intensity and location of the development, the type of rainfall event, and the size of the drainage area (FEMA, 2008). In 2006 and 2007, coastal New Hampshire experienced the worst flooding since at least the beginning of the last century (Ibid).

Riverine Flooding: Dover is vulnerable to flooding from its two rivers, the Bellamy and the Cochecho, during extreme precipitation events. These two rivers gather runoff from a 170-square-mile watershed (Figure 15). Figure 16 reflects FEMA's delineation of the 100- and 500-year flood plains. The 100-year floodplain is an area that has a 1% chance of flooding in any given year, while the 500-year flood plain has a 0.2% chance of flooding in any given year. FEMA is currently in the process of updating the 100-year and 500-year floodplain maps for the Dover. Future increases in annual precipitation and an increased frequency of extreme precipitation events are expected to further increase the flood risk probability along Dover's waterways.

Dover is also at risk from sea level rise. While the average elevation in Dover is 80 feet above sea level, a 5 to 6 foot rise in the average sea level—which is projected to occur by the end of the century according to the high emissions scenario—would lead to higher tidal inundation and raised groundwater levels (Figure 17). Higher sea levels will also reduce the capacity in the Cochecho and Bellamy Rivers to absorb precipitation during storms, which will likely increase the magnitude of flooding during extreme precipitation events.

The increase in frequency of extreme precipitation events is expected to increase flooding risk due to stormwater runoff. In developed landscapes, stormwater runoff flows quickly off of impermeable and hard surfaces into drainage ditches, streams, and culverts. This large load of water picks up sediment and debris along its path, and can erode stream banks and wash out roads. Further, stormwater runoff can cause sewage overflows in combined sewer systems and wash contaminants into waterways. Minimal runoff has been associated with reduced water quality and environmental degradation, while significant volumes of runoff can overwhelm stormwater infrastructure, leading to costly damages.

