Climate Adaptation Chapter

Developing a comprehensive climate adaptation chapter will strengthen Durham's understanding of its vulnerabilities and create a framework for a more resilient and sustainable community. This chapter includes a summary of recent climate data, as well as existing reports completed in New Hampshire to provide Durham staff, decision- makers, local boards and commissions, and community stakeholders with the knowledge and tools needed to act. The purpose of the chapter is to consolidate many of the adaptation and resilience planning efforts the Town has completed over the years and identify the most significant climate change risks and vulnerabilities that need to be addressed to protect and enhance Durham's natural and built environment, the welfare of residents and visitors, economic well-being, and overall quality of life.

Adopted by the Durham Planning Board on June 14, 2023.

Our Vision

The Town of Durham is a leader in addressing climate change and advances innovative and forward-thinking solutions that mitigate risk, strengthen resiliency, and build a more sustainable future.

Foundation

During the early development of this chapter, the Master Plan Steering Committee, and a select group of local stakeholders, in partnership with staff from UNH Extension/NH Sea Grant and the Strafford Regional Planning Commission (SRPC), participated in two planned sessions to determine which climate-related topics (sea-level rise, groundwater rise, more extreme and frequent storms and precipitation, warmer temperatures, etc.) the Town should focus on. Input received was organized into three overarching climate topics, including built infrastructure, natural and working lands, and community and economy.

In addition to the two stakeholder sessions, the project team also offered an opportunity for residents to participate in one of two virtual public input workshops, which were held in October 2021, to provide comments on the draft chapter and its recommendations. A follow up survey was distributed to participants in the workshops, as well as promoted through the Town's media services (Friday Updates and website) for all members of the public to contribute. A summary of the results from these sessions and the survey can be found in the Appendix.

To the greatest extent possible, each topic was discussed using the best available existing condition data, as well as projected climate change impacts identified in statewide, regional, and local plans. Recommendations developed as part of this Master Plan chapter were structured to reflect these issues and to provide a list of prioritized actions to ensure the Town is resilient against future climate scenarios.

I. Introduction: Climate Risks in New Hampshire

Using the most recent climate science resources, this section summarizes the causes of climate change and its associated risks that Durham will need to address to increase its resiliency, reduce impacts, and adapt to changing conditions.

A Call to Action

Durham is already confronted with the impacts of a changing climate. As an inland coastal community, Durham has witnessed a variety of coastal hazards, including flooding from storm surge and extreme precipitation. Some of the most susceptible areas to coastal flooding include low-lying areas along the Oyster River and its tributaries, at the confluence of the Oyster River and Little Bay, and along the shores of both Little Bay and Great Bay. These areas are all within the coastal floodplain area, making them particularly vulnerable to flooding from seasonal high tides, coastal storms, and sea-level rise. Notable back-to-back 1% annual chance storm events occurred in 2006 and 2007 that brought severe rain and flooding and caused major damage to roads and other infrastructure. Larger storms such as Tropical Storm Irene (2011) and Hurricane Sandy (2012) resulted in minimal damage from rain and wind; however, these storms caused hundreds of millions of dollars in damage to other parts of the country, and similar storms in the future may take a different path hitting New England more directly.

Quick Fact: The National Oceanic and Atmospheric Administration estimated that Hurricane Sandy caused at least $70 billion in damages, making it among the costliest storms in U.S. history.

Based on extensive scientific research and climate projections, these coastal hazards are expected to continue and likely increase, creating new challenges, such as impacts to water resources, infrastructure (including transportation networks, electrical grid, and communication networks), the food system, human health, and the environment. The public, policy- and decision-makers, the scientific community, and planning agencies all over the world will need to work together to generate and implement solutions to mitigate the impacts of these emerging threats.

This chapter builds upon past climate-related work the Town has completed and is intended to examine the most significant climate change risks and vulnerabilities that need to be addressed. It offers recommendations to help Durham reduce impacts and adapt to life in a changing climate. This chapter and its goals should be revisited whenever new climate science and guidance reports are published such as the Intergovernmental Panel on Climate Change assessments, to evaluate urgency.

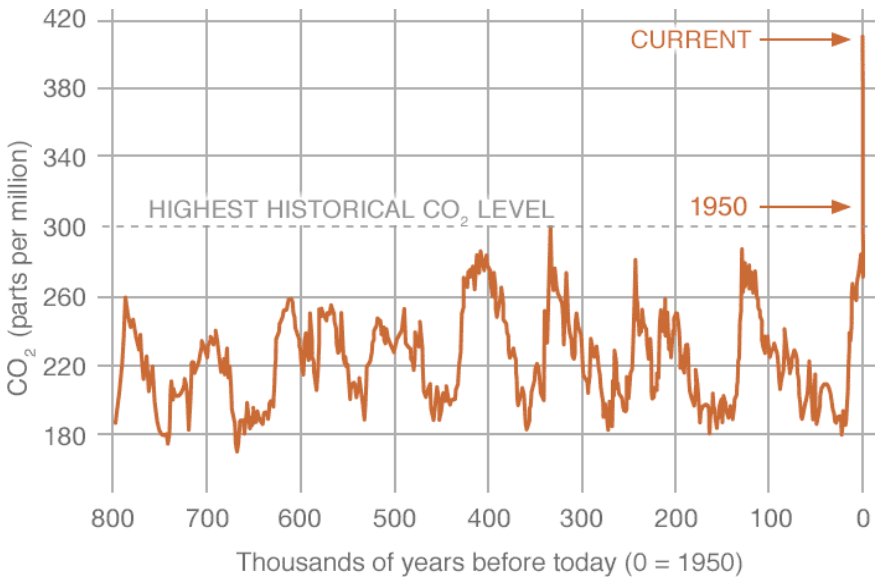
Introduction

Certainly, the Earth's climate has fluctuated throughout its history. According to the National Aeronautics and Space Administration's (NASA) Global Climate Change, there have been seven cycles of glacial advance and retreat over the last 650,000 years, with most of these changes driven by fluctuations in the Earth's orbit that alter the amount of solar energy the planet receives, especially in the northern hemisphere, combined with the powerful **ice-albedo feedback loop** (ice is more reflective than land or water surfaces). This is an example of a positive feedback loop; feedback loops can either be positive or negative. Positive feedback loops exacerbate the impacts of climate change by amplifying a system change, whereas negative feedback loops reduce the effect of a system change and can help maintain balance. Other influences on Earth's climate on shorter timeframes (annual to century scales) include variations in solar output and volcanic eruptions that generate particles that reflect sunlight, which can brighten the planet and cool the climate. These processes are natural and will continue to affect the planet's climate; however, an extensive and ever-growing body of scientific evidence—the IPCC's Fifth Assessment and the Fourth National Climate Assessment for example— point to human activities, and especially the burning of fossil fuels, as being responsible for the warming of the planet over the past 50 years.

As of December 2022, concentrations of carbon dioxide (CO_2) in the Earth's atmosphere have reached 420 parts per million (ppm). For context, according to ice core samples, CO_2 concentrations never exceeded roughly 300 ppm over Earth's last three glacial

cycles (Figure 1); studies have shown that human activities have raised atmospheric concentrations of CO_2 by 150% since pre-industrial levels in 1750.

Figure 1: Proxy Measurements of CO_2 taken from Reconstruction of Ice Cores (Source: NOAA)



Atmospheric levels of other greenhouse gases, including methane, nitrous oxide, and CFC have also risen over the past several decades as well. This increase in atmospheric greenhouse gases is primarily responsible for the rise in the planet's average surface temperature of about 1.6°F since the late 1800s, with most of the warming occurring in the last 50 years. Nineteen of the twenty warmest years on record have happened since 2001. This warming trend is considered extremely likely to continue.

These increases in temperature have affected the Earth's climate in many ways. Ocean temperatures have warmed, the Greenland and Antarctic ice sheets are rapidly losing mass, glaciers are retreating all over the world, global sea-level is rising, snow cover has decreased, and the number of record high temperatures and intense rainfall events has been increasing since the 1950s.

Climate Change in New Hampshire

Greenhouse Gas Emissions

The New Hampshire Department of Environmental Services (NHDES) conducts an annual greenhouse gas (GHG) emissions inventory that tracks the six main GHG's, including carbon dioxide, methane, nitrous oxide, and three industrial process gases (hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride). According to 2017 data, carbon dioxide makes up the majority of NH's GHG emissions (92%), primarily due to burning fossil fuels for heat, electricity, and to power motor vehicles. GHG sources are usually categorized into the following sectors: transportation, electricity generation, residential, commercial, industry, waste and wastewater, and agriculture. Transportation is the predominant sector, producing an estimated 47% of the state's GHGs.

Fortunately, a large majority of NH is forested, with these areas acting as a carbon sink. This process, called **carbon sequestration**, could be responsible for absorbing and storing nearly 25% of CO_2 emissions from the burning of fossil fuels in the state. Intact forested ecosystems are also a major factor in **climate resiliency** for New Hampshire. It is estimated that a 40-acre forest in northern New Hampshire holds the same amount of carbon as 53,000 automobile tanks of gasoline. Large undeveloped and unfragmented forested blocks are also very important for wildlife and biodiversity conservation and as of 2019, 47% of large forest blocks in the state are permanently conserved. **Climate corridors,** identified by the Nature Conservancy as part of their Resilient and Connected Landscapes project, facilitate tree and wildlife species range shifts as temperatures and habitat continue to change. Intentionally keeping areas forested and protected is a natural safeguard for fresh drinking water and clean air for local communities and offers numerous benefits for the state overall, both now and in the future.

Air Pollution

New Hampshire has a network of 13 air quality monitoring stations that continuously monitor air pollutants. NHDES staff track progress in reducing air pollution and inform the public about air quality in their communities and any necessary health precautions. New Hampshire's regulated air pollutant levels have generally dropped since the 1970s, but air quality in many parts of the country still fails to meet health-based air quality standards. While the impact of climate change on the production of fine particulate matter pollution has been inconclusive, warmer temperatures associated with climate change will increase ozone production and ozone concentrations in urban areas. This is likely to lead to more pollution-related cardiorespiratory illness and death in the state.

Increased Temperature on Land

Temperature, of course, is one of the most used indicators for climate change. Historically, New Hampshire has been characterized by cold, snowy winters and mild summers but there has been significant evidence this seasonal definition is changing. According to datum from the NOAA National Centers for Environmental Information, since the early 20th century, the average annual temperature in the state has increased by approximately 3°F, and state's maximum temperatures have increased between 0.5°F and 2.6°F. The state's temperature change has been continuously recorded at three meteorological stations in southern New Hampshire (Keene, Durham, and Hanover) for the last century and all three weather stations show consistent long-term minimum and maximum temperature increases. Overall, more than half of the state's warmest years on records have occurred since 1990.

According to Wake et al. 2014, while the number of hot days has increased slightly across southern New Hampshire, there has been a dramatic increase in the rate of winter warming over the last four decades at all three stations, which may be linked to decreases in snow cover through changes in surface albedo, or reflectivity. In Durham specifically, the number of hot days has increased slightly over the last five decades (+0.8 days per decade) and the number of cold days has reduced significantly. (-5.0 days per decade).

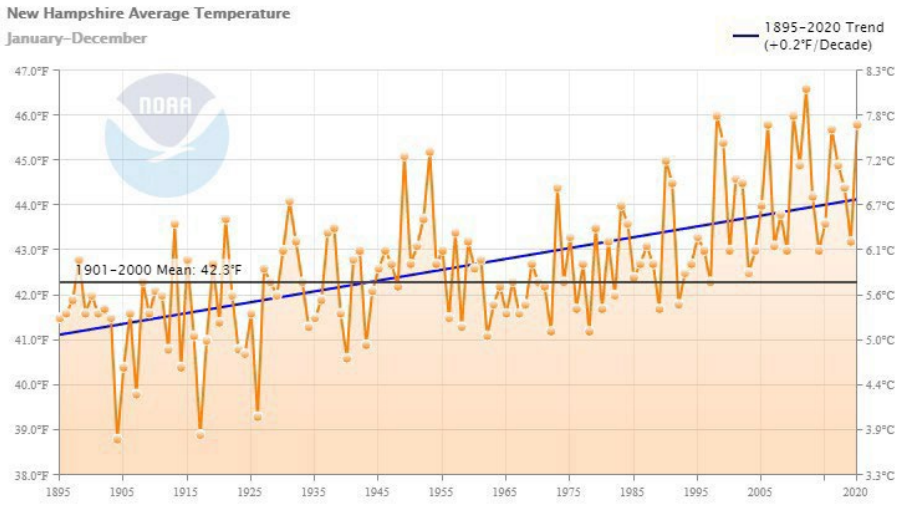


Figure 2. New Hampshire Average Temperature Change (1895-2020). (Source: NOAA NCDC)

Changes in the distribution of hot and cold extreme temperatures can lead to the increased frequency, duration, and intensity of heat waves, increased nighttime warming, longer growing seasons, drought length and intensity, crop failure, and the expansion of suitable habitat for both Lyme disease-bearing ticks and invasive species such as the emerald ash borer.

According to the EPA, accompanying the rising temperatures is a steady lengthening of the United States' **growing season**. The average growing season has lengthened by two to five weeks across the U.S since the beginning of the 20th century, with a particularly large increase over the last 30 years. Since 1970, datum collected in Concord, NH shows an increase of 27 days between the first and last frost of the year and in Durham specifically, the growing season has increased by 10 days per decade since 1960.

As the Northeast is known for its long, cold winters, and warm to hot summers, this seasonality is an important cultural and economic driver of regional economies such as

agriculture, commercial fishing, forest products, and tourism. Cold, snowy winters help support regional tourism such as fishing, hunting, and winter sports. Timber harvesting on wet sites often occurs in the winter when soils are frozen, or snow covered, and maple sugaring depends on sufficient cold winters for adequate sap quantities. Milder winters and early springs are adversely impacting the region's tourism, farming, and forestry activities.

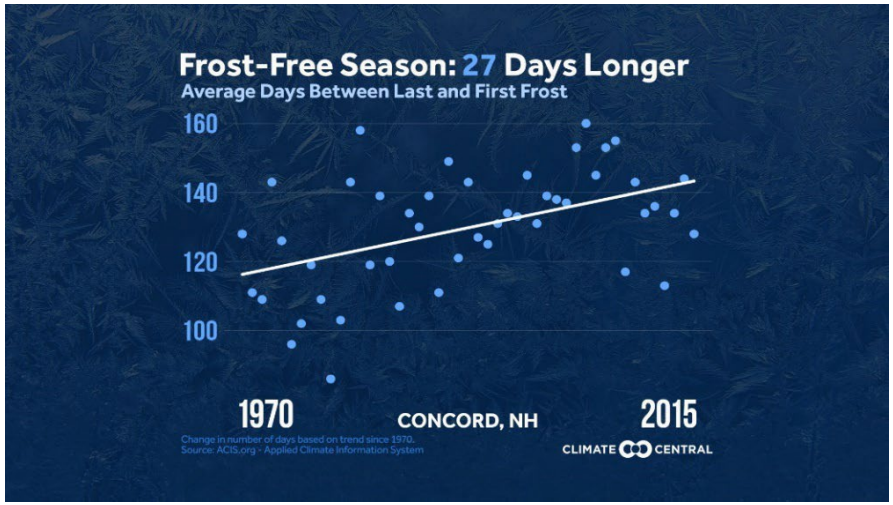


Figure 3: Length of Frost-Free Season in Concord, NH, 1970-2015
(Source: (Applied Climate Information System) ACIS.org)

The growing season determines what crops can be grown in a region and changes can have both positive and negative effects. While a longer season can allow farmers to diversify their crops or have multiple harvests from the same plot, it can also limit the types of crops grown, increase the heat stress on crops, encourage invasive species or weed growth, and increase pests and irrigation demands. Farmers will need to combat the northward expansion of the European corn borer and the Western corn root worm on their crops, and the warmer temperatures will likely allow the codling moth—an apple tree pest—to complete a third generation requiring additional insecticide applications.