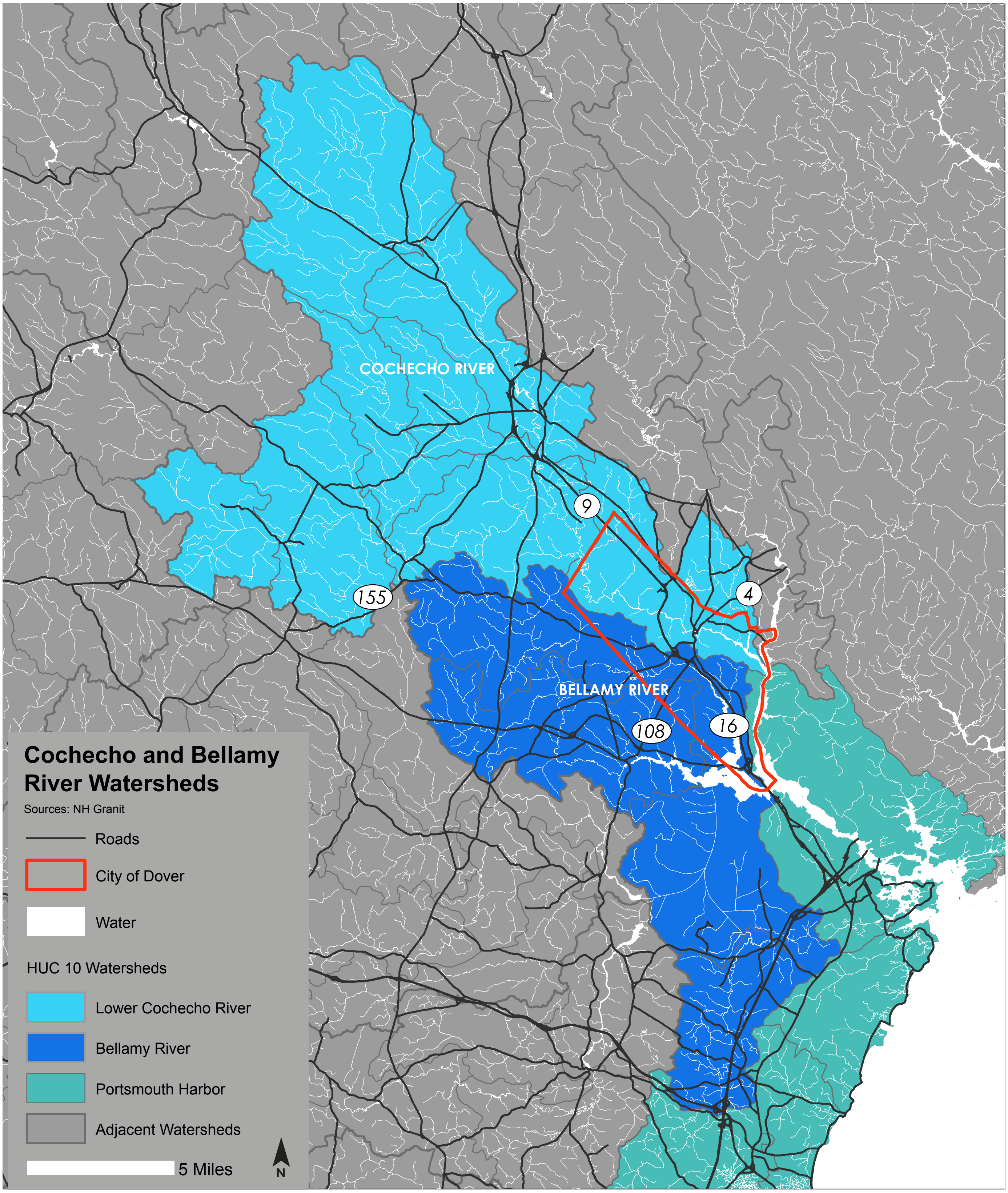


Figure 15. Dover's Watersheds

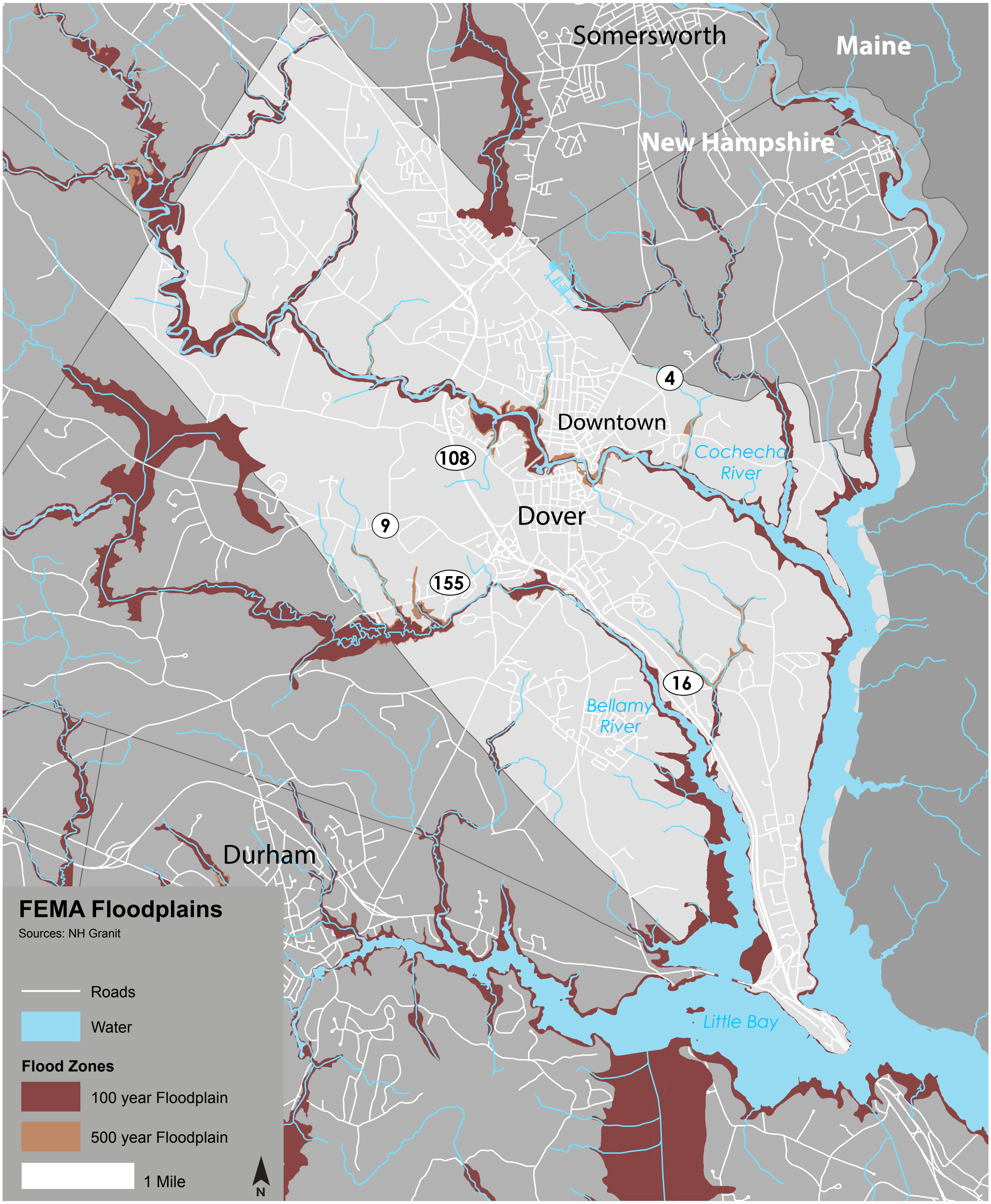
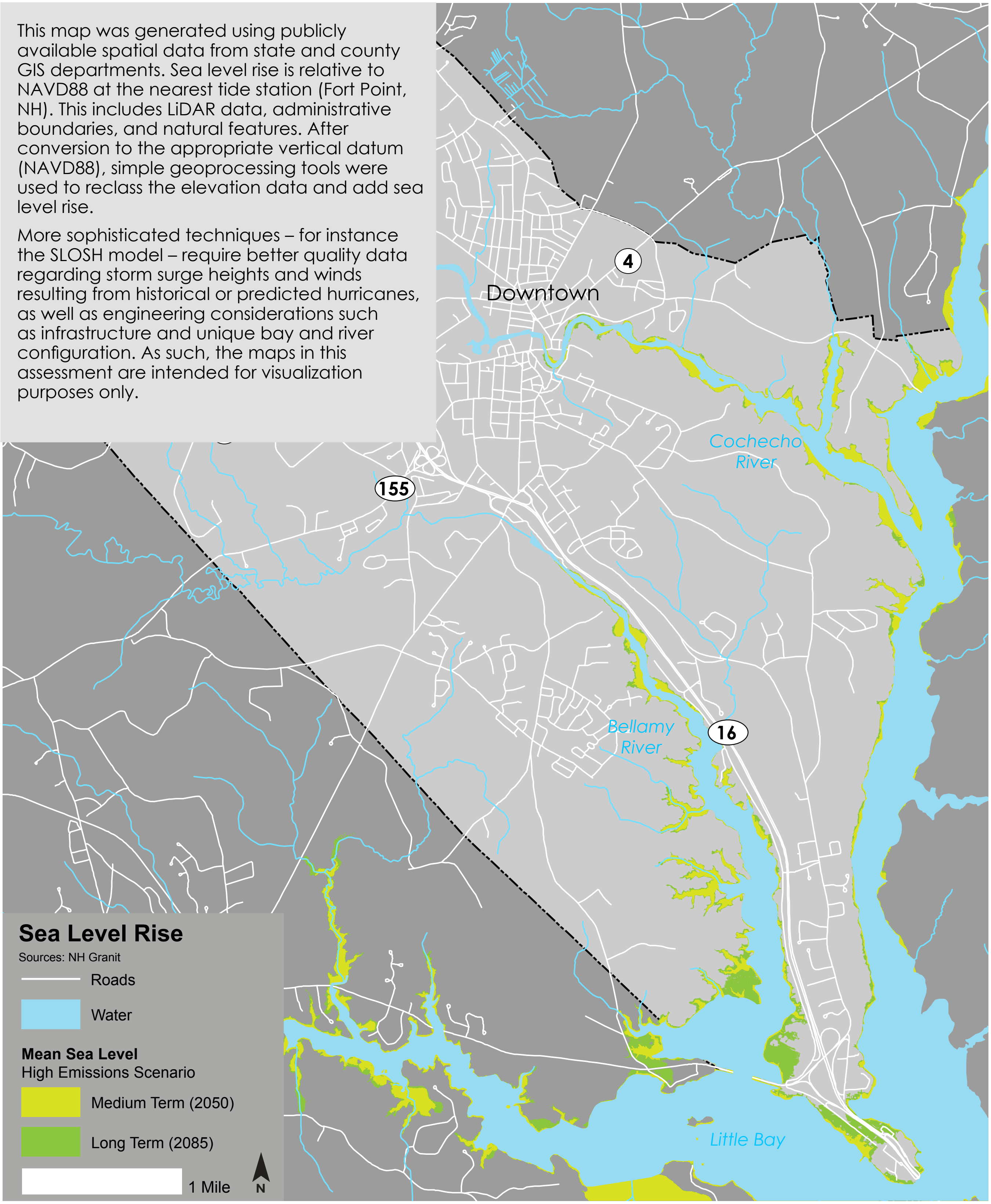


Figure 16. Dover's 100 and 500 Year Floodplains



This map was generated using publicly available spatial data from state and county GIS departments. Sea level rise is relative to NAVD88 at the nearest tide station (Fort Point, NH). This includes LiDAR data, administrative boundaries, and natural features. After conversion to the appropriate vertical datum (NAVD88), simple geoprocessing tools were used to reclass the elevation data and add sea level rise.

More sophisticated techniques – for instance the SLOSH model – require better quality data regarding storm surge heights and winds resulting from historical or predicted hurricanes, as well as engineering considerations such as infrastructure and unique bay and river configuration. As such, the maps in this assessment are intended for visualization purposes only.