Increased Temperature in the Ocean

Worldwide, ocean temperatures are also increasing. The Gulf of Maine is warming at an accelerating rate, three times as fast as the average global rate in the last three decades and seven times as fast in the last 15 years. In 2012, during the most intense ocean heat wave in the last three decades, sea surface temperatures in the Gulf of Maine were a record-breaking 69.98°F. These warming temperatures are having cascading effects on environmental and ecological patterns such as marine species migrating northward in search of colder waters, and are already impacting NH fishing grounds with the closure of the Gulf of Maine Shrimp Fishery based on depleted shrimp populations. These changes also lead to higher levels of evaporation and greater moisture in the air, which contributes to more precipitation and extreme weather events.

Quick Fact: The Gulf of Maine is warming seven times as fast as the average global rate over the past 15 years.

As oceans grow warmer, **ocean acidification** increases as well. Several factors contribute to this, an important one being ocean absorption of carbon dioxide from human activity. Another factor is increased pollutants from wastewater and stormwater runoff in coastal waters, which increases net primary production, resulting in higher respiration and carbon dioxide which in turn furthers coastal acidification. Ocean acidification is important because carbonate ions—which are less abundant than hydrogen ions in the seawater—are important block structures for seashells and coral skeletons. Decreases in ions due to acidification make building and maintaining carbonate structures more difficult. Local researchers have recently begun to examine the effects of ocean acidification on marine species in the Gulf of Maine.

More Rainfall and Less Snow

As winter warms in New Hampshire, snowfall and snow cover will continue to decrease (See Increased Temperature on Land). Although snowfall amounts in recent winters have varied, overall snowfall has been decreasing at most monitoring stations and the number of snow-covered days is decreasing throughout the state. This is because as cold seasons warm, more precipitation falls as rain instead of snow. Precipitation across the region has increased in the last century, with the highest number of extreme precipitation events happening in the last decade. Between 1958 and 2010, the northeastern United States experienced a 70% increase in precipitation during heavy rain events. The statewide average for annual precipitation is 44.2 inches, with higher amounts in the southern and eastern parts of the state due to proximity to the Atlantic Ocean. This average in southeastern New Hampshire is projected to increase by 5-10% by mid-century and 7-15% by 2100—with a subsequent increase in flooding. The increase is expected to be greatest in the winter and spring, intermediate in the summer, and lowest in the fall.

These observations in total and seasonal precipitation are due to an increase in the intensity and frequency of individual precipitation events, with the Great Bay watershed showing a 15-38% magnitude increase of extreme daily precipitation since the 1950s. These large precipitation events have contributed to significant springtime flood events in coastal New Hampshire and are projected to increase the risk of future flooding. Extreme precipitation events also cause non-coastal flooding of rivers, streams, roadways, and active agricultural fields which can result in contamination of farmland soils by floodwaters as well as crop failure.

Wiswall Bridge during May 2006 Flood Event (Photo Credit: Durham Hazard Mitigation Plan)

Sea Level Rise, Groundwater Rise, and Storm Surge

Since reliable record keeping began in 1880, global sea levels have risen approximately eight inches and are projected to continue rising another one to four feet by 2100. Since 2005, roughly two-thirds of this global sea level rise can be attributed to the tectonic shifts in mass from continents into the ocean and melting glaciers and ice, a consequence of rising ocean and land temperatures. According to the NH Coastal Flood Risk Summary, Part 1: Science (2019), if global GHG concentrations stabilize and then decline by the end of the century, coastal New Hampshire is likely to experience between 0.5 to 1.3 feet of relative sea level rise (RSLR) by 2050 and 1.0 to 2.9 feet by 2100. If GHG concentrations continue to grow throughout the 21st century, coastal New Hampshire is likely to experience RSLR of 1.5 to 3.8 feet by 2100. It is very likely that coastal NH will experience direct impacts from RSLR on coastal property, public infrastructure, human health, public safety, local economies, and natural resources including more

extensive coastal flooding, migration and loss of saltmarshes, coastal erosion, saltwater intrusion, higher tides, and groundwater rise. Culturally, these impacts will affect a large part of New Hampshire's populations with strong ties to the ocean and activities surrounding it.

Quick Fact: Even if greenhouse gas emissions stabilize by the end of the century, coastal New Hampshire is likely to experience between 0.5 to 1.3 feet of sea level rise by 2050, and 1.0 to 2.9 feet by 2100.

As sea levels rise, **groundwater** will rise along with it to reach a new equilibrium between aquifer recharge and groundwater discharge and withdrawals. New Hampshire's Groundwater Rise Zone is projected to extend up to 2.5 to 3 miles inland from the coast, which is 3-4 times farther inland than tidal-water inundation from sea level rise. The inland extent and magnitude of groundwater rise will vary depending on local geology and proximity to streams and freshwater wetlands. This RSLR-induced **groundwater rise** may increase groundwater-quality degradation, saltwater intrusion, and streamflow and may have potential impacts to underground infrastructure and wetlands in the coastal region.

New Hampshire's coastline is subjected to both large tropical storms or hurricanes from lower latitudes and North Atlantic storms or nor'easters. These storms temporarily raise sea levels due to several different processes and the impact of this **storm surge** depends on how the timing of the storms coincides with the tides. There is strong correlation between sea surface temperatures and increased hurricane activity and, considering the projected increases in sea surface temperatures over the next century, Atlantic storms could become more intense and more frequent. Intense hurricanes, extreme hurricane winds, and hurricane precipitation are more than likely to increase by the year 2080 and the possible damage effects of extreme storm intensity and frequency must be considered when assessing risk. According to The NH Coastal Flood Risk Summary Part I: Science (2019), the challenge of projecting future storm surge effect is exacerbated by unknown changes to topography that will occur in the years leading up to future storm events. These uncertainties regarding future storm intensity increases due to climate change make it difficult to account for possible effects but overall, as sea level rises and storm intensity increases, storm surge-related inundation, erosion, and damage are expected to worsen over the next century.

Coastal Flooding at Town Landing during 2017 King Tide Event
(Photo Credit: Strafford Regional Planning Commission)

Drought

Drought is yet another prominent extreme weather event that is increasing due to climate change. In the 21st century, droughts have been characterized by hotter temperatures, longer durations, and greater spatial extent with recent years being punctuated by periods of moderate to extreme drought development. Droughts are also exacerbated by growing human demands on water resources. Drought conditions have historically been driven by sea surface temperatures, internal atmospheric variability, and land-atmosphere feedback, but human-caused climate change is increasingly affecting the frequency, intensity, and extent of droughts. While it is projected there will be increased precipitation in New Hampshire, the intensity of naturally occurring droughts is projected to increase as well. This is because higher summer temperatures will increase the rate of depletion of soil moisture during dry spells and the projected increases in average annual precipitation will take place primarily during the winter and spring. Practically, this could look like rainier winters and springs with more extreme precipitation events and longer periods without precipitation more prone to drought in the summer and fall.

For example, over the past two decades, the state has experienced several significant periods of drought including in 2001-2002; 2015-2016, 2020; and most recently 2021. The most recent drought period only ended due to extreme precipitation in the month of July 2021. The NH Drought Management Program determined that the drought that impacted the state in the early 2000s was the third worst on record, and that recent droughts were due to a combination of a below average snowpack in the spring, little precipitation to recharge the groundwater, and the inability of watersheds to store large volumes of water due to their geology. With extreme variation in environmental conditions due to climate change, drought probability may grow in the future.

The large amount of water resources and relatively sparse population in New Hampshire have tended to minimize the impacts of drought events in the region, but this protection may be endangered in the future with increases in drought frequency or severity combined with population growth and increased development. Increased development means more impervious surfaces, and more impervious surfaces will contribute to additional precipitation runoff and less groundwater recharge during rain and flooding events. Impacts from climate change may cause a 10% increase in annual groundwater recharge rates in the New Hampshire coastal region over the next century; however, increases in impervious surfaces may reduce this recharge 5 to 10%. Land development associated with increases in demand due to population growth will also increase groundwater withdrawals for drinking water and will contribute to intensified groundwater depletion during droughts.

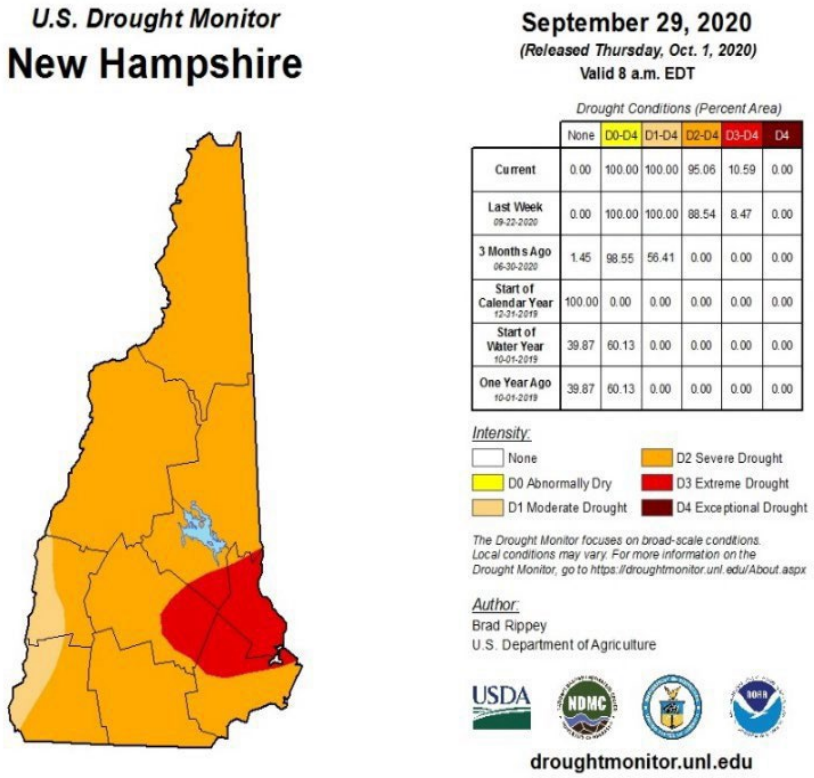


Figure 4: US Drought Monitor: New Hampshire (10/20/20)
(Source: US Drought Monitor)

Species Migration and Invasive Species

The timing of biological events (bird migration, wildlife breeding, plant flowering and fruiting) is determined by variables such as seasonal temperature, food availability, and pollination. In the Northeast, flowering dates are occurring one week earlier than the mid-1800s and migratory birds are arriving and breeding earlier, revealing a shift in migratory patterns. Forests are a defining feature of New Hampshire and climate change has the potential to alter the forest species composition, distribution, abundance, and productivity – as well as their associated species— in several ways. While not uniform and depending on the suitable habitat characteristics for species (such as soils, elevation, latitude, and other factors), some tree species will experience decreases in suitable habitat, while others will see expansion of suitable habitat as the climate changes. Decreases in suitable habitat are projected to be greatest in Southern and Coastal New England.

While already a major threat to native New Hampshire ecosystems, nonnative plant and animal species are becoming more of a concern because of their increased potential to outcompete native species. Some nonnative species can establish themselves faster than native species because they lack competitors and are better able to respond to climate change-induced changes such as warmer temperatures, earlier springs, and reduced snowpack. Additionally, the warmer temperatures are likely to expand the ranges of certain invasive species that were previously limited by colder northern temperatures. Fewer days below freezing is leading to increases in rates of pest outbreaks and vector-borne diseases (disease that results from an infection transmitted to humans and other animals by blood-feeding arthropods, such as mosquitos, ticks, and fleas) such as Dengue fever, West Nile Virus, Lyme disease, and malaria. All these factors can lead to a decline of natural species, increases in nonnative or invasive species, and a reduction in biodiversity.

Planning for Climate Change

Associated with these changes are increased risks that will likely impact community health and safety, public and private infrastructure, economies, as well as historic, natural, and cultural resources. To increase overall climate resilience, it is important that communities are proactive in their planning to reduce greenhouse gas emissions, increase energy efficiency, increase local food production, and implement effective adaptation strategies.

To plan for a resilient future, climate change must be studied and understood. Long-term impacts are largely dependent on a global ability to curb greenhouse gas emissions, but since we do not know exactly how, when, or if we will achieve this, scientists use multiple emissions scenarios to model and predict what the future might look like. While short-term projections are relatively consistent, scenarios increasingly vary the further into the future they go. Planning via a range of projections will assist communities in adapting to whatever may come. As science and technology continue to advance, these models will become more precise, and it is essential for communities to use the most up-to-date climate predictions. The state has produced several reports that provide guidance for incorporating climate risk into land use planning and decision making. The NH Coastal Flood Risk Summary Part I: Science (2019), developed by a team of scientific experts from the University of New Hampshire, provides updated projections of sea-level rise, coastal storms, groundwater rise, precipitation, and freshwater flooding for the coastal region. The companion document to the Science report, the NH Coastal Flood Risk Summary Part II: Guidance (2020), offers guiding principles for enhancing coastal flood resilience, and is designed to help municipal decision makers and design engineers select and incorporate updated coastal flood risk projections into planning, regulatory, or site-specific efforts. The Guidance creates a common framework allowing for flexibility, encourages creativity, integrates science, and prioritizes equity and justice approaches in private, local, state, and federal entities.

Amidst planning for climate change, planners and decision-makers must be concerned about equity and social justice. Underrepresented communities, including communities of color, people with low incomes, the elderly, the disabled, the young, and indigenous peoples, may be disproportionately affected by climate change impacts. Municipalities need to consider how these underserved populations may be impacted by policy changes. to include them in decision-making processes, and to create ways to increase local awareness.

"The purpose of the climate adaptation Chapter is to develop strategies that protect areas at risk. . . due to climate change and to identify various regulatory and non-regulatory options that can be considered by the Town."

-Todd Selig, Town Administrator

Living Shoreline Installation at Wagon Hill on Great Bay (Photo Credit: NHDES)

II. Identifying Local Impacts

To project what climate change may look like in Durham, future impacts were broken into three categories including built infrastructure, natural and working lands, and community and economy.

Built Infrastructure

Long-term resilience to climate change will involve protecting important buildings and infrastructure within the Town of Durham. Datum from Durham's 2017 C-Rise report indicates that increased tidal flooding will impact a number of the Town's water resources that will in turn impact several transportation assets and a handful of critical facilities including water and sewer pipes, a sewer lift station, and two dams.

Transportation

Durham is actively reducing their greenhouse gas emissions and is a leader in sustainable transportation among NH municipalities; however, transportation infrastructure in Durham is and will continue to be subject to myriad climate impacts. Sea level rise will lead to future road flooding, limit evacuation route access, and cause public transportation route failures. More extreme storms and precipitation will contribute to increased flooding and culvert failures and extreme heat will lead to faster degradation of pavement and higher costs for maintenance. Pedestrian traffic may be reduced due to increased heat and there are potential health risks associated with pedestrian use of public transit infrastructure during extremely warm weather. Additionally, climate-induced migration is likely to contribute to population growth here in Durham, increasing demand and dependance on the transportation network. All these impacts should be approached in a proactive and equitable manner to allow for mitigation and adaptation efforts that benefit the entire Durham community.

Local, Private, and State Roadways

Increased flooding, storm surge, and erosion impact coastal community transportation networks by damaging infrastructure and placing coastal populations at risk in the face of increased storm impacts. According to Durham's C-RiSe assessment, about 1.57 miles of roadway within the Town (1.4% of all roadway center miles in Durham) will be affected under the highest sea level rise scenario (6.3 feet of sea level rise (SLR) plus storm surge (SS)).

Other transportation-related assets vulnerable to sea level rise and storm surge include parts of the Town's urban compact zone (24.4 acres) located in neighborhoods near Route 108 along the Oyster River and Beards Creek; three evacuation routes along Route 4, Route 108, and Back River Road; and two NHDOT future planning projects on Bay Road over Great Bay inlet and Route 4 over Johnson Creek (see Table 1).

Table 1: Roadway Miles Subject to Future Flooding

Roadway Ownership	Name	Miles Impacted (w/ 6.3 feet of sea evel rise (SLR) plus storm surge (SS))
State	Dover Road (Rt. 108)	0.08 mi.
State	Newmarket Road (Rt. 108)	0.01 mi.
Town	Piscataqua Road (Route 4)	0.39 mi.
Town	Back River Road	0.30 mi.
Town	Bay Road	0.03 mi.
Town	Cedar Point Road	0.24 mi.
Town	Jackson's Landing	0.01 mi.
Town	Old Landing Road	0.14 mi.
Town	Riverview Road	0.03 mi.
Town	Watson Road	0.01 mi.
Private	Adams Point Road	0.12 mi.
Private	No Name	0.17 mi.
Private	Colony Cove Road	0.01 mi.
Not Maintained	Bunker Lane	0.02
	Total Miles	**1.57 mi**

Source: Durham's C-RiSe Report

Additionally, some roadways will be susceptible to increased flooding problems from extreme precipitation and stormwater runoff issues. As the climate changes, more frequent and more severe storms may exacerbate these ongoing issues along these roadways. Identifying these roadways by analyzing culvert impacts, future floodplain projections, and pavement conditions can help build resiliency in these areas.

Pavement Condition

Rising sea levels will also result in a rise in groundwater levels. In some places, this may result in the groundwater intersecting with aggregate (basic materials used in road construction, such as gravel, sand, recycled concrete, etc.) drainage layers of coastal road infrastructure, reducing the service life of the pavement. A recent project looking at groundwater rise impacts specific to Durham and a groundwater study from the University of New Hampshire both identify roadways along the coast that may be vulnerable to future groundwater rise. Results showed reductions in service life for all evaluated sites; the magnitude and timing of these impacts depended on several variables.

Climate change may also influence the properties of pavement materials and affect pavement response and performance. According to a study by UNH researchers, potential impacts include the following: increased hot days and heat waves leading to potential increases in rutting and the migration of liquid asphalt; delayed onset of seasonal freezes and earlier onset of seasonal thaws may increase pavement deterioration due to more freeze-thaw cycles; and increased precipitation volumes and intensity that could increase soil moisture and reduce the strength of unbound granular materials of the subbase.

Culverts

While Durham has not done a complete analysis of the vulnerability of the Town's culverts to sea level rise, culverts adjacent to affected roadways may experience future flooding problems and washouts. As part of the C-RiSe project, the Town assessed ten culverts within the 100-year floodplain that will be affected by sea level rise and storm surge for hydraulic flow capacity and aquatic organism passage. The assessment was based on runoff associated with the current 10-, 25-, 50-, and 100-year storms. The hydraulic portion of the analysis showed that none of the culverts were able to fully pass stormwater flows, meaning headwater would overtop the road in all storm scenarios. Eight culverts provide no or reduced aquatic organism passage. Only one culvert had a transitional rating for any hydraulic flow capacity scenario and only two had full aquatic organism passage ratings.

The NHDES Coastal Program also assessed New Hampshire tidal crossing infrastructure for coastal resilience in 2018. The project collected data on the tidal crossings, prioritized each crossing's attributes based on management objectives, and provided these results to stakeholders. The report identified several tidal crossings in Durham with a variety of replacement priorities. Scoring ranged from one to five where one was the lowest replacement and five was the highest replacement priority.

Table 2: Results of Culvert Assessment

Hydraulic Rating	10-yr storm	25-yr storm	50-yr storm	100-yr storm
Pass	0	0	0	0
Transitional	2	9	9	9
Fail	10	10	10	10

Pass: Headwater stage is below the lowest top of the culvert at the site; Transitional: Headwater stage is between the lowest top of culvert and the top of the road; Fail: Headwater stage overtops the road.

Source: Durham's C-RiSe Report

Identified crossings include:

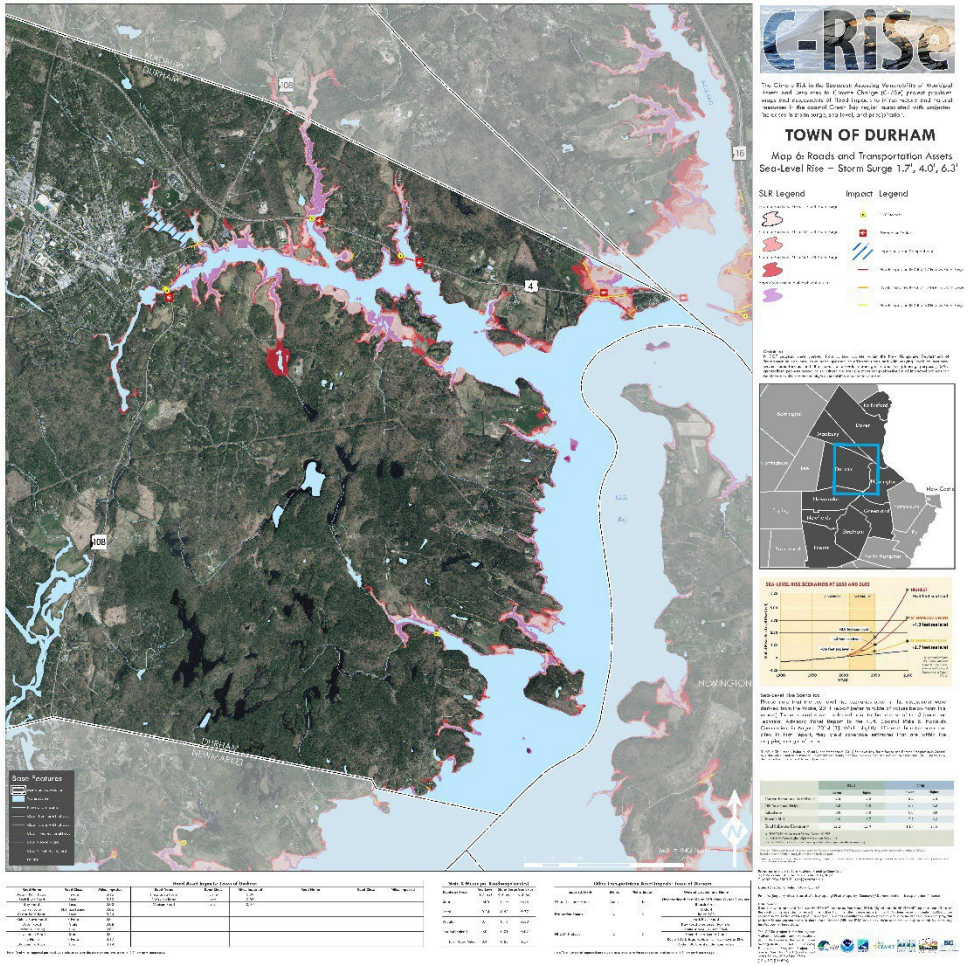
- Bunker Creek at Route 4 with an overall score of 4 (replaced in 2020)
- Johnson Creek at Piscataqua Road (overall score of 2)
- Beard's Creek at Dover Road (overall score of 5)
- Oyster River at Newmarket Road (overall score of 3)
- Unnamed stream over Bay Road (overall score of 2)

With this information as a starting point, Durham can improve resiliency to washouts and future flooding issues by incorporating sea-level rise and increased precipitation into culvert and tidal crossing improvement and replacement projects (for example, by using the NH Coastal Flood Risk Summary, Part II: Guidance (2020). With some improvements already scheduled in the Capital Improvement Plan, the Town has already begun to address the top culvert priorities and decrease possible vulnerabilities. Further recommendations include incorporating high priority tidal crossings into relevant planning documents including the Capital Improvement Plan, the Hazard Mitigation Plan and transportation planning documents.

State Transportation Projects

Some state-level transportation projects are vulnerable to climate change impacts, including red listed bridges that might be susceptible to sea level rise. In New Hampshire, red listed bridges are those with one or more major elements in poor condition. State-owned red listed bridges are inspected twice a year and municipally owned red listed bridges are inspected once a year. The Metropolitan Transportation Plan outlines planned projects through 2041 whose improvements will ensure structural safety and compatibility with sea level rise and storm surge scenarios. The map below illustrates state and municipal roadways vulnerable to sea-level rise and coastal storm surge flooding.

As NHDOT continues to focus on increasing bridge resiliency to sea level rise, upfront project costs will increase. Bridge infrastructure is continually more expensive as it accounts for higher flood levels and requires more land, more built infrastructure, and complex plans for adaptation. These added costs are and will be reflected in the NHDOT budget requirements and may increase the burden on the state's tax paying population. However, incorporating climate projections into infrastructure projects now will likely reduce the need (and associated costs) for future maintenance and repair due to flooding impacts.



Did You Know?

US Route 4 is a critical east-west route in NH that carries over 16,000 vehicles per day and crosses several environmentally sensitive areas. The Bunker Creek Bridge replacement was part of the State's Ten-Year Transportation Improvement Plan and was number eight on the 2014 Bridge Priority List. Updates for the single-span reinforced concrete slab bridge included widening to accommodate bicyclists and pedestrians, correcting two geometric deficiencies, and raising the height of the bridge by approximately four feet for continued access to safe waterway recreation opportunities in the area and to accommodate 100-year flooding concerns. The project, completed in the fall of 2020, was awarded a Best-Value Design-Build Contract from the American Council of Engineering Companies of New Hampshire for its excellent innovation, teamwork, and reduced impacts.

Local Transportation Projects

Durham's Capital Improvement Plan (CIP) is a planning and fiscal management tool used to coordinate the location, timing, and financing of capital improvements over a ten-year period. The CIP includes project descriptions, priority rankings, a year-by-year schedule of expected funding, and an estimate of project costs and financing sources. By providing plans for strategic investments, the CIP helps ensure that municipal development and infrastructure investments are consistent with a community's plans and vision. Durham's CIP contains several transportation-related projects that could be impacted by a variety of climate change scenarios.

The CIP identifies three culverts projected to be replaced between 2021 and 2023. Identified culverts include one on Oyster River Road in the Faculty Development neighborhood ($80,000 estimated project cost), a culvert on Mill Road near Foss Farm ($70,000), and another on Mill Road at College Brook ($85,000).

The CIP also identifies the Longmarsh Culvert-to-Bridge Replacement as a priority. This project includes replacing the existing culverts at Longmarsh Road crossing of Longmarsh Brook with a clear span bridge. The existing culvert built in the 1980s has been reconstructed numerous times due to storm events in 2006, 2007, and 2010. The combination of a low roadway profile elevation and inadequate hydraulic capacity of the culverts results in the road being overtopped frequently. The proposed improvements would replace the culvert with a clear span bridge with greater hydraulic capacity and higher roadway. Total estimated project costs are $1,300,000 with the project taking place in 2025.

As with the state transportation projects, climate impacts will increase the costs and complexity of municipal projects. These added costs will affect the Town's capital improvement budget and could increase the burden on the Town's tax paying population. However, proactively incorporating climate projections into infrastructure projects can save money for the Town in the long run as replacement of transportation infrastructure after a damaging event often costs more. Making climate-related adaptations now will likely reduce the need (and associated costs) for future maintenance.

Did You Know?

Under the Operation Division of the CIP is the Oyster River Pedestrian Bridge on the Stevens Woods Property, a project spearheaded by residents to connect downtown Durham to a network of trails. The bridge crosses the Oyster River from Thompson Lane to Stevens Woods and is restricted to pedestrian uses. A 100-foot aluminum span bridge was recently built to clear the high-water marks on both banks of the river. The project was primarily funded with private donations, the purchase of an easement by UNH, and a grant from the NH State Trails Program. The new bridge was installed in early 2021 and will be named after Dr. Kenneth Rotner, a Town Councilor and School Board member, who passed away in 2020.

In fiscal year 2021, Durham Public Works requested and received funding to conduct assessments of critical drainage assets to develop a drainage master plan. This work was initiated and included on-site structural evaluation and video inspections of five

major culverts on major collector and single access roadways including Madbury Road, Edgewood Road, and Ross Road. Funding for the Ross Road culvert construction improvements has been included in the American Rescue Plan funding allocation for Fiscal Year 2022.

The proposed funding requests over Fiscal Year 2023 through Fiscal Year 2026 provides the necessary funding to construct the Madbury Road Complete Streets Improvements. (CIP)

Urban Compact Area

Urban Compact Areas are state-owned roads that are maintained and managed by the municipality. Roads within the Urban Compact Area are designated as Class IV highways, and Urban Compact Agreements usually delegate responsibilities for the highway between the community and NHDOT. Typically, the municipality is responsible for winter maintenance, street sweeping, and other ordinary maintenance. Projects in this area can be locally or state/federally funded and with this flexibility, they are usually subject to less regulation. The funding source for a project in this area will affect the requirements, design, and public input process, and most projects are included in the municipality's Capital Improvement Plan.

For Durham, the Urban Compact Area is located in neighborhoods near Route 108 along the Oyster River and Beards Creek. While most of the maintenance responsibility falls to the Town, this area could provide an opportunity for NHDOT and the Town to discuss the shared costs associated with climate resilience and recovery. Part of the Urban Compact Area will be affected by SLR scenarios as identified in the C-Rise assessment. Currently, infrastructure resilience and climate change have not been considered by NHDOT within the Urban Compact Area, and a discussion between NHDOT and the Town could address how impacts such as sea level rise, groundwater rise, and increased heat may affect these areas and whose responsibility it will be to pay for repairs and maintenance would be beneficial.