Figure 17. Sea Level Rise. Mean Tidal Inundation along the Cochecho and Bellamy Rivers: High Emissions Scenario, Medium and Long Term.

Vulnerabilities

Neighborhoods and Properties: The residential neighborhoods off of Middle Road, Back Road and Dover Point Road, as well as downtown Dover, are vulnerable to flooding associated with sea level rise and extreme precipitation events. According to Dover's Hazard Mitigation Plan, there are approximately 110 structures in the city that fall within the FEMA 100-year floodplain (2012). These structures will become more vulnerable to future flooding under projected climate changes. Buildings can be severely damaged by floodwaters, causing displacement of residents and businesses. Basements can also become damaged from higher groundwater levels and leaks associated with flood events and rising sea level. Flooding may also cause residences and businesses to lose power and water service, and road closures caused by flooding can prevent access to homes, businesses, and services, such as hospitals and schools.

Critical Facilities and Resources: According to Dover's 2012 Multi Hazard Mitigation Plan, critical facilities and resources include those places that may be needed during an emergency. Included in the plan's list are emergency response facilities (ERFs) such as police and fire stations, and City Hall, transportation and communication networks including major roads, bridges and cell towers, and non-emergency response facilities (NERFs) including water and wastewater treatment. These facilities and resources are mapped in Figure 19. According to the critical facilities data provided by the Strafford Planning Agency, there are no emergency and non-emergency response facilities within Dover's 100- and 500-year floodplain. However, according to Dover's 2012 Multi-Hazard Mitigation Plan, five bridges (Watson Road over Cochecho River, Sixth Street over Blackwater Brook, Atlantic Avenue over Fresh Creek, Bellamy Road over Bellamy River, and General Sullivan Bridge) may be vulnerable to flooding (Figure 19).

Social Vulnerabilities: In addition to facilities and resources that may be necessary during an emergency, the City of Dover has identified facilities and populations that should be protected during an emergency (Figure 20). Facilities the City of Dover may prioritize protecting during a flood event include commercial areas, hazardous material facilities, historic buildings, and medical facilities. Displacement caused by flooding is a major social vulnerability. Populations with lower physical mobility are more sensitive to flood impacts. Sensitive populations (such as the elderly, very young, and presently ill) have lower physical mobility rates and are therefore at risk from major hazards. Highlighted populations include nursing homes, correctional facilities, congregate care, and schools. In addition, lower-income households may have limited savings and can be especially hard hit by the disruption of work and expenses of recovery associated with

Figure 18. Amtrak Downeaster headed South from Dover Station

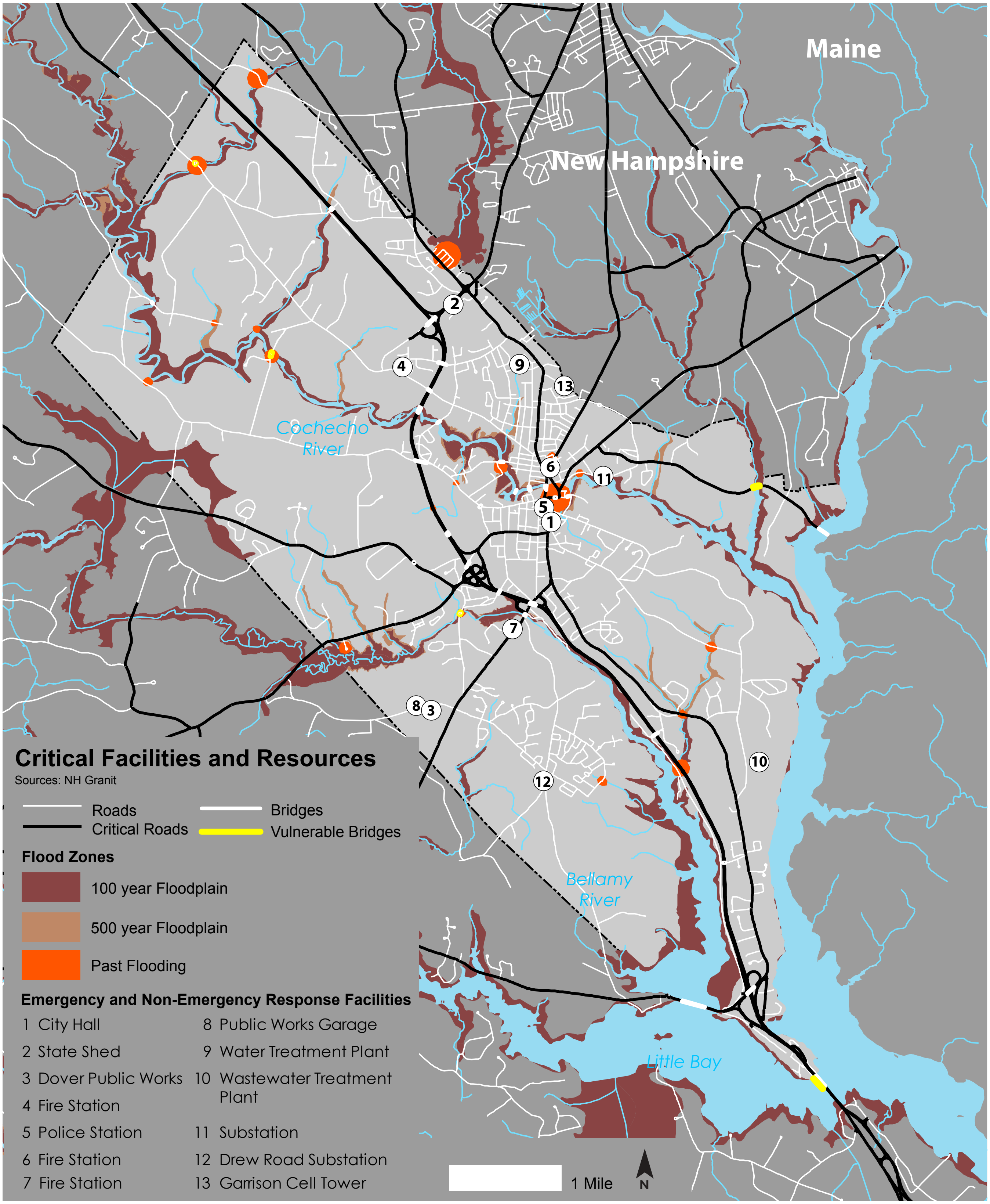


Figure 19. Critical Facilities and Resources (Multi-Hazard Mitigation Team)

flooding. Figure 21 reflects poverty rates by census tracts set against potential flood risk extents (100- and 500-year floodplains). Lastly, during interviews with various stakeholders for the New England Climate Adaptation Project, participants were asked to identify ‘trouble spots’ where flooding has happened in the past. These places, listed in Table 4, include road segments, pump stations, and properties which have flooded in the past.

Adaptation Options

In an effort to reduce impacts from stormwater runoff, the City of Dover has been engaged for decades in efforts to upgrade its stormwater system by separating storm water and sewer lines, upsizing and replacing old pipes, and working to keep catch basins clean from debris. Other flooding mitigation strategies identified in Dover’s Hazard Mitigation Plan include bridge repair, new pumps and drainage systems, road reconstruction and raising roads, improved monitoring, and conducting a needs assessment for stormwater infrastructure.