Public Transit System

Public transportation is an important part of the Durham community and bridging the gaps in a transit system ensures certainty and reliability for riders. It is especially important for promoting equity and accessibility as it encourages healthier habits for its riders, is safer than individual vehicles, and supports community cohesion. Additionally, public transit reduces traffic congestion, gas use, and air pollution. It also promotes personal mobility, access, and personal freedom with a diverse set of options. Durham is serviced by the University-run transportation network which includes Wildcat Transit—operating in Durham, Dover, Madbury, Portsmouth, and Newmarket— and the Campus Connector, which serves Durham. Both provide ADA services on-campus. The Wildcat Transit is also connected to COAST, a regional transit service connecting ten communities from Farmington, NH, to Kittery, ME. In 2019, COAST route systems logged over 427,000 passenger trips, totaling almost 3.5 million passenger miles, thereby reducing private vehicle miles significantly for the regional roadway system. As a federally funded entity, COAST is required to provide door-to-door demand response services to anyone qualifying under ADA and living within three-fourths of a mile of a fixed bus stop. As COAST does not operate directly in Durham, this ADA service does not apply, but there are other demand-response services available in the Town through the Alliance for Community Transportation (ACT). The Community Action Partnership of Strafford County is a member of ACT and works to improve community transportation services in the southeast New Hampshire region. This could serve as an example of integrating equitable transportation practices within the Town and providing climate-related co-benefits. Additionally, Ready Rides operates in Durham providing door-to-door transportation to essential services for the Town's aging and disabled populations.

Amtrak's Downeaster also services Durham, connecting the Town to Boston, MA, and Portland-Freeport-Brunswick, ME. In fiscal year 2019, over 57,000 passengers rode the Amtrak Downeaster to and from Durham. Durham introduced ZipCar, a car sharing service open to community and campus members, in the fall of 2009. As of 2020 over

1,900 members have joined from Durham, logging over 56,000 hours, and traveling more than 425,000 miles.

UNH Wildcat Transit (Photo Credit: UNH)

Extreme heat events, projected to increase with climate change, may impact Durham's public transportation network and the residents who use it. An increase in heat can require dropping the speed of trains, increasing travel times for commuters using the Downeaster, and potentially increasing freight travel times to and from the Town. Durham also has two fairly new senior living communities, RiverWoods and Harmony Homes by The Bay. RiverWoods has plans to develop trails and a sidewalk to provide access to downtown. A higher frequency of heat waves in summer months means higher concentrations of ground-level ozone which may affect populations with chronic health problems when using these paths and trails during summer months. Increased heat-related morbidity and mortality is projected to be one of the most significant impacts of climate change on human health and the northeast is particularly vulnerable.

Evacuation Routes

Important transportation routes leading in and out of Durham are critical to protecting life and property. Interruptions to access for the community due to sea level rise, riverine flooding, and storm surges can cause significant issues for emergency response and evacuation. Mutual aid with surrounding communities, isolation prevention planning, and evacuation routes can all be disrupted by increased climate impacts.

According to Durham's 2020 Emergency Operations Plan, there are three major transportation routes that run through the Town: US Route 4, NH Route 108, and NH Route 155A. These three routes, along with Main Street, are primary evacuation routes and are susceptible to all hazards and inland flooding risks. These routes must provide safe access to critical sites, such as shelter facilities, medical and supply distribution points, during an emergency. The plan notes that all roadways in Durham are susceptible to hazards such as flooding, high winds, and hazardous materials spills.

River flooding during large storm event (Photo Credit: Durham Hazard Mitigation Plan)

According to SPRC's Coastal Sea Level Rise Impacts Viewer, there are two bridges in Durham that will be affected by two feet or more of sea level rise: where Route 108 and Route 4 cross the Oyster River. Both are recognized as critical transportation links for evacuation. Flooding and potential road closures at these points would significantly affect the Town's mutual aid services with Dover and Newington, increase emergency response times, and create isolation challenges for individuals who may need to shelter in place. During the Mother's Day flood in May 2006, severe rain and flooding damaged roads and caused road closures. Bennett Road and Longmarsh Road saw significant damage, were closed during the storm, and left approximately 120 people stranded due to the Bennett Road closure.

Additionally, impacts to evacuation routes in neighboring communities, such as Dover and Madbury, will greatly impact the continuity and effectiveness of Durham's evacuation routes. If certain infrastructure fails on an evacuation route, it can greatly affect emergency response as well as increased traffic burdens on local roads. If the Little Bay Bridge were shut down, the most likely detour for north-south access is NH108, through Durham, which does not have the capacity for that amount of inflowing traffic. US Route 4 in Madbury is susceptible to future tidal flooding and will affect travel along this network. Climate impacts and transportation infrastructure span political boundaries; planning for impacts outside of Durham's boundaries is just as important as planning for those within the Town. Effective planning for these scenarios depends on collaboration among municipalities that share evacuation routes.

Those who rely on public transportation will be more at risk to transportation infrastructure failures or disruptions. It is critical to determine who these populations are, determine their location, and account for their safety and well-being when planning and preparing for emergency evacuation and response, in coordination with NHDOT.

Cross-Boundary Transportation Issues

One of the main transportation impacts climate change will have on Durham is cross-boundary transportation network issues. One example is the Downeaster. Tidal impacts on the Scarborough marshes could create a failure in the route to and from Portland, Maine, cutting off access to those who rely on public transportation. Additionally, some evacuation routes are susceptible to all hazards including inland flooding such as Durham Point and Bay Road. Road flooding, exacerbated by climate change, may create a significant break in the road at certain points that would limit this evacuation route.

While Durham can plan for local impacts, building resiliency within its jurisdiction, some challenges are out of the Town's control. Evacuation routes travel through multiple communities; accounting for transboundary routes is critical. Additionally, certain transportation responsibilities fall to the NHDOT, not the local municipality. When climate resiliency and recovery updates need to be made to transportation assets, it can be unclear whose jurisdiction the updates fall under. Responsibility for cost and maintenance of these projects should be determined proactively.

Shared costs and shared infrastructure can be part of the solution to climate impacts to transportation with the right planning and communication across organizations. Clarifying jurisdictions and planning in partnership with adjacent communities and NHDOT will help prepare the Town of Durham for transportation issues that may arise outside traditional municipal boundaries but will nonetheless affect the Town.

Diversity, Equity, Inclusion in Transportation Planning

Transportation planning for climate impacts presents opportunities to advance the community's overall health and equity. All members of Durham's community must be included and supported when planning for increased resiliency to climate change, especially as certain community members who rely heavily on transportation infrastructure for their social and economic well-being have increased sensitivity and exposure to climate impacts.

Some traditional barriers to an equitable transportation decision-making process include how public meetings are structured and how projects are presented to the public. Historically marketed to populations that are already actively involved, information about meetings and projects can be difficult for underserved populations to access. The traditional in-person structure, typically lacking childcare, for example, limits public participation to specific populations and may exclude others such as single working mothers, those without reliable transportation, and those with jobs outside of the traditional nine-to-five schedule. One lesson learned from the COVID-19 pandemic is that online meetings can enhance accessibility regarding public participation and should be used to the maximum extent practicable.

Another major barrier to equitable transportation planning is how data is gathered. Data collection is usually quantitively heavy, relying on census data and analysis completed by planners and staff. Pairing quantitative information with qualitative data through communication with community members is an important way to capture the complete picture of a planning scenario.

Municipal Infrastructure, Energy Systems, and Other Key Resources

Water Infrastructure

Durham's water infrastructure includes stormwater, wastewater, and drinking water systems, and dams. Each of these systems faces climate change impacts. Extreme precipitation is projected to increase in the warming climate, causing more frequent and severe floods and a greater risk to water infrastructure failure, long-lasting droughts and warm spells can compromise dams due to drying, a reduction in soil strength, erosion, and subsidence or sinking of land, and there are currently no common nation-wide design standards or operational guidelines to address how water infrastructure should be designed and operated in the face of climate change.

Procedures for probability of failure and risk assessments for water infrastructure are based on past flood and rainfall data that assume the frequency and severity of extremes do not vary significantly over time. But in the face of climate change, these frequencies and severities have been changing. Multiple hazardous events such as the combination of riverine flooding, storm surge, and sea level rise, can lead to even more extreme impacts on a community, the environment, and infrastructure, and most risk assessments consider these events in isolation. The failure of one system can lead to the failure of interconnected systems, such as the water-energy infrastructure, and should be considered in future hazard mitigation planning.

Stormwater Infrastructure

A stormwater drainage system is designed to collect or convey stormwater within the Town. Components include municipal streets and roads, drainage pipes, culverts, catch basin, curbs, gutters, ditches, and manmade and natural channels. As sea levels continue to rise, some storm drain outlets, or outfalls, may end up underwater. This is called tail water. When outfalls are partially or completely submerged, stormwater is unable to travel out of the Town, increasing the level and duration of floods. A recommendation is for the Town to conduct a spatial analysis using GIS data to determine the vulnerability of stormwater infrastructure to potential sea level rise and use this information for sea level rise induced flood preparation and mitigation efforts.

A sea level rise impacts on groundwater levels and water quality analysis was completed for the Town in early 2022, in which the Town's stormwater infrastructure was evaluated. Assets, including catch basins, culverts, outfalls, and stormwater pipes in certain areas in Town were identified as being vulnerable to potential groundwater rise. Additional field work will need to be conducted to obtain more specific depth data; however, the final report should be consulted during future planning efforts to repair or replace existing stormwater infrastructure.

Wastewater

Durham's Wastewater Division operates and maintains the Town's wastewater treatment plant, four pumping stations, almost 20 miles of collection lines, septage receiving, sludge disposal, and wastewater service installations. Currently, 1.3 million gallons of sewage are treated daily, with an average retention time of just over 24

hours. Durham's Wastewater Treatment Plant has a sufficient capacity based on current demand and is equipped to meet future demand. The Great Bay Total Nitrogen General Permit allows for Durham to have a future discharge capacity of 2.5 million gallons per day. This permit regulates the amount of nitrogen that can be discharged into the Great Bay watershed by wastewater treatment facilities. The nitrogen discharge permits came into effect in 2021 and Durham's treatment processes are in place to meet these standards.

Clarifying tank at wastewater center (Photo Credit: Town of Durham)

Some areas of the Town's water and sewer infrastructure are vulnerable to potential sea level rise. According to the C-Rise Assessment, 0.26 miles of sewer pipes and 0.11 miles of water pipes will be impacted by the highest sea-level rise and storm surge scenario, for a total of 0.37 miles (1.8% total pipes in the Town). One primary sewer lift station near Beards Creek Dam will have minor impacts from any sea level rise plus storm surge (SLR+SS) scenario. If drinking water infrastructure fails, the risk of exposure to pathogens and harmful chemicals may increase for both residents and people working in the Town. Flooding can cause inflow and infiltration of pollutant sediment into the sewer system and cover of sewer mains (the main drain carrying sewage). If too much clean water enters the sewer systems, it can flow back through sewer pipes, flooding basements and causing manholes to pop open and release wastewater onto roadways.

Traditional homeowner insurance policies do not often cover these kinds of damages, unless additional coverage is purchased, creating increased costs for residents.

Drinking Water System

Long-term protection of ground and surface water resources is essential for high quality drinking water. Durham utilizes both for its public drinking water sources. The Town owns and operates the Lee Well and pump stations, Foss Farm (3 million gallons per day) and Beech Hill (600,000 gallons per day) Storage Tanks, the Town reservoir behind the Wiswall Dam on the Lamprey River, Technology Drive and Madbury Road pressure stations, and a portion of the distribution systems serving the town. The Durham Reservoir, fed primarily by the Oyster River, Chesley Brook, and Dube Brook, serves as an alternative source of drinking water for the Town, with an estimated storage volume of 9 to 14.7 million gallons The Oyster and Lamprey Rivers also provide drinking water. The Spruce Hole Bog Water supply is jointly owned by UNH and the Town to provide additional capacity and redundancy to the UNH-Durham water system. In March 2020, the joint UNH/ Durham Water Treatment Plant became operational, replacing the Arthur Rollins Treatment Plant constructed in 1935.

Did You Know?

The Spruce Hole Conservation Area provides over 35 acres of protection for the Spruce Hole Aquifer—a public water supply for Durham and UNH. The Spruce Hole well can yield up to 1.04 million gallons per day and serves as a redundant water supply source. This well will be used to meet future water supply demands and peak summer and fall water demands. In 2014, a water supply line was laid from Durham's Packers Falls gravel pit throughout the Spruce Hole Conservation Area to an existing water line on the Oyster River Forest.

Drinking water protection is currently implemented on a community scale and the Town's drinking water aquifers receive some protection under the Aquifer Protection Overlay District in the zoning ordinance. This overlay district is intended to protect and maintain existing and potential groundwater supplies and related groundwater recharge areas within the Town.

Because water bodies and aquifers span municipal boundaries, a regional approach to managing these finite resources is essential to maintain Durham's drinking water quality and quantity. The Town has given significant attention to managing these resources and their watersheds—demonstrated by the joint water system's 2017 Source Water Sustainability Award—but long-term conservation measures and assessment of future capacity and demand remains an essential focus to maintain adequate drinking water supplies for the Town.

In the face of climate change, Durham will likely become a receiving Town for climate migrants. While increases in the Town's population could affect current long-term water treatment and drinking water plans, the Department of Public Works uses projections for future growth and buildout analyses to inform future water infrastructure needs. The Town has worked closely with the UNH Stormwater Center to project future water needs, as well as manage current water resources and permits.

The Town of Durham has not reported any instances of dry wells resulting from drought, but water conservation protocols were enacted in response to a drought in 2016. However, the Town has few intensive water users, so overall local impacts of this drought were limited. The Town's 2020 Emergency Operations Plan currently ranks droughts as a low risk overall based on its potential impacts.

Dams

According to the 2017 Durham Hazard Mitigation Plan, the potential for dam breach or failure from catastrophic flooding is high in Durham. Lonsinger Dam has been identified as critical infrastructure that is most likely to be damaged by flooding, based on past flooding area datum. The Oyster Reservoir Dam, Mill Pond Dam, Wiswall Dam, Durham Reservoir Dam, and Beard Creek Dam are all Class B, meaning that dam failure would most likely result in no loss of lives but still would cause major economic loss to structures or property.

Oyster Ricer Dam at Mill Pond (Photo Credit: VHB)

Aging and deteriorating dams and levees represent an increased hazard when exposed to climate change scenarios such as extreme rainfall. According to the C-RiSe Assessment, Durham can expect to see two dams impacted by sea level rise plus storm surge scenarios: Mill Pond Dam and Beards Creek Dam. The Hazard Mitigation Plan also ranks inland flooding as a high risk with its impact on riverine flooding and potential for dam breaches.

Did You Know?

The Oyster River Dam at Mill Pond separates saltwater from the freshwater portion of the Oyster River in the Town of Durham. This dam was designated into the NH River Management and Protection Program in 2011. Due to its age, engineering significance, and local history, it is also listed on the NH Register of Historic Places. The 9.5-acre Mill Pond formed by the dam offers numerous recreational activities, but water quality has declined, with portions of the pond filled with sediment, converting open water to wetland habitat. The NHDES Dam Bureau has identified several safety deficiencies as well as concerns with its structural integrity and stability. The dam does not currently meet the safety standards to pass a 50-year storm event with at least one foot of freeboard between the water surface and the top of the dam abutments.

As part of the Oyster River Dam at Mill Pond Feasibility Study, prepared for the Town of Durham by VHB and partners, several alternatives were developed to address the known structural deficiencies of the dam. Following lengthy study, public feedback, and thoughtful statements by each member of the Durham Town Council, the Council acted in September 2021 by a vote of 7-2, to move forward with dam removal of the historic, head of tide Mill Pond Dam on the Oyster River.

Energy Systems

Durham's residents have a vision of being a sustainable and resilient community with an ability to thrive in the face of shifts in energy supplies, a changing climate, and swings in the regional, national, and international economy. Addressing energy challenges within the Town is a current priority with its dependence on fossil fuels. While the Town has already begun integrating sustainable energy, its dependence on fossil fuels leaves the community vulnerable to energy supply and price volatility. Like many New England Towns, Durham is faced with two specific challenges: high- energy usage for home heating in a low population density and a cold climate with limited opportunities to seek economies of scale.

Renewable and Reduction Efforts

In 2016, the second largest solar array in the state was finalized with the installation of 2,100 solar modules (640-kW) sited on the former gravel pit in Lee. These panels now provide the equivalence of all the energy used by Durham's Town-owned buildings with the exception of the wastewater treatment facility.

Solar project at the former gravel pit in Lee
(Photo Credit: ReVision Energy)

GCoM Commitment, GHG Inventory Overview, and Target Setting

In January 2021, Durham, in conjunction with the Energy Committee, joined the Global Covenant of Mayors (GCoM), a movement of more than 10,000 cities and local governments intent to reduce environmental impacts. The GCoM pairs research and innovation, data-based solutions, and city climate finance to leverage technical assistance for municipalities to achieve their climate adaptation needs and goals. By joining this movement, the Town has pledged to reduce greenhouse gas emissions, prepare for the impacts of climate change, increase access to sustainable energy, and track progress towards these objectives. As part of this commitment, Durham is required to measure current emissions through completing a greenhouse gas inventory, measure risks through completing a climate risk and vulnerability assessment, set emission and risk reduction goals, and create an action plan that outlines specific reduction actions and ways to measure progress towards Durham's goals.

In August 2020, Durham partnered with UNH Sustainability Institute to complete a Municipal Greenhouse Gas Inventory and Estimation of Carbon Benefits in Conservation Land to measure the greenhouse gas emissions and removals from the built environment, transportation, agriculture/livestock, wastewater, solid waste, and land use sectors. This inventory found that in 2019, all sectors combined emitted approximately 90,257 metric tons of carbon dioxide equivalents, and land use removed approximately 28,161 metric tons of carbon dioxide equivalents (tCO2e)– about 31.2% of emissions.

Durham's sources of emissions were from the built environment (49.2%), transportation (43.5%), land use changes (3.0%), agriculture/livestock (2.1%), wastewater (1.4%), and solid waste (0.8%). Durham's two largest emission categories, the built environment and transportation, are the highest emission sources for most communities and have the largest potential for emission reductions.

The built environment emissions occur from the use of stationary energy and electricity. The largest contributors to the built environment emissions were natural gas (47.8%) and electricity (24.8%), followed by fuel oil (14.8%), propane (7.9%), landfill gas (2.6%), and wood (0.4%). When breaking emissions down by sector, UNH accounted for 41.1% of emissions, followed by Residential (30.7%), Commercial (24.0%), ORCSD (2.7%), and Municipal (1.6%). However, where the energy is sourced also plays a large role in emissions. When considering emissions per unit energy, Residential had the highest emissions, followed by Commercial, Municipal, and UNH. UNH's low emissions per unit energy were due largely to its use of recaptured landfill gas consisting mostly of methane, which is a better alternative to natural gas or fuel oil. On the other hand, Residential emissions were largely due to use of electricity, and Commercial emissions were largely due to use of natural gas. These emissions can be reduced by shifting from natural gas to electricity powered equipment, such as heat pumps, as well as by switching to renewable energy sourced electricity.

Emission sources from transportation were from motor vehicles, largely from pass-through traffic, which is similar to most community-scale greenhouse gas inventories. Due to lack of local data sources, Durham's transportation emissions were estimated based on a national vehicle mix, which estimates vehicle type composition. Light duty vehicles, such as sedans, SUVs, and pickup trucks, accounted for 82.8% of Durham's transportation emissions, while heavy duty vehicles, such as large vans, buses, and commercial and semi-trucks, accounted for 15.8%, and motorcycles and mopeds accounted for 1.4%. Emissions from electricity used by electric vehicles were included within the Built Environment emissions. Strategies for reducing emissions within this category include encouraging low and no-carbon modes of transportation, such as walking, biking, and using public transportation, as well as increasing the use of electric powered over gas powered vehicles.

Durham's sources of removals were from forests remaining forests and reforestation (80.0%) and trees outside forests (20.0%). This highlights the importance of trees since

they are Durham's only source of carbon removals within the Community-Wide GHG Inventory, while the remaining sectors are sources of carbon emissions. However, forests and trees should not be considered as direct carbon offsets in climate mitigation efforts because doing so underestimates the actual reductions Durham needs to make to meet reduction targets. This decreases the perceived need to reduce emissions and can minimize Durham's actual efforts in reducing human-caused emissions. In addition to this, carbon sequestration is part of Earth's natural carbon cycle that regulates climate and makes the planet habitable. Therefore, associating all carbon sequestration with offsetting anthropogenic emissions disregards this natural balance, and again underestimates Durham's emissions.

Durham's per capita greenhouse gas footprint (5.4 tCO2e/person), which excludes land use changes for proper comparison, was lower than the state and national averages of 10.3 and 15.2, respectively, as well as many nearby NH communities (Concord – 11.5, Keene: 12.0, Portsmouth: 19.9.) This can be attributed to the numerous efforts Durham and UNH have already taken to date to increase sustainability and reduce emissions.

In consideration of balancing other community goals that may require changing forest land uses, this analysis states that although general tree conservation is beneficial for sequestering carbon, avoiding forest fragmentation should be prioritized. Not only does this keep emissions lower, as older trees have higher amounts of carbon storage and thus emit more than younger trees when removed, but it also allows the forest to continue providing habitat for Durham's local species, prevents local and invasive species that thrive in additional sunlight produced by forest removal from negatively impacting nearby remaining trees, and helps reduce stress on trees during droughts by shading the soils and keeping more moisture in. Therefore, the analysis recommends completing a more specific tree inventory in Durham to determine high priority forest areas that should avoid deforestation and amending local zoning and other policies accordingly.

Durham set a goal to reduce Town-wide emissions by 35.5% below 2019 levels by 2030, and net-zero emissions by 2050. This goal was set to meet the ambition of the United States' April 2021 nationally determined contribution made in line with the Paris Agreement, as required by GCoM. Within the next two years, Durham will complete a climate risk and vulnerability assessment, create goals to reduce risks, and develop a Climate Action Plan that will include specific actions Durham will take to meet and track its progress towards meeting the emission and risk reduction goals.

Did You Know?

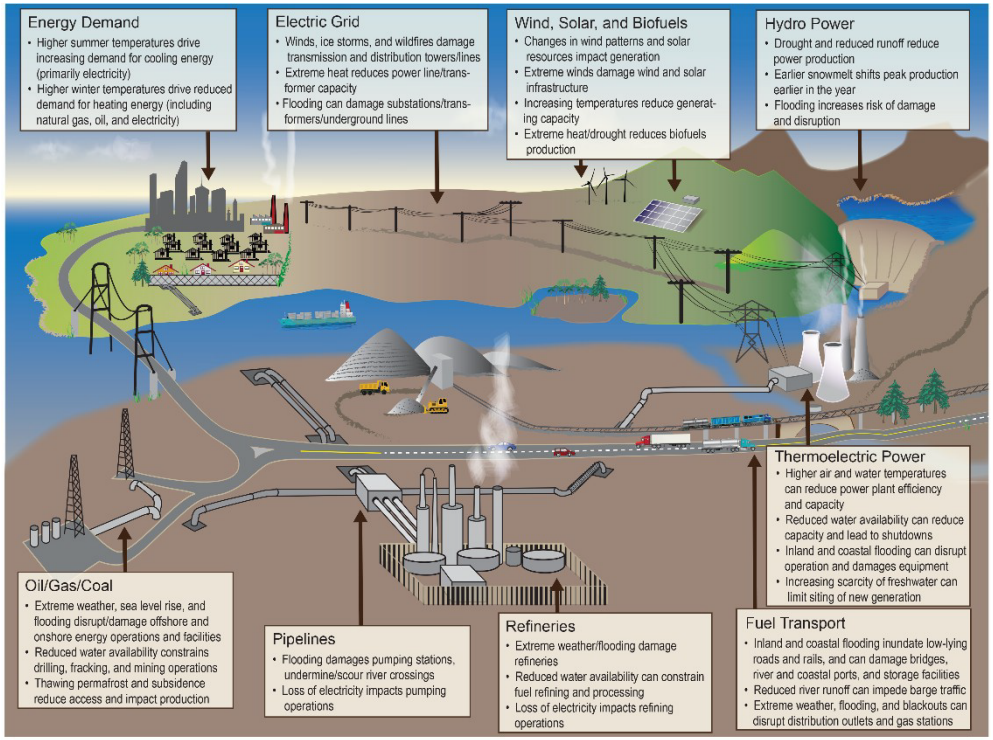
Durham has set the following energy targets as required by the GCoM:

- Reduce Town-wide emissions by 35.5% below 2019 levels by 2030.
- Reach net-zero emissions Town-wide by 2050.

Community Aggregation

Durham has expressed interest in a Community Power Aggregation (CPA) project through the NH Community Power Coalition. This type of program enables municipalities to garner lower cost power for their residents and can allow communities to participate in the energy market to push for more renewable power sources and inventive solutions. Through CPA the Town could provide residents with a higher percentage of green electricity at an affordable rate as the default electric supplier. The New Hampshire Business review cites the CPA model as an important role for municipalities looking to achieve renewable energy goals.

Durham would approach moving to a CPA model through phases of research and investigation to discover available informational resources and networks, while surveying the implications of current renewable power options.



Potential Impacts of Extreme Weather and Climate Change
(Photo Credit: Fourth National Climate Assessment)

Land Use

Nature-based solutions can provide productive measures to mitigate climate change impacts like GHG emissions. One solution is to engage in land conservation; Durham has put roughly 40% of its land into protection, which includes Town and UNH-owned lands. From 2006 to 2016, Durham experienced a net loss of forest land and wetlands while gaining in grassland and settlement, resulting in a net GHG balance or sequestration of -25,470 tCO_2e/y (tons of carbon dioxide equivalent per year). Through this emission report, the Town discovered discrepancies in GHG contributions based on landownership. Compared to their share of emissions:

- UNH contributes their share of GHG removals but more than their share of emissions.
- The Town contributes more than their share of emissions and removals.
- State-owned land contributes more than their share of emissions and removals.
- State-owned land contributes the most concentrated share of GHG emissions per hectare.

Emissions removals from Durham's forests and trees, which are carbon sinks, are the only source of carbon sequestration for the town. They sequester 35% of the community's emissions.

Vulnerability of Energy Systems

Energy systems are already impacted by extreme weather events, and climate change will only serve to increase the frequency and intensity of these impacts. With increases in high winds, hurricanes, heat waves, intense cold periods, snow events, ice storms, and extreme rainfall, critical energy infrastructure may experience longer-lasting power outages which may cause imbalances in fuel availability and demand. Since economic security is dependent on affordable and reliable energy supplies, outages and shortages can have cascading effects on other critical sectors from agriculture to banking and healthcare to transportation.

Precipitation Events

The Northeast is particularly susceptible to more frequent and intense precipitation events. These are expected to increase flood risks for highly developed coastal and inland energy infrastructure. Coastal flooding, including wave action and storm surge, can affect gas and electric asset performance, damage infrastructure, and disrupt energy generation, transmission, and delivery. Any increase in hurricane intensity will exacerbate energy infrastructure exposure to storm surge and wind damage. Numerous hurricanes throughout Durham's history have caused power outages and

infrastructure damage, including bringing down power lines from strong winds and felled trees. Ice storms and snowstorms have interrupted the Town's electric power for multiple days with downed utility wires and created public safety issues.

Sea Level Rise

The NextEra Nuclear Power Plant in Seabrook is the leading electricity generator in the state. And while the Town of Durham is taking steps to reduce its dependency on outside electricity sources, any service disruptions or damage to the NextEra Nuclear Plant represents potential vulnerability. The Town of Seabrook has completed a vulnerability assessment looking at the susceptibility of lowing lying areas around the plant. Future steps could include detailed analysis of the power plant's vulnerability to sea level rise to see how the region's electricity availability could be impacted by sea level rise and whether the facility poses any significant safety risks.

Tidal Portion of the Oyster River (Photo Credit: Wikimedia Commons)

Wildfires

Durham's Hazard Mitigation Plan identifies wildfires as a moderate vulnerability. Historically, wildfires peaked in the late 1940s and early 1950s in New Hampshire, likely related to increased fuel loads from trees downed in the 1938 hurricane. With the high fuel load created by the 1998 and 2008 ice storms, combined with the knowledge that New Hampshire is one of the most forested states in the contiguous United States, wildfires are again a concern in the state. Increases in the risk of wildfires due in part to climate change may not be as significant here as in other parts of the country; however, wildfires can directly damage transmission poles and other electricity infrastructure. A greater threat may come from smoke and particulate matter, which can ionize the air, create an electrical pathway away from transmission lines, and shut down the lines.

Heat Waves

Temperature increases across the United States are expected to drive greater air conditioning demands and create greater grid spikes in the summer months. Electricity costs are expected to rise as a result of increased demand and reduced efficiency of power generation and delivery during extreme heat events. Additionally, higher temperatures affect thermoelectric power plants (where heat is converted to electricity) by reducing thermal efficiency and generating capacity, as well as the current-carrying capacity of transmission and distribution lines. While these effects are expected to have greater impacts in other regions of the U.S., New Hampshire power grid and energy providers will be challenged to provide adequate power in the face of increased air conditioning usage.

Drought

Water availability will affect energy systems in the Northeast as today's power plants account for the largest share of all freshwater withdrawals in the United States. Reductions in mountain snowpack and snowmelt timing will affect hydropower production, and reduced water supplies can create **energy-water collisions** (a range of issues where water resources and the power sector interact). Drought will likely

threaten fuel production and may impact the availability of wood and wood waste products for heating, fuel production, and electricity generation.

Energy Planning

Advances in technology and more energy related funding sources have enabled Durham to improve its energy resiliency. The Town can continue to enhance its resiliency efforts in several ways. Planning and operational measures that anticipate climate impacts and seek to prevent damages are essential. Long-term upgrades to the Town's electrical infrastructure are already underway; understanding and planning for future conditions will further improve resiliency. For example, hardening measures to protect assets from damage during extreme weather events could include adding natural or physical barriers to elevate, waterproof or further protect equipment can improve system performance. It is important to note that while hardening assets in place is effective for some situations, other assets may need to be relocated to be more cost-effective and resilient in the long term.

Public-private partnerships can be leveraged to share lessons learned and to coordinate actions that increase community resiliency overall. Conducting vulnerability assessments, developing resilience plans, and implementing resiliency solutions on a regional scale can address the interdependencies between the Town of Durham and its neighboring communities and state partners. Additionally, financing energy efficiency and resiliency technology can have long payback periods that can bring higher upfront costs to Town taxpayers. Partnerships can help offset these costs and reduce the financial burden on individual entities.

Future energy planning should consider that historically underserved or marginalized populations often face greater risks from climate change and energy system vulnerabilities. Planning efforts should, to the greatest extent possible, ensure these populations are able to participate throughout the entire planning process, from the development of resiliency ideas to the implementation. Doing so can lead to more effective resilience actions and provide co-benefits to the community overall.