Reducing Exposure: One way to reduce the risk of flooding is to reduce the exposure of people and community assets to flooding. For example, “managed retreat” refers to strategically moving people and structures out of floodplains. Once structures have been removed from the floodplains, the land can be restored to a more natural state to provide flood mitigation, wildlife habitat, and open space. The City of Cranston, RI, is employing this strategy on a small scale with a program that purchases homes that have been repeatedly flooded using funding from FEMA (City of Cranston, 2012).

Another way to reduce exposure to river flooding is through protection strategies, such as using structural measures (e.g. floodwalls) to reduce the likelihood that the rivers will overflow their banks. The downside to engineered structural protection measures is that if they are breached by floodwaters the economic losses tend to be very high, in large part due to the “levee effect”—that is, the tendency of development to occur on the other side of a protective structure. These structural strategies also tend to be less flexible than other adaptation options in that they need to be designed to a certain specification in advance even though unexpected climate and environmental changes could occur. More natural approaches can also provide protection against flooding, such as wetlands that can help store and slow down rising flood waters (Ramsar Convention on Wetlands). Low impact development approaches, like retention ponds and increasing groundwater infiltration by replacing or removing impervious surfaces such as pavement, may also reduce flooding risk.

Reduce Sensitivity: Dover can reduce flooding risk by “accommodating” flooding and reducing the sensitivity of buildings and infrastructure to flood impacts, so that even if an asset is exposed to flooding, the damage is very limited. One option for accommodating flooding is flood-resilient building design. For example, homes and buildings can be elevated above the projected flood height or they can be dry- or wet flood-proofed. Another accommodation approach is to use flood resistant infrastructure, such as electric transformers that are saltwater resistant.

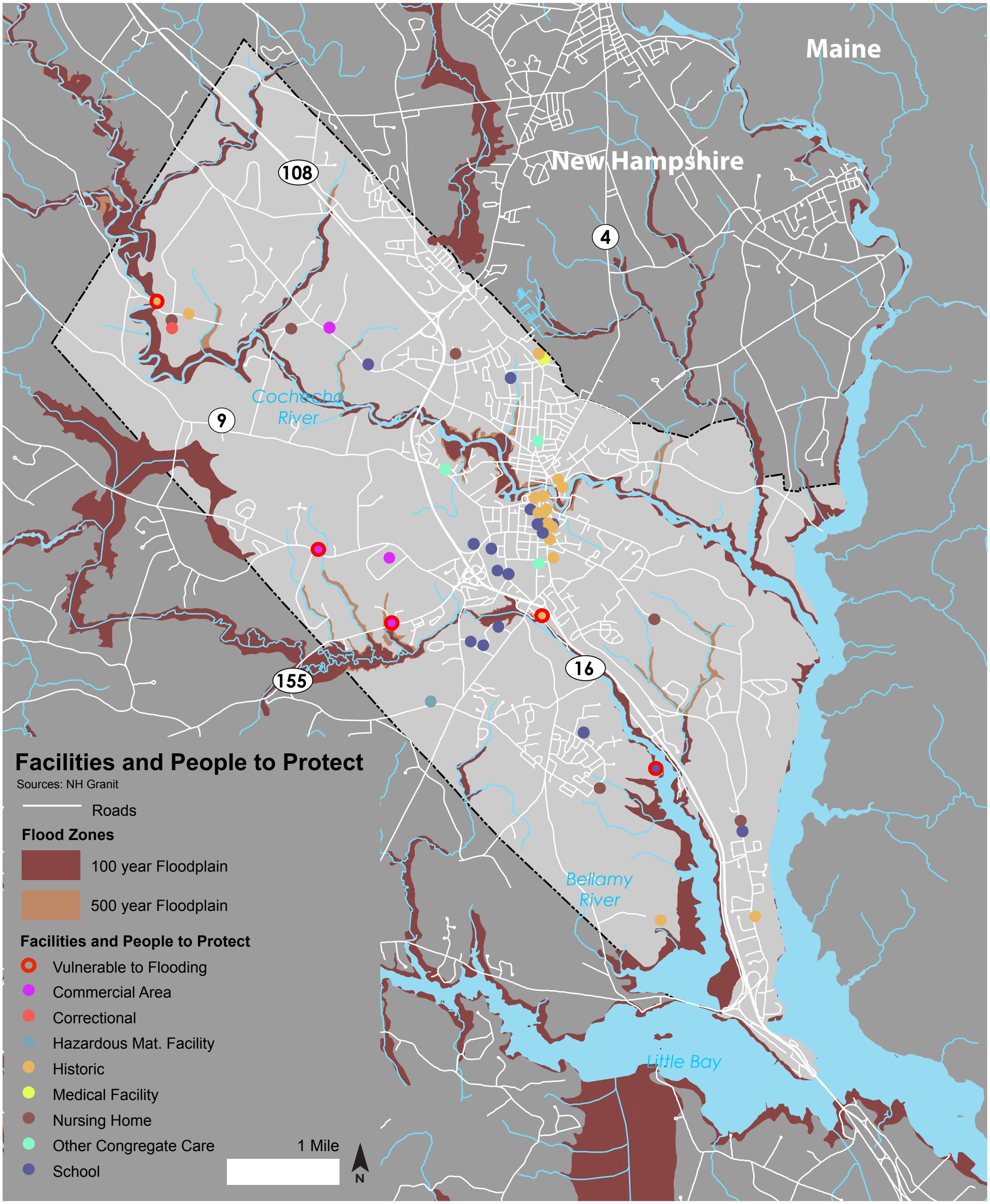


Figure 20. Facilities and People to Protect during an Emergency

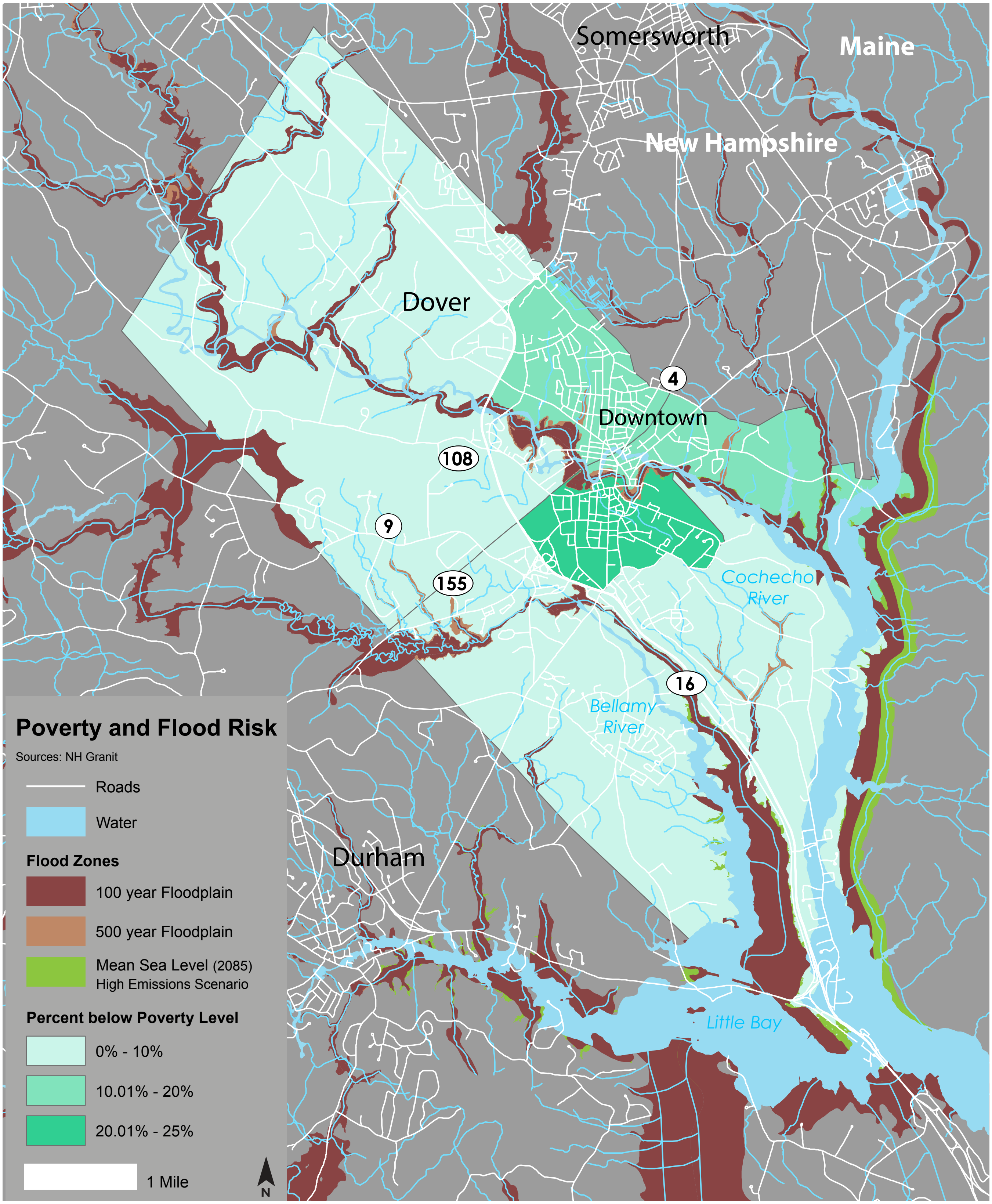


Figure 21. 2010 Poverty Rates by Census Tracts and Flood Risks

Table 4. Resources at Risk from Flooding (Stakeholder Interviews)

"Trouble Spots" in Dover as identified during stakeholder interviews	
Downtown	
Broadway near New York Street	Central Avenue Bridge
Cochecho River behind the dam	Ela Street
Henry Law Park	Kelley's Row Restaurant
Oak Street	Sawyer Woolen Mill
Snows Court	
Dover Point	
Dover Point Road	Cote Drive
Center Drive	Spur Road
Hilton Park area	
Wentworth Terrace	
Other	
Barbadoes Pond	Bellamy Reservoir, near Tolend Road and French Cross Road
Bellamy Road culvert	
North end of Sixth Street	Cochecho Country Club and development on Fairway Drive
Waterfront property	
Sewer pump stations	
Willand Pond	

Increase Adaptive Capacity: Building adaptive capacity, or the ability for people and assets to bounce back from flooding, is another way to reduce Dover's vulnerability. Flood insurance and other forms of financial security can help people rebuild after a climate-related disaster. Community organizations and affiliations have also been shown to help people recover from disasters more quickly (Swim et al., 2011). Successful efforts employ various strategies that are coordinated in time and location. The City of Dover can support and coordinate with local organizations to facilitate recovery in response to flood events.

a) Restored Wetland

b) Floodwall

c) Hurricane Barrier

d) Pervious Pavement

e) Flood Resilient Building

f) Low Impact Development

Figure 22. Flood Adaptation Options

Figure 23. Road Closure at the Corner of Fourth Street and Snow Court due to Flooding, 2006

Figure 24. Cochecho River Flooding Dover, 2007

Figure 25. Flooding in Henry Law Park in the City of Dover, 2007

Figure 26. Cochecho River fFooding Henry Law Park, 2007

Heat Waves

Risks

Heat waves are driven by extremely warm temperature events, which are expected to increase significantly in Dover. Heat waves are particularly dangerous for human health and infrastructure when they last for long periods of time, when evenings do not cool down, and when heat is coupled with high humidity.

Vulnerabilities

Social Vulnerabilities: The very young, the very old, and the presently ill are the most vulnerable to the health impacts of heat exposure. People who live in substandard housing without high-quality ventilation and those unable to afford air conditioning are also susceptible to heat exposure. Higher temperatures can also contribute to more air pollution, which disproportionately affects the young and the elderly.

Electricity Infrastructure: Extremely high temperatures can cause electricity wires to sag and come into contact with trees or structures. Prolonged heatwaves can also damage other electricity distribution equipment, such as transformers, which are designed to cool down during the evenings. Since the greatest electricity demand tends to occur during hot summer afternoons, hotter days may cause electricity demand to outstrip supply, which could result in reliability problems, such as brownouts or blackouts.

Adaptation Options

Reduce Exposure: One option for reducing the health impacts of heatwaves is to reduce the exposure of vulnerable populations. Strategies include providing cooling centers during heat waves, retrofitting substandard housing, and providing assistance for people who cannot afford their electricity bills. Dover could also increase green space and tree canopy within the downtown core to mitigate the urban heat island effect.

Reduce Sensitivity: Options for reducing the vulnerability of electrical infrastructure to heat waves include improving the equipment and implementing energy efficiency measures that reduce stress on the electricity system during heat waves. Many electric utilities employ innovative demand management techniques, including programs that compensate customers who agree to have the electrical supply for certain devices (such as irrigation pumps or air conditioners) cycled on and off during periods of peak demand to reduce overall energy use. Some large industrial utility customers can even agree to run their operations at night, which reduces the load on the system during daytime peaks. General energy efficiency policies and practices also serve to lower average energy demand. Distributing and diversifying electricity sources is another way to improve electrical system reliability during extreme weather events. This could involve backup generation options, electricity storage options, and on-site energy options, such as rooftop solar power. Finally, maintaining and updating aging distribution infrastructure, such as transmission lines and transformers, is important for preventing system failures during heat waves (Vine, 2102).

a) Building Retrofits b) Cooling Center c) Urban Canopy

Figure 27. Heat Wave Adaptation Options

Water Supply

Risks

Projected climatic changes may increase the occurrence of droughts and alter water levels and water quality in Dover's aquifers. The threat of increased drought in Dover is driven by the projected decrease in summer precipitation and an increase in summer temperatures, which may result in more evaporation and transpiration. For this report, we have not included drought projections because of their high uncertainty. However, previous analysis has suggested that, in the long term, much of New England may experience a significant increase in drought. For example, short-term drought (up to one month in duration) is expected to increase by two to three-fold by the end of the century under the high emissions scenario (Hayhoe et al., 2007).