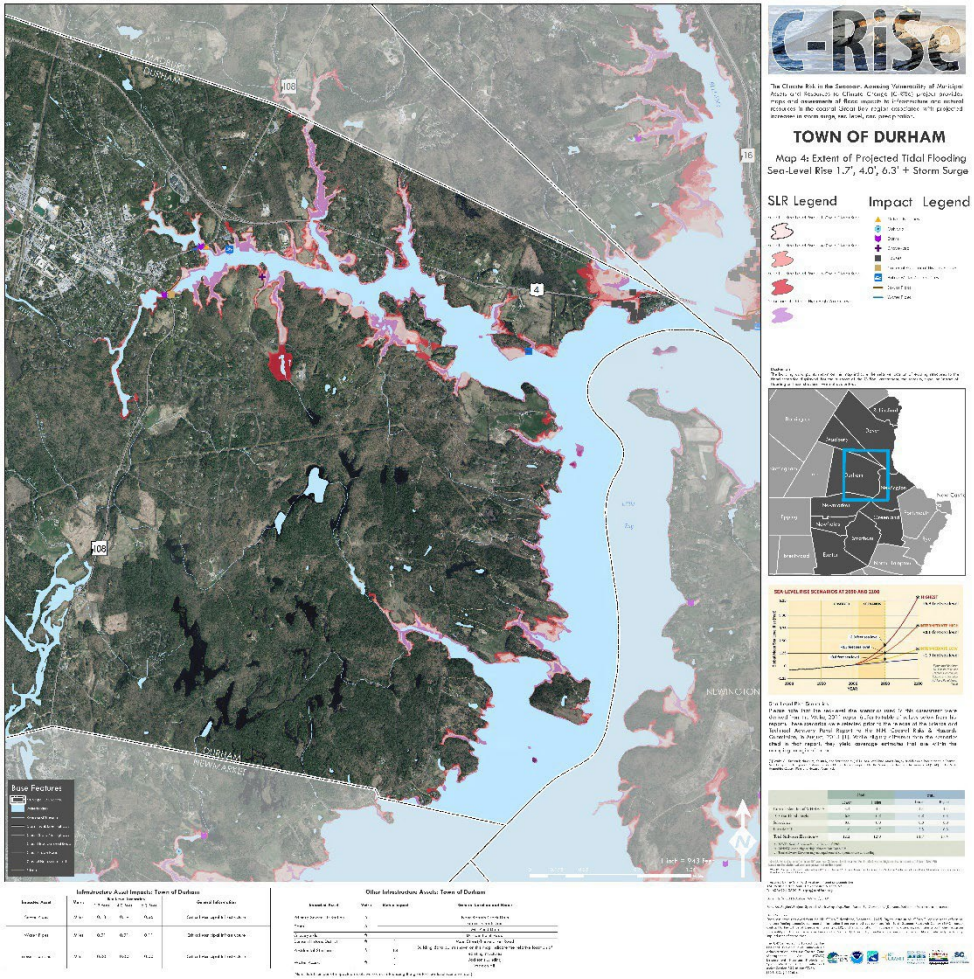
Resilience investment opportunities addressing specific extreme weather events
(Photo Credit: Energy Sector Resilience Solutions)

Other Key Resources

According to the C-RiSe Assessment, there are four other key resources vulnerable to sea level rise and storm surge scenarios. Two are water access points at Jackson's Landing and Wagon Hill Farm, one graveyard on Durham Point Road, and one area of the Durham Historic District along Main Street/Newmarket Road.

Municipal infrastructure that is designed for historical climate conditions is more vulnerable to future weather extremes, with lower energy performance and risk of corrosion of structures with inundation. Higher temperatures associated with climate change increase the stress on cooling systems and higher indoor temperatures can reduce thermal comfort and office worker productivity which can lead to building closures, especially when buildings do not have air conditioning.

Upgrades to municipal infrastructure and the electrical grid may be needed to handle higher temperatures and building codes and rating systems are currently focused on historical extreme weather events. Forward thinking design can protect these assets and limit investor risk exposure by accounting for more extreme climate induced impacts to infrastructure in building codes and zoning regulations. Further adaptation planning can also be informed by data on changing hazards and vulnerability assessments.



Natural and Working Lands

For the purposes of this chapter, natural lands refer to an area of relatively undeveloped land that has substantially retained its characteristics as provided by nature or has been substantially restored, or which can be feasibly restored to a near-natural condition and which derives outstanding value from its wildlife, scenic, open space, parkland or recreational characteristics, or any combination thereof. Working lands refer to any managed forests, agricultural lands such as farms, gardens, grazing lands, or managed grasslands used for other agricultural purposes that provide food or other valuable materials such as timber to the communities and add to the local economy.

Durham's ecological character is tightly interwoven with its wealth of natural resources, such as heavily forested areas; open fields, pastures, and active farmland; and both freshwater and tidal systems, including the Oyster River and Great Bay estuary. In a state where eight of every ten acres is forested and access to water is considered to be abundant, the Town's vision for the future is closely tied to and heavily dependent on the health of its natural and working lands. These resources will be exposed to increased stresses with changes in climate, weather patterns, and sea level rise. Degradation will damage their ability to provide ecosystem and economic services and may lead to long-term, irreversible harm. To protect its natural and working lands, Durham needs to employ strategic planning methods and management practices that will increase resiliency and long-term stability.

Did You Know?

Over 50% of Durham's land cover (roughly 8,000 acres) has forest cover, made up of mixed forest, evergreen, and deciduous tree species.

Adams Point Wildlife Management Area (Photo Credit: Webmaster)

Forests

Durham's forests provide many benefits to the community, and the Town's Master Plan Natural Resources chapter identifies their protection and management as an area of critical concern. Durham's forests provide many valuable services, including:

- Wildlife habitat, especially for species of Greatest Conservation Need[1]
- Places for recreational activities
- Scenic quality, community character, and property values
- Reduction to the impacts of stormwater and improved water quality
- Improvements to air quality
- Decreases in air temperatures for residential areas, as well as animal habitats.
- Reduction in noise pollution
- Economic opportunities such as timber harvesting
- Maple syrup and other tree syrup production
- Foraging for mushrooms and medicinal plants

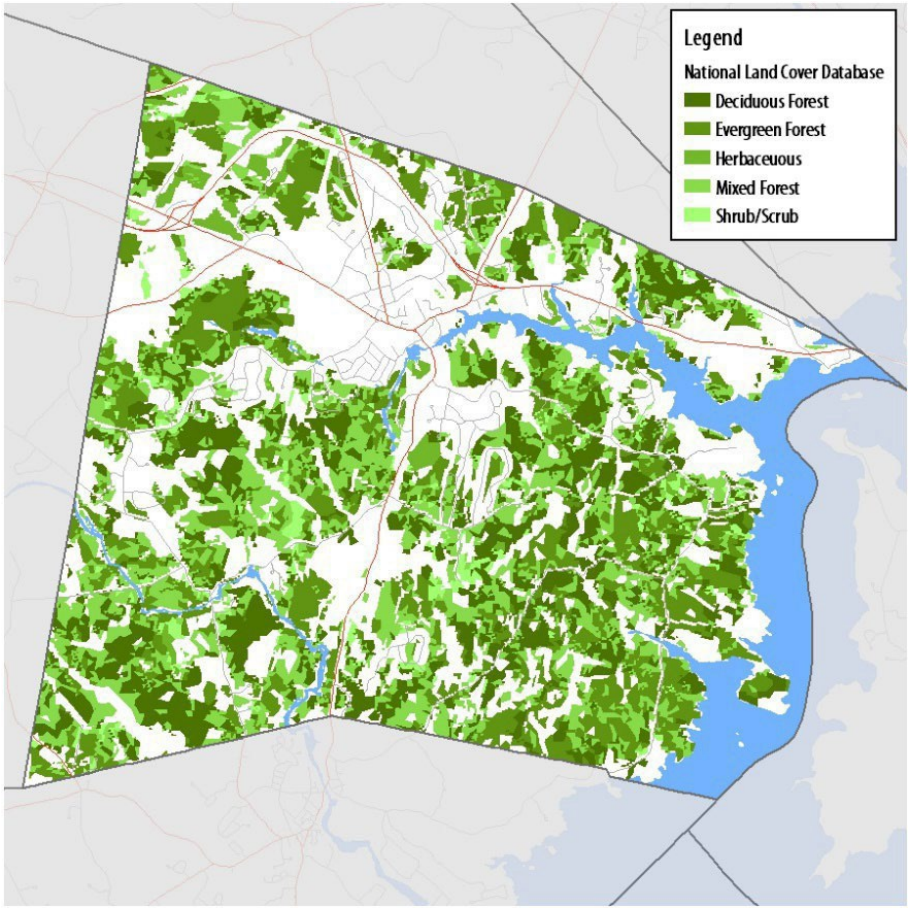
According to the 2011 National Land Cover Database (NLCD), over 50% (8,102.2 acres) of the Town has forest cover. While this database is ten years old, it contains the most accurate spatial data available.

Over 7,500 acres, or 93% of total forest cover in Durham comprises of *mixed forest* (neither deciduous nor evergreen species are more than 75 percent of total tree cover), *evergreen* (more than 75 percent of the tree species maintain their leaves all year; the forest canopy is never without green foliage), and *deciduous* (more than 75 percent of the tree species shed leaves simultaneously in response to seasonal change). Herbaceous and shrub/scrub forests make up the remaining forest cover types.

Table 3: Forest Resources

Land Cover Type	Total Acreage	Total Percentage
Mixed Forest	2,708.9	17.1%
Evergreen Forest	2,441.8	15.4%
Deciduous Forest	2,355.8	14.9%
Shrub/Scrub	374.9	2.4%
Herbaceous	220.8	1.4%

Source: NLCD, 2011



Forest Resources in Durham (NLCD, 2011)

[1] Species of Greatest Conservation Need are species in NH that are in declining numbers, facing reduced habitat, climate change and a lack of connectivity. (NH WAP 2015)

Associated Climate Vulnerabilities of Forests

Climate strongly influences forests' ecological functions (i.e., water storage and tree productivity) and determines forest composition, growth rate, animal species, carbon storage and water availability amongst many others. Warmer winters and longer growing seasons will increase the rates of evaporation and water use by New Hampshire forests. This may reduce summertime soil moisture and increase the occurrence and length of droughts, which can in turn decrease forest productivity and increase tree susceptibility to invasive insects and disease. Tree susceptibility to pests has cascading effects on fall foliage, wood supply and other economic resources for the state, including a decrease in harvest productivity.

Current modeling suggests that dominant tree species are likely to undergo range shifts in response to the warming temperatures and changes in precipitation. Projected models indicate that the current spruce-fir forests could entirely disappear from the Northeast. Moreover, the current mix of northern hardwood and softwood tree habitat that is present throughout most of New Hampshire is likely to be completely replaced and dominated by maple, birch, and beech forest conditions. While the productivity of forests in the future is still unclear, there is a potential that longer growing seasons and higher atmospheric CO_2 may in fact increase productivity. However, increased drought, changes in habitat, pests, disease, and air pollution may also hinder growth and productivity.

Climate change may also affect the biogeochemical sequence or "nutrient recycling" in Northeast forests. This refers to the movement of elements through soils, plants, surface water, and the atmosphere. Changes in this cycling may enhance the release of heat-trapping greenhouse gases from soils and subsequently accelerate climate warming. Soils contain large pools of carbon so even small changes in the could result in substantial feedbacks to climate warming. Similarly, deforestation and dramatic land use changes such as creation of development or infrastructure can exacerbate the effects of climate change on forests by increasing air temperatures, reducing the amount of moisture available and perpetuating the positive feedback loop of global warming that has serious repercussions for weather patterns in southern NH. In turn, unhealthy or compromised forests and working lands also contribute to and intensify the effects of climate change due to their limited ability to sequester carbon, prevent erosion and floods, optimize air temperature and water quality and quantity amongst many others.

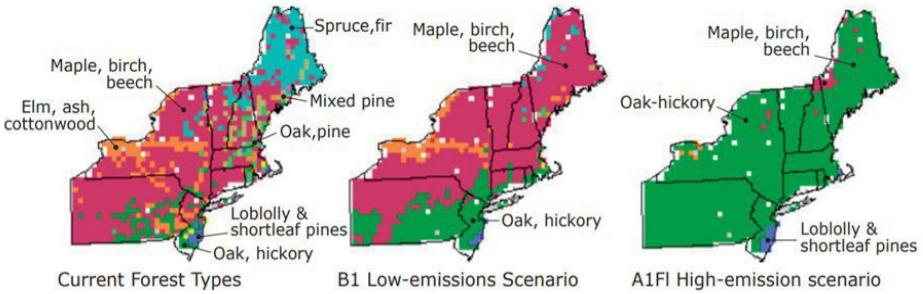


Figure 5: Current and projected suitable habitat for major forest types in New England under low and high emissions scenarios.

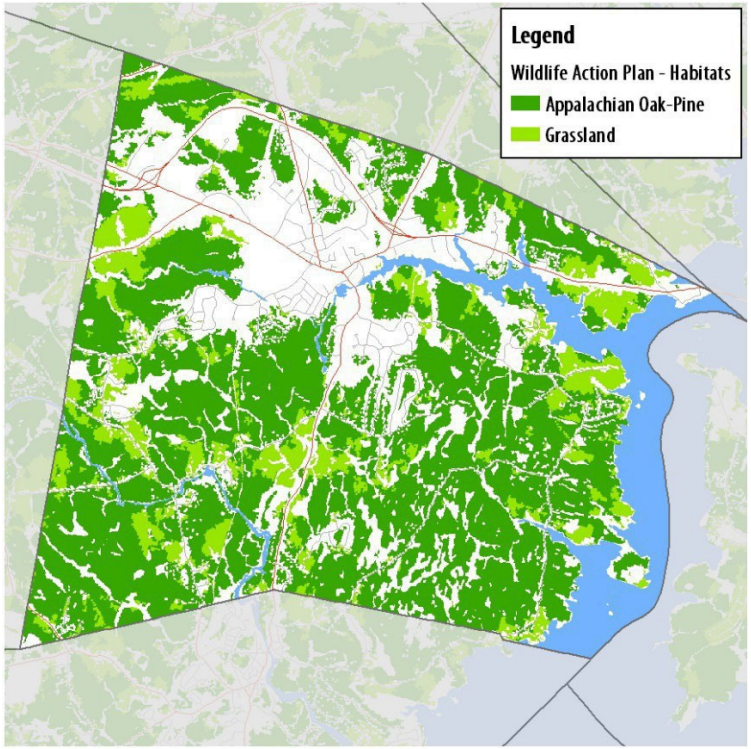
While climate change may affect individual species of trees in different ways, common threats to Durham's forest and associated vegetation include increased wildfires due to drought-induced water shortages, increases in forest pests due to warmer conditions, long-term habitat shifts north or up slope, and frequent disturbances from extreme storms and potential hurricanes. The abundance of various tree species and distribution of tree ages is expected to react to climate change, but the degree and type/direction of change may differ among forest types. It is likely that the species-based definitions of natural communities may change as individual tree species react differently to changes in temperature and water availability.

According to the 2020 Wildlife Action Plan, Durham has two primary land habitat profiles: Appalachian oak-pine forest and grassland (see Table 4). The predominant habitat type in Durham is the Appalachian oak-pine forest, which accounts for nearly 50 percent of all habitat types in the Town.