In addition to the risk of drought, water supply may be impacted by changes to groundwater levels and aquifer recharge. Higher summer temperatures and reduced summer precipitation and winter snowpack accumulation can further stress spring and summertime inputs, reducing aquifer recharge. In addition, sea level rise may function to raise groundwater levels, particularly if there is less recharge, as recharge actually provides a force to counteract groundwater levels rising because of sea level rise and salt water intrusion (Bjerklie et al., 2012). However, the intrusion of seawater into the Dover aquifer may change the water quality by, for example, raising the salinity level of the water (EPA, 1986).

Vulnerabilities

Drinking Water Supply: Dover residents receive drinking water pumped from eight wells located throughout the city. These wells draw water from four underground aquifers (City of Dover, 2013). The duration and frequency of droughts will determine their impacts on water supply. Drought can particularly impact the potable water supply. Residents that rely on wells may be particularly vulnerable if a drought causes groundwater levels to fall, because they are not relying on water stored in reservoirs. Prolonged drought could potentially impact Dover's water supply, but the vulnerability of that water supply has not been analyzed in this study.

Adaptation Options

Reduce Exposure: Dover may be able to reduce its exposure to drought-induced water supply shortages by acquiring additional above ground water supplies, such as reservoirs.

Reduce Sensitivity: Dover can reduce its sensitivity to drought-induced water supply shortages by decreasing municipal and industrial demands through water conservation efforts.

a) Additional Reservoirs b) Water Efficiency c) Irrigation Efficiency

Figure 28. Water Quantity Adaptation Options

Ecosystem Impacts

Risks

Climate change could affect the diverse ecosystems (Figure 30) and wildlife that exist in and around Dover. For example, streams and ponds could become too warm to support native fish species. Increased tick and mosquito populations due to warmer and wetter conditions could affect the health of woodland mammals and humans. Additionally, sea level rise could drastically affect some of the unique coastal habitats located near Dover.

Vulnerabilities

A vulnerability assessment of habitats and species within Dover has not been completed. However, national studies have characterized the types of habitats and species that may be most vulnerable to climate changes (Bradley et al., 2012; Halpern et al., 2007; Kittel et al., 2011). Highly fragmented habitat is more vulnerable to pest outbreaks, including vector borne diseases and invasive species (Jump et al., 2005). Already stressed species whose habitat and food sources have been reduced are more sensitive to additional stresses, such as extreme heat, water loss, and diseases (Anderson Texeria et al., 2013). Aquatic species that cannot tolerate large fluctuations in temperature are threatened by increases in water temperature, which can be caused by stormwater surges, extreme precipitation events, and heatwaves (Wainwright and Weitkamp, 2013). Nearshore habitats—including deltas and estuaries, which are nurseries for juvenile fish—are highly sensitive to saltwater intrusion and extended periods of inundation, which may be caused by sea level rise and extreme precipitation events (Rogers-Bwennett et al., 2001). Coastal wetlands are also vulnerable to sea level rise and changing climatic conditions, and may need to migrate inland to survive.

Adaptation Options

Increase Adaptation Capacity: An important adaptation strategy for ecosystems is to increase their resilience and their ability to bounce back and cope with disruptions. One way to do this is through reducing other human-induced stresses on ecosystems, such as pollution and habitat fragmentation, since healthier populations and habitats will be more likely to adjust to a changing climate. Land behind wetlands can also be set aside to allow wetlands to migrate inland as the sea level rises, although such ecosystems may not be able to migrate fast enough to avoid the rising tides.

a) Protect Wetlands

b) Vegetated Waterway Buffers

Figure 29. Ecosystem Adaptation Options

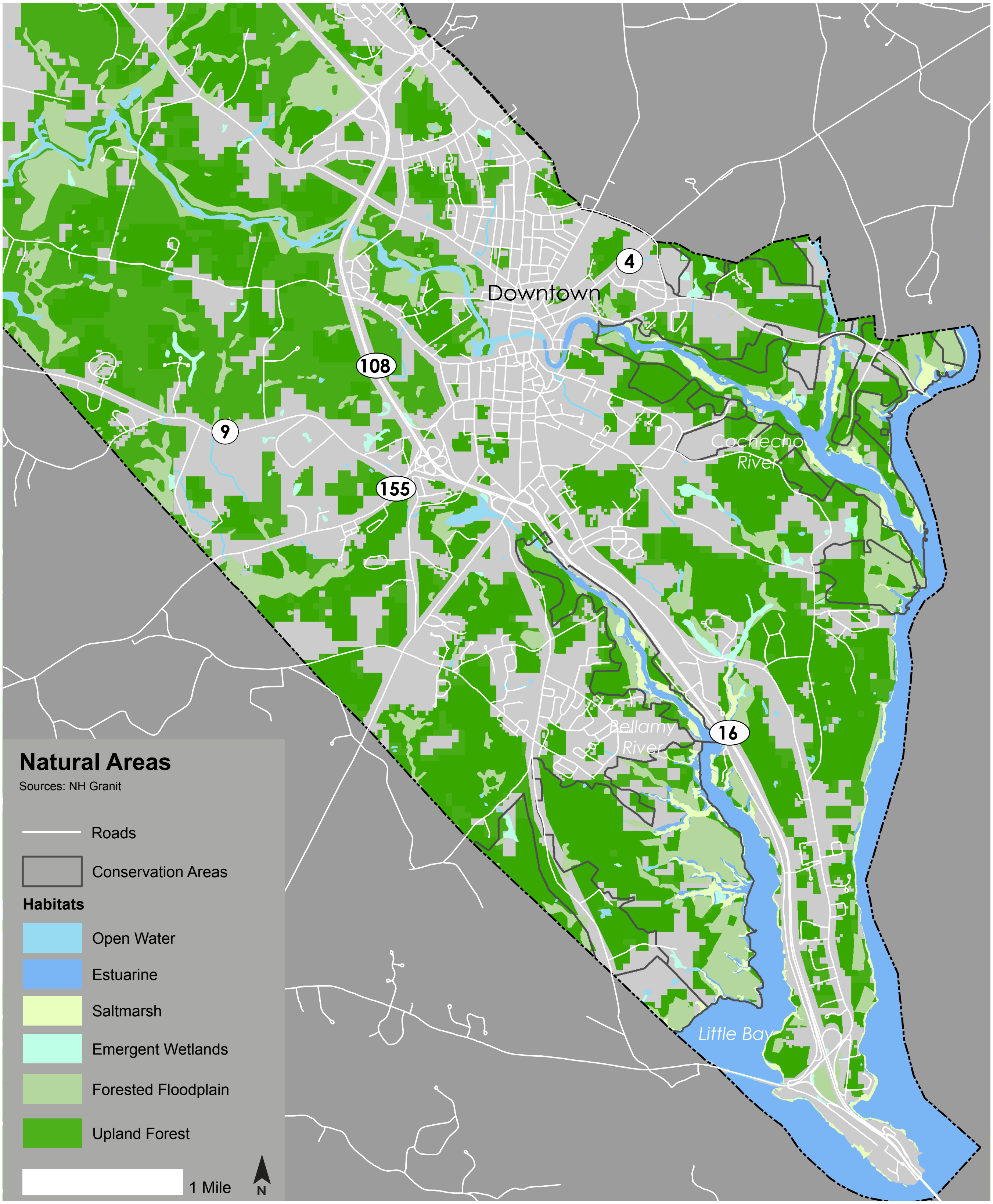


Figure 30. Dover's Habitat and Conservation Areas

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Cover. City of Dover. Photo credit: Chris Keeley