Table 4: Habitat Types

Habitat Type	Total Acreage	Total Percentage
Appalachian Oak-Pine	7,384.3	47%
Grassland	1,607.9	10.1%

Source: Wildlife Action Plan, 2020



Wildlife Habitat Types in Durham(Wildlife Action Plan, 2020)

The following information comes directly from the Wildlife Action Plan: Appendix B – Habitat Profile and the UNH Cooperative Extension Wildlife – Habitats of New Hampshire section of the UNH website.

Appalachian Oak-Pine Forest

This forest system is found predominantly in southern and central New Hampshire, where the climate is warmer and drier, elevations are lower, have a longer growing season, and fire is more frequent. It is also the most dominant forest type in the Town of Durham as it covers 47% of the Town's total acreage. Moreover, this forest type supports 104 vertebrate species in New Hampshire, including 8 amphibians, 12 reptiles, 67 birds, and 17 mammals. State endangered wildlife species living in this forest type include timber rattlesnake and eastern hognose snake.

Associated Climate Vulnerabilities to Appalachian-Oak-Pine Forests

Warming conditions related to climate change are allowing more cold-limited forest pests to move further north into New Hampshire's forests, including the emerald ash borer, balsam wooly adelgid, and gypsy moth. These pests can cause significant habitat degradation and mortality in the Appalachian-oak-pine forest habitat. Glossy buckthorn, Japanese barberry, and burning bush are three invasive plant species that have been observed in this habitat and may also increase habitat degradation as they outcompete or displace native species.

Grasslands

Grasslands, a significant wildlife habitat in Durham (1607.9 acres or ~10%), are growing increasingly rare in the state. More than 70 species of wildlife use these open areas to meet their needs for food, cover, or breeding. They are made up of a variety of different grass species, sedges and wildflowers and grow in open areas that lack shrubs or trees. Agriculture and farming are the progenitors of grasslands. Most of today's grasslands are a result of active, sustainable management by farmers and landowners. Management of grasslands prevents loss due to forest succession. Grasslands provide

important habitat diversity, especially for several grassland-nesting bird species. Many of these birds, such as the grasshopper sparrow, bobolink or eastern meadowlark, lay their eggs in fields that must be of certain size, however, they often are lands used for agricultural purposes and the mowing seasons may correlate with nesting seasons for these bird species. As a result, grassland nesting birds have been disappearing from these areas and have declined in numbers.

Associated Climate Vulnerabilities of Grasslands

While grasslands are resistant to climate change with proper management in place, increased diversity and abundance of invasive species could impact these areas. More intense management resulting from longer growing seasons and an increased demand for grass-based biomass fuel as an alternative to fossil fuels could lead to potential loss or disruption of this significant wildlife habitat. Moreover, more frequent drought conditions and an increase in temperatures might also negatively affect the growing season, the health of grasslands and their ability to provide sufficient support for the wildlife. Warmer and hotter temperatures may lead to an invasion of new species that might destabilize the system and increase grassland's vulnerabilities to climate change. Other species such as turtles or butterflies, who are attracted to the grasslands and depend on them for ecosystem services, may lose their natural habitat.

Other Significant Vegetative Habitat Types

While not predominant in Durham, there are several other vegetative habitat types, including temperate swamp and hemlock-hardwood pine forest that are important natural resources likely to be impacted by future climate change.

Temperate Swamps

These wetlands are distinct from peat swamps based on their hydrology, water chemistry, and species composition, but have similar structures as forested wetlands. Found in southern and central New Hampshire, they are typically isolated or stagnant basins with saturated organic soils and make up 254.1 acres (or 1.6%) in Durham. Red maple, highbush blueberry, black gum, and winterberry can be commonly found in this ecosystem and many other diverse plant species. These habitats are critical for flood control, pollutant filtering, shoreline stabilization, sediment retention and erosion control, wildlife habitat, and food web productivity.

Associated Climate Vulnerabilities of Temperate Swamps

The hemlock wooly adelgid, a known invasive insect, has been spreading to the northeastern United States. However, an eastern hemlock, a common tree species of temperate swamps, has no resistance to adelgid damage and which leads to an increased mortality for this tree type. Moreover, greater precipitation increases runoff from roads, agricultural fields, and construction sites, and leads to elevated levels of sediments in swamps which can decrease plant diversity and create favorable conditions for invasive species.

Hemlock-Hardwood Pine Forests

This forest type is state mostly south of the White Mountains and below an elevation of 1,500 ft. This is a transitional forest type that consists mostly of White Pine and Hemlock trees and usually occurs in areas that are likely to succeed to hemlock and/or beech unless periodic fires take place. Moreover, it is the most widely distributed forest type in New Hampshire and supports 140 vertebrate species in the state, including 15 amphibians, 13 reptiles, 73 birds, and 39 mammals. Threatened and endangered wildlife species occurring in this forest type include timber rattlesnake and eastern hognose snake. The Town of Durham currently has 180.6 acres of hemlock-hardwood-pine forest which make up 1.1% of the Town's area.

Associated Climate Vulnerabilities of Hemlock-Hardwood Pine Forests

Like the Appalachian-oak-pine forest, invasive species pose a threat to this habitat. The hemlock woolly adelgid is of concern as it attacks the eastern hemlock, which has no resistance to adelgid damage and mortality. The woolly adelgid's range is moving northward as it becomes less cold-limited because of increased temperatures. Other invasive species are likely to expand northward into New Hampshire as a result of climate change and can displace or outcompete native plants in this habitat.

Moreover, there is a strong incentive in certain parts of the state to develop renewable wind energy facilities in response to climate change. The locations for these wind turbines are typically located along ridgetops which are most suitable for energy efficiency. Hemlock-hardwood-pine forest habitat could be lost as they are cut down and replaced by the turbines and their transmission corridors for wind energy.

Invasive Species

Climate change will have widespread impacts on natural resources, including a likely increase of invasive species, making it harder to manage and control them. Invasive species, which includes both plant and animal (pests) species, are not native to a particular ecosystem and their introduction can result in the degradation of natural habitats as they can move aggressively into an area and out-compete native species. If left uncontrolled, they can degrade a community's woods, meadows, wetlands, rivers, and yards, and impact wildlife. Moreover, invasive species can infest and overwhelm the working and natural lands and negatively impacting their health and productivity. It's anticipated that climate change will exacerbate the impacts of invasive species by facilitating the northern migration into the state of species not yet present or currently limited; by reducing the winter kill that helps limit the establishment and spread of some pests and pathogens; and by reducing the resilience of New Hampshire's habitats due to drought and other climate related stressors.

Beginning in 2009, Durham has compiled information on invasive plant species that are found on Town-owned properties including Wagon Hill Farm, Weeks Lot, Oyster River Forest, Doe Farm, Longmarsh Preserve, Stolworthy and Milne, Mill Pond property, and Thompson Forest (see Table 5). While it's impossible to completely eradicate these plants, the Town has developed an Integrated Pest Management Approach to control them on Town properties including Oyster River Forest, Doe Farm, Thompson Forest, Milne Nature Sanctuary, and Mill Pond Park.

A more comprehensive list, which was compiled by the Town's Land Stewardship Coordinator in 2021.

Early detection and rapid response are practices enabling land managers to identify new and spreading invasive plants and take management action quickly. The cost for invasive plant management and control efforts can be extensive in terms of time and money and they are not always successful. There are a number of resources Durham can utilize to increase their success in detecting and taking action on combating invasive species. NH Fish and Game developed a guide, Picking Our Battles, as an invasive plant control strategy for Durham. This guide identifies three invasive species that have not fully taken root in Durham, which means they are the easiest battles to fight: blunt-leaved privet, garlic mustard, and perennial pepperweed.

The guide also contains a map identifying priority areas for invasive plant management in the Town based on the areas of high ecological significant, areas that provide ecological services to human activities, and areas that have a high risk of spread for invasive.

Table 5: Non-Native Plants Found in Durham (2009-19)

Asian bittersweet	Japanese barberry
Autumn olive	Japanese knotweed
Black Locust	Multiflora rose
Burning bush	Norway maple
Bush honeysuckles	Oriental bittersweet
Common barberry	Purple loosestrife
Common buckthorn	Reed Canary Grass
Common reed	Wild parsnip
Garlic mustard	Winged euonymus
Glossy buckthorn	

Source: Town of Durham

Other Important Natural Resources Impacted by Sea Level Rise

The C-RiSe vulnerability assessment evaluated the vulnerability to sea level rise of several important land resources: existing conservation lands and areas identified in the Wildlife Action Plan as having a high potential for biological habitats.

The C-RiSe assessment found approximately 30 conservation easements and/or town owned lands sensitive to sea level rise and coastal storm surge flooding. Some of the largest properties include the Rollins tract, Smith Trust, and Wagon Hill Farm, which represent approximately 40% of all the protected lands impacted by sea level rise with a storm surge under the highest emission scenario. In addition, important lands found in the Wildlife Action Plan along the Oyster River and its tributaries and along the shoreline of Little and Great Bay were identified as vulnerable. While the C-RiSe assessment evaluated the vulnerability to sea level rise and storm surge of many resources, it did not assess the threat to agriculture in the Great Bay communities. Extending this assessment to consider soils of local and statewide importance, as well as prime farmland soils, would provide the Town a better understanding of how much viable farming soils will be available in the future as sea levels continue to rise and other pressures encroach on productive soil resources.

Beyond providing important benefits for coastal ecosystems, many of these areas are actively managed by farmers and farm service providers for hay and other crops, as well as offering recreational opportunities for residents and visitors and must be managed effectively to ensure long-term accessibility.

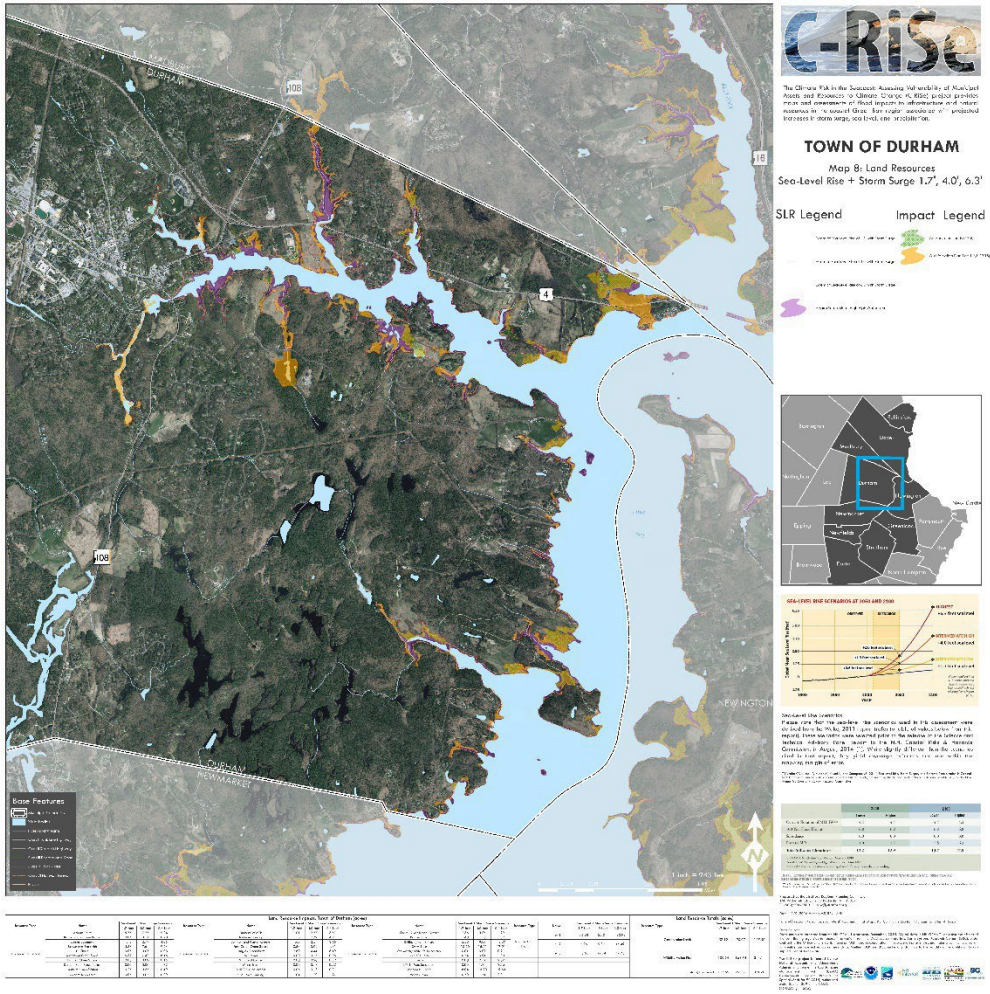
Surface Waters and Saltmarsh

According to the 2020 Wildlife Action Plan, Durham has three primary water habitat profiles: open water, wet meadow/shrub wetland, and salt marsh. Given the Town's geographic location on the Great Bay estuary, it is not surprising that open water is the predominant habitat type – making up approximately 11% of the Town's total area.

Table 6: Water Resources

Habitat Type	Total Acreage	Total Percentage
Open Water	1,778.4	11.2%
Marsh/Shrub Wetland	729.1	4.6%
Salt Marsh	160.0	1%

Source: Wildlife Action Plan, 2020



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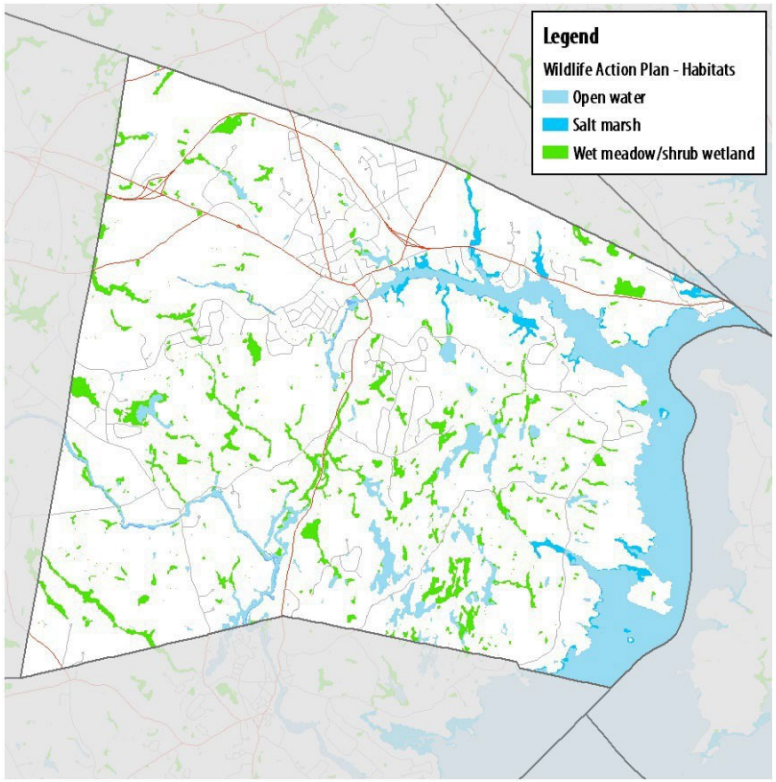


Wildlife Habitat Types in Durham(Wildlife Action Plan, 2020)

Open Water

Durham's predominant open water habitat type is an estuarine system where tidal portions of the Oyster River meet salt water in Little Bay and Great Bay from the Atlantic Ocean. These sub-tidal and intertidal areas are dominated by soft sediments such as eelgrass beds, oyster reefs, and mudflats. Estuarine habitats occur only in the Great Bay and Coastal watersheds and support uniquely adapted plant and animal species not found in other parts of the state such as hawks, heron, and eagles.