Executive Summary: Outdoor summer movies at Brown University; Floodwall. Reprinted with permission of the Daily Hampshire Gazette. All rights reserved; Flood Resilient Building. Photo by: Jeffrey Tortaro, Design firm: Tsoi/Kobus & Associates in Cambridge, MA; Wetland Restoration; Woonasquatucket Wetland Restoration http://www.dem.ri.gov/programs/benviron/water/wetlands/wetplan.htm; Tree Canopy. Tree Canopy, Courtesy of Douglas Still, City Forester, Providence, RI; Additional Reservoir. Wikicommons; Vegetated Waterways. Barnstable, MA

City Hall. Photo credit: Chris Keeley

Figure 9. Watson Waldron Dam on the Cochecho River. Photo credit: Carri Hulet

Figure 13. Dover City Hall. Photo credit: Chris Keeley

Figure 14. Central Avenue Dam on the Cochecho River Photo credit: Carri Hulet

Figure 18. Amtrak Downeaster headed South from Dover Station. Photo credit: Pat Corlin

Figure 22. Flood Adaptation Options. Restored Wetland. Three Bridges Foundation; Floodwall. Reprinted with permission of the Daily Hampshire Gazette. All rights reserved. Fox Point Hurricane Barrier. FEMA; Pervious Pavement. USDA; Flood Resilient Building. Photo by: Jeffrey Tortaro, Design firm: Tsoi/Kobus & Associates in Cambridge, MA; Low Impact Development, Southeast Michigan Council of Governments.

Figure 23. Road closure at the corner of Fourth Street and Snow Court due to flooding; 2006 Photo credit: Strafford Regional Planning Commission

Figure 24. Cochecho River flooding Dover; 2007. Photo credit: Strafford Regional Planning Commission

Figure 25. Flooding in Henry Law Park in the City of Dover; 2007. Photo credit: Strafford Regional Planning Commission

Figure 26. Cochecho River flooding Henry Law Park; 2007. Photo credit: Strafford Regional Planning Commission

Figure 27 Heat Wave Adaptation Options: Building Retrofits. RafterTales; Cooling Center. NYC Urbanlife Blogspot; Urban Canopy. The Sanguine Root.

Figure 28 Water Quantity Adaptation Options: Additional Reservoirs. Wikicommons; Water Efficiency. Wikicommons; Irrigation Efficiency. Wikicommons.

Figure 29. Ecosystem Adaptation Options: Protected Wetlands. Fletcher Creek, Connecticut. Ducks Unlimited; Vegetated Waterway. Barnstable, MA. School Street Bridge, Cotuit

Appendix 1: Methodology for Downscaled Projections and Sea Level Rise

The Dover downscaled projections were generated as output from four different global circulation models (GCMs) that have been well-established and evaluated in the peer-reviewed scientific literature: 1) the US National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1; 2) the United Kingdom Meteorological Office's Hadley Centre Climate Model version 3 (HadCM3); 3) the National Center for Atmospheric Research's Parallel Climate Model (PCM) and 4) Community Climate System Model Version 3 (CCSM3) (Table A1). These models have different climate sensitivities, where sensitivity refers to the amount of temperature change resulting from a doubling of atmospheric CO_2 concentrations relative to pre-industrial times. GFDL, CCSM3, and HadCM3 have medium sensitivity, and PCM has a low sensitivity.

Each global model produces output in the form of geographic grid-based projections of daily, monthly, and annual temperatures, precipitation, and other climate variables. GCMs operate on the scale of hundreds of miles, which is too coarse a resolution to distinguish changes across different towns and cities in a given region, such as New England. However, scientists used state-of-the-art statistical downscaling models to capture historical relationships between large-scale weather features and local climate, and use these to translate future projections down to the scale of local weather station observations. In this project we used a relatively new statistical downscaling model, the Asynchronous Regional Regression Model[2]. This report uses the projections downscaled to the meteorological station in Durham, NH, because it is the closest station to Dover.

Two different climate change scenarios drove the projections from the GCMs: a high emissions scenario (A1fi) and a low emissions scenario (B1). The high emissions scenario assumes that the world will experience economic growth dependent primarily on fossil fuels and that atmospheric concentrations of CO_2 will reach 940 parts per million by 2100. The low emissions scenario assumes that economies will shift to cleaner, less fossil-fuel intensive technologies, and that atmospheric concentrations of CO_2 will reach 550 parts per million by 2100[3]. The purpose of choosing a high emissions and a low emissions scenario is to create a likely range of future climatic change that Dover may experience during the 21st century.

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[2] More information on the statistical downscaling method used is provided in: Stoner, AMK, K Hayhoe, X Yang and DJ Wuebbles (2012) An asynchronous regional regression model for statistical downscaling of daily climate variables. Int. J. Climatol. DOI: 10.1002/joc.3603.

[3] The emissions scenarios and GCM simulations used in this report consist of models that contributed to phase 3 of the Coupled Model Intercomparison Project (CMIP3). These are the results presented in the Intergovernmental Panel on Climate Change (IPCC) Third (2001) and Fourth (2007) Assessment Reports. More recent scenarios combined with CMIP5 climate projections were recently released (September 2013) in the IPCC Fifth Assessment Report.

The projections are also presented in three time frames: short term, medium term, and long term. The short term refers to the time period between 2010 and 2039, the medium term refers to the time period between 2040 and 2069, and the long term refers to the time period between 2070 and 2099. The historical baseline refers to the time period between 1980 and 2009. We averaged the results of the historical baseline and climate projections over their respective 30-year timeframes. This period is long enough to filter out any inter-annual variation or anomalies and short enough to show longer climatic trends.

Table A1. Global Circulation Models

Origin	Model	Scenarios	Equilibrium Climate Sensitivity (°C)*
National Center for Atmospheric Research, USA	CCSM3	A1fi, B1	2.7
National Center for Atmospheric Research, USA	PCM	A1fi, B1	2.1
Geophysical Fluid Dynamics Laboratory, US	GFDL CM2.1	A1fi, B2	3.4
UK Meteorological Office Hadley Centre	HadCM3	A1fi, B3	3.3
* data from IPCC 2007 Fourth Assessment Report, Chapter 8.			

Table A2. Downscaled Projections for Dover: Temperature Anomalies

Temperature Anomaly (°F)							
	Historical	**Short Term (2010-2039)**		**Medium Term (2040-2069)**		**Long Term (2070-2099)**	
	1980-2009	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
Annual TMIN	35.7	38.1	38.2	39.3	41.3	40.2	44.6
Annual TMAX	58.0	60.3	60.3	61.7	63.6	62.6	67.0
Winter TMIN	15.6	18.6	18.7	19.9	21.8	20.9	25.5
Winter TMAX	35.2	37.4	37.2	38.4	39.3	39.1	41.9
Summer TMIN	55.7	58.1	58.4	59.5	61.5	60.4	64.7
Summer TMAX	79.8	82.3	82.0	84.2	86.6	85.2	90.5

Table A3. Downscaled Projections for Dover: Temperature Extremes

Temperature Extreme (days per year)							
	Historical	**Short Term (2010-2039)**		**Medium Term (2040-2069)**		**Long Term (2070-2099)**	
	1980-2009	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
<32°F	155	144	143	136	121	132	102
>90°F	10	16	17	25	46	31	75

Table A4. Downscaled Projections for Dover: Precipitation

Precipitation (inches)							
	Historical	**Short Term (2010-2039)**		**Medium Term (2040-2069)**		**Long Term (2070-2099)**	
	1980-2009	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
Annual mean	43.6	45.5	46.4	47.7	48.6	48.8	50.8
Winter mean	8.4	9.8	10.2	10.2	10.5	11.1	12.1
Summer mean	11.4	10.9	10.3	11.2	10.9	10.6	11.0

Table A5. Downscaled Projections for Dover: Extreme Precipitation Events

Extreme Precipitation (events per year)							
	Historical	**Short Term (2010-2039)**		**Medium Term (2040-2069)**		**Long Term (2070-2099)**	
	1980-2009	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
1" in 24 hrs	10.1	11.1	12.0	12.7	13.0	13.1	15.0
2" in 48 hours	4.4	5.9	6.0	7.0	7.0	7.7	9.0

Extreme Precipitation (events per decade)							
	Historical	**Short Term (2010-2039)**		**Medium Term (2040-2069)**		**Long Term (2070-2099)**	
	1980-2009	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
4" in 48 hrs	8.0	6.6	4.6	7.9	9.7	9.4	11.0

Relative sea level rise (SLR) at a site is considered to be the sum of global climate change and local subsidence. Other factors such as circulation changes are not considered. Based upon research done in Portsmouth, NH (Wake et al, 2011), it is only necessary to consider global changes in the area of Portsmouth, NH, since subsidence is insignificant. Therefore the estimates of global SLR can be taken from Figure A1 (Vermeer and Rahmstorf, 2009), similar to the later projections of Parrish et al (2012) used for the US National Climate Assessment. For any particular time period, we suggest using the upper and lower values in the gray areas in the curve. Thus the SLR is approximately 1 to 2 feet by 2050 and 3 to 6 feet by 2100.

Table A6. Downscaled Projections for Dover: Sea Level Rise

Sea Level Rise (feet)						
	Short Term (2025)		Medium Term (2050)		Long Term (2085)	
	Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Sea Level Rise	0.5	0.8	1.0	1.7	2.0	4.7

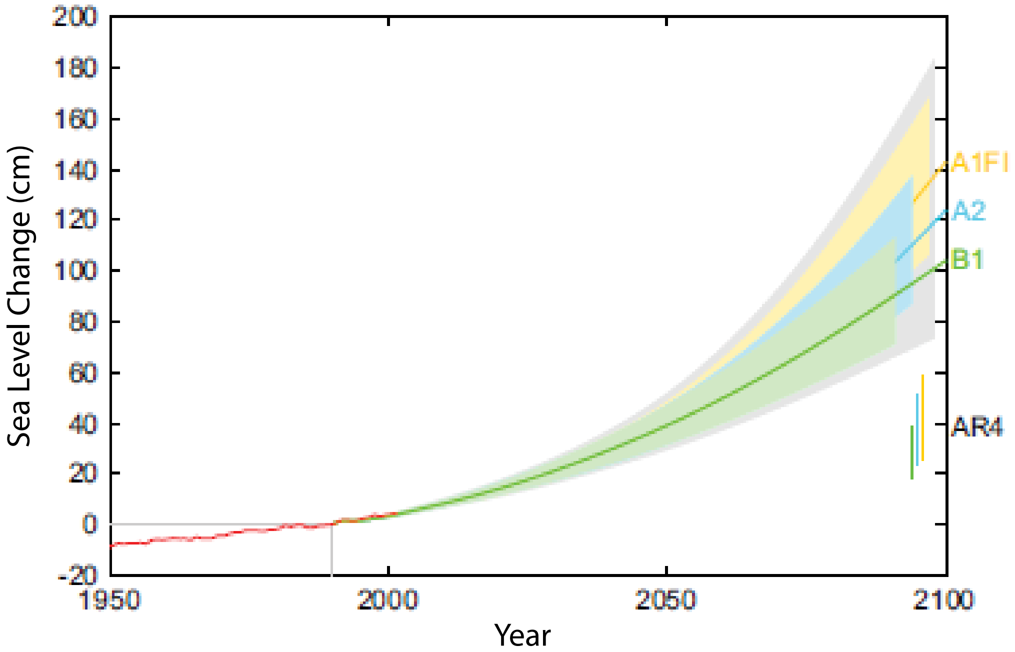

Figure A1. Sea Level Rise Projections *(Vermeer and Rahmstorf, 2009)*

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Parris, Adam, Peter Bromirski, Virginia Burkett, Daniel R. Cayan, Mary Culver, John Hall, Radley Horton, et al. 2012. Global sea level rise scenarios for the US National Climate Assessment. Silver Spring, MD: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Oceanic and Atmospheric Research, Climate Program Office.

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Appendix 2: Additional Resources

Below are additional resources on climate change risks and adaptation at various scales.

New Hampshire

New Hampshire Dept. of Environmental Services. 2009. New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future. Prepared by the New Hampshire Climate Change Policy Task Force. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/nh_climate_action_plan.htm

Northeast

Carbon Solutions New England (CSNE). 2011. Climate Change in the Piscataqua /Great Bay Region: Past, Present, and Future. http://climatesolutionsne.org/sites/climatesolutionsne.org/files/greatbayreport_online.pdf

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Union of Concerned Scientists, 2007. "Confronting Climate Change in the Northeast: Science, Impacts, and Solutions. http://www.northeastclimateimpacts.org/

National

National Research Council, 2010. "America's Climate Choices; Panel on Adapting to the Impacts of Climate Change." National Academies Press, Washington D.C. http://www.nap.edu/catalog.php?record_id=12783

National Climate Assessment Development Advisory Committee. Draft Climate Assessment Report 2014. http://ncadac.globalchange.gov/.

United States Global Change Research Program, 2009. "Global Climate Change Impacts in the United States". Second National Climate Assessment. http://www.globalchange.gov/what-we-do/assessment/previous-assessments/global-climate-change-impacts-in-the-us-2009

International

IPCC. 2007. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2007. Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

IPCC. 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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