The Town's warmwater ponds, rivers, and streams vary in size, shape, and depth. The larger waterbodies include the Durham Reservoir, Oyster River, and Lamprey River. Submerged aquatic vegetation found in ponds and lakes provide critical spawning and nursery habitat for several fish species. Turtles, amphibians, and fish feed on the abundant invertebrate species found on aquatic plants. The Oyster River and Lamprey River are the Town's primary freshwater rivers. They may be home to a number of Species of Conservation Concern, including the state threatened bridled shiner, banded sunfish, and the state endangered brook floater. Both rivers allow for recreational uses such as fishing, swimming, and boating.

Associated Climate Vulnerabilities of Open Water

Warming water associated with climate change is likely to exacerbate the speed and geographic spread of species-specific disease to oyster reefs and eelgrass beds. Rising sea-levels may lead to culverts and other tidal restrictions (head-of-tide dams) that could block fish passage. Increased stormwater runoff due to more frequent rainstorms may lead to periods of decreased salinity, increases in turbidity, erosion, incidence of algal blooms, and nutrient load.

Marsh and Shrub Wetland

Emergent marsh and shrub swamp systems are usually grouped into three habitat categories: wet meadows, emergent meadows, and scrub-shrub wetlands. These wetlands help filter pollutants by preventing them from getting into local streams, stabilizing the shoreline from erosion, and helping to hold water to reduce flooding. Eighteen species of conservation concerns, including the Spotted turtles, Canada warblers, New England cottontail, and American woodcock depend on this habitat and even more wildlife species use this habitat for foraging, nesting, breeding, and cover. In Durham, marsh and shrub wetlands make up 4.6% of the Town's area and play a crucial role in maintaining the ecosystem's health.

Associated Climate Vulnerabilities of Marsh and Shrub Wetlands

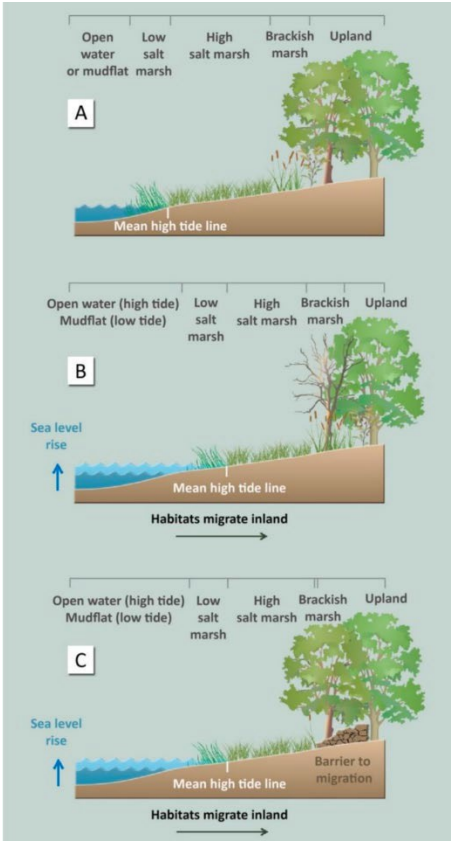
Similar to temperate swamps, more extreme precipitation events will create more runoff from roads, agricultural lands, and construction sites, which can lead to higher levels of sedimentation in these habitats. Increased sedimentation leads to decreased plant diversity and offers more favorable conditions for invasive plants. Lower ranking threats to this habitat related to climate change include habitat degradation from changes in precipitation patterns that change the duration and seasonality of flooding, as well as increased temperatures making this habitat more vulnerable to invasive species.

Coastal groundwater is also supposed to rise with sea level, which will affect groundwater quality, the stability of existing infrastructure, and the ability of the ecosystem to function properly. Groundwater rise modeling caused by sea-level rise (SLR) was conducted by the University of New Hampshire and the study found that SLR groundwater signal was detected three times further inland than modeled tidal flooding caused by SLR. The more inland communities that might not be directly affected by the sea level rise will therefore be more impacted by freshwater flooding and rises in the groundwater levels. The largest observed groundwater rise caused by SLR usually takes place in marine and estuarine deposits which are commonly found in Durham, as well as peninsulas that are surrounded by tidal water bodies on three sides of the land. As a result, freshwater wetlands are expected to expand in depth and area size by 3% by the year 2030 and by 25% in 2100.

Saltmarsh

Salt marsh is a grass dominated tidal wetland that exists in the transition zone between the ocean and upland. They are one of the most productive ecosystems in the world, provide habitat for many wildlife species, and can help protect coastal areas from storm surges. They also provide multiple benefits to people, including flood mitigation, healthy fisheries, storm protection, and long-term carbon storage. Salt marsh plant species are salt tolerant and adapted to fluctuating water levels. Over time, organic matter accumulates in these marshes and forms peat. As the marsh continues to build up more peat, their migration can keep pace with historical sea levels rates. While salt marshes can act as natural erosion control, traditional shoreline stabilization structures such as rip raps or seawalls, have been shown to impede on salt marsh migration, exacerbate erosion, destroy intertidal habitat and alter sediment transport patterns.

In Durham, salt marshes cover about 160 acres or 1% of the Town's land cover and are primarily located along the tidal shoreline of the Oyster River and its tributaries (Johnson and Bunker Creeks), Little Bay and Great Bay, and Royalls Cove. Some of these areas remain lightly developed and, in some cases, completely undeveloped and protected under land conservation easements or publicly owned. Several properties that contain protected river frontage, home to a salt marsh, are the Smith Trust, Wagon Hill Farm, Johnson and Bunker Creeks/Great Bay WMA, Deer Point Open Space, Crommet and Lubberland Creeks Preserve and Adams Point. There are a handful of other riparian conservation areas that provide protection to existing and future salt marsh habitats.



Did You Know?

In 2019, the Town of Durham, in partnership with NHDES, UNH, and the Great Bay National Estuarine Research Reserve, designed and installed a living shoreline at Wagon Hill Farm—the first of its kind in the state. The restoration project was designed to reduce erosion, replace salt marsh habitat that has been lost or damaged, improve shorelines appearance, and accommodate salt marsh migration resulting from sea level rise. The Town and UNH currently have grant funds to monitor the project over the next five years to determine the suitability of the design and any necessary adaptive management strategies. The site features an educational kiosk outlining the project history and purpose.

Associated Climate Vulnerabilities of Salt Marsh

Rising sea levels are the greatest climate related threat to current salt marsh habitats, but scientists believe that marshes have the ability to migrate inland and can keep pace with the rising water levels if not blocked by infrastructure or development. This is dependent on an adequate supply of sediment or peat and as well as natural or human-made barriers present. Future sea level rise scenarios predict that, if salt marshes are not able to migrate, much of today's low marsh will be mostly submerged and transformed into mudflats or sub-tidal bays. The current high marsh will change to low marsh, and high marsh will likely migrate upland several feet, if allowed (see Figure 6). Other climate related threats to salt marshes are warmer temperatures leading to increased risks from invasive species (i.e., European green crabs) and habitat degradation from more stormwater run-off associated with increases in the frequency of large rainstorms.

The Sea-Level Affecting Marsh Migration (SLAMM) model simulates the dominant processes involved in wetland conversion and shoreline modification under different scenarios of sea level rise. The model tracks the rise of water levels and the salt boundary in 25-year time steps and predicts changes to wetland habitat based on known relationships between wetland types and tide ranges. According to the SLAMM model, Durham is one of only several communities in the coastal watershed where current conditions allow for potential salt marsh growth as sea levels rise. Upwards of roughly 200 acres of potential salt marsh will have the opportunity to migrate into surrounding upland areas; however, the Town may lose upwards of 140 acres of salt marsh habitat due to coastal inundation.

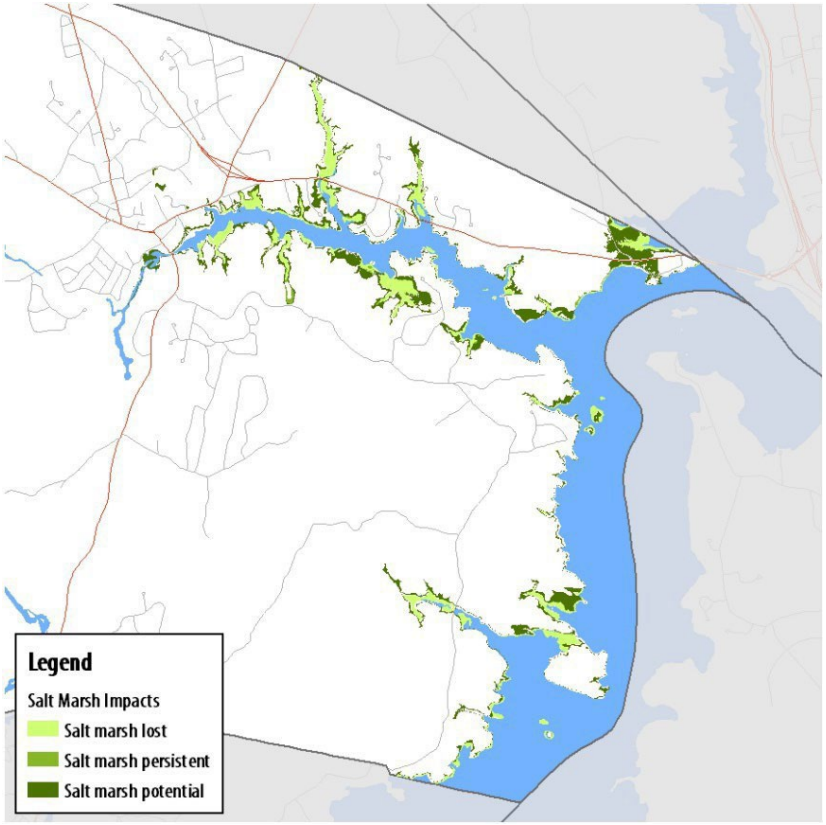
Table 7: SLAMM Results for Durham

2100 Timeframe with 6.6ft of SLR	Total Acreage
Salt Marsh Lost	143.4
Salt Marsh Persistent	10.5
Salt Marsh Potential	205.4

Source: New Hampshire Fish and Game, 2014

Quick Fact: If certain areas remain undeveloped, Durham may offer upwards of 200 acres of future salt marsh migration potential.

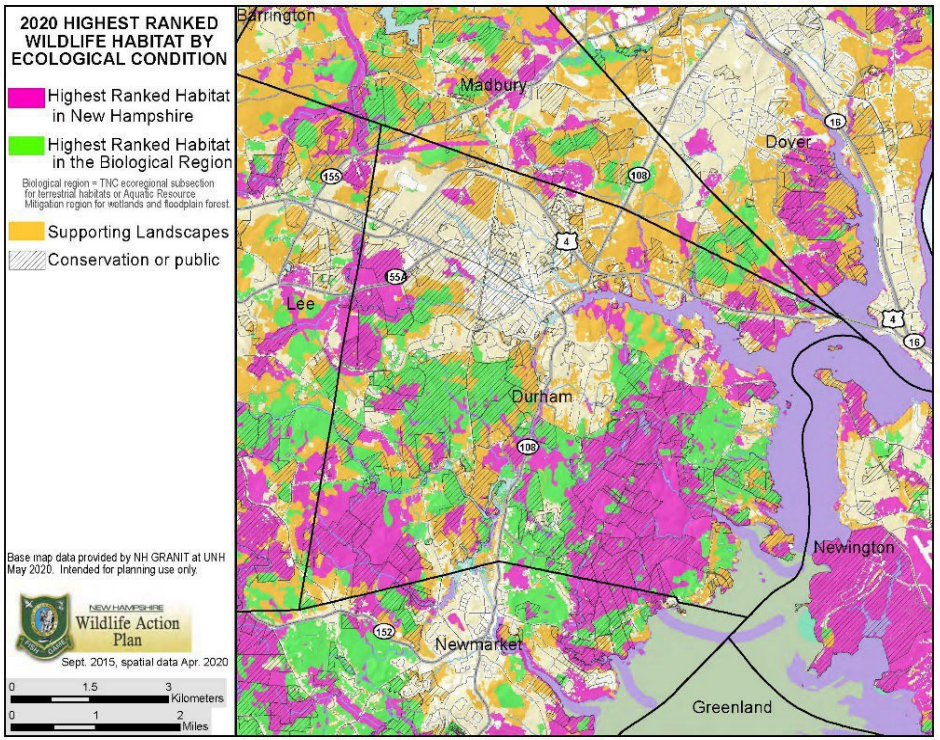
Tidal areas with the highest potential for salt marsh migration are found along the tidal portion of the Oyster River and the Johnson Creek and Bunker Creek tributaries, Royalls Cove, north of the Adams Point boat launch, and at the mouth of Crommet Creek. Protecting riparian areas through living shoreline efforts and best management practices for landscaping is likely to retain the functions of these natural systems.



SLAMM Results for Durham (New Hampshire Fish and Game, 2014)

Wildlife

According to New Hampshire's Wildlife Action Plan, Durham contains a significant amount of high-ranking wildlife habitats and is potentially home to 77 Species of Great Conservation Need, including 13 known state listed endangered species, and an additional 10 known state listed threatened species (see page 20 in Durham's Supplemental Material to their Natural Resources Chapter for a complete list of rare species and exemplary natural communities in the Town).



Highest Ranked Wildlife Habitat by Ecological Condition (Wildlife Action Plan, 2020)

Associated Climate Vulnerabilities to Wildlife

Wildlife Habitat Distribution

A shift in vegetative species composition and ranges will create changes in wildlife habitat types and distribution, which may affect some wildlife species more than others. Species that are more mobile may have a greater ability to relocate and seek more favorable living habitat than those that more restricted in their ability to travel or are more dependent on a certain species that is disappearing. These species may experience greater declines or disappear completely. Warmer temperatures and a decrease in snow cover will likely influence wildlife distribution. Changes in vegetation

composition over time may influence the growth of food sources, impacting the type and amount available to wildlife.

Changes in the water cycle, with increased spring flows and lower summer flows also have impacts on wildlife. Fish populations that spawn in the spring may be more vulnerable to shifts in the timing of snowmelt runoff. Reductions in summer low flows increase stress to aquatic organisms because of less available habitat and increased water temperature (especially for cold-water species). Lake ice-out date changes may affect the rate of summer oxygen depletion in the lakes and the productivity and abundance of aquatic organisms.

Sea Level Rise

According to the C-RiSe assessment, Durham's natural resources are vulnerable to sea level rise (SLR) and coastal storm flooding, which also poses a threat to wildlife habitat. When using the 6.3' SLR plus storm surge scenario, impacted lands include thirty conservation easements or town owned lands and other wildlife habitat lands identified in the Wildlife Action Plan along the Oyster River and the shoreline of Little Bay and Great Bay. While Durham's water resources will not be quite as impacted as land resources in terms of acreage, the town's freshwater wetlands in the tidal and estuarine zones will be the most affected by sea-level rise induced groundwater rise.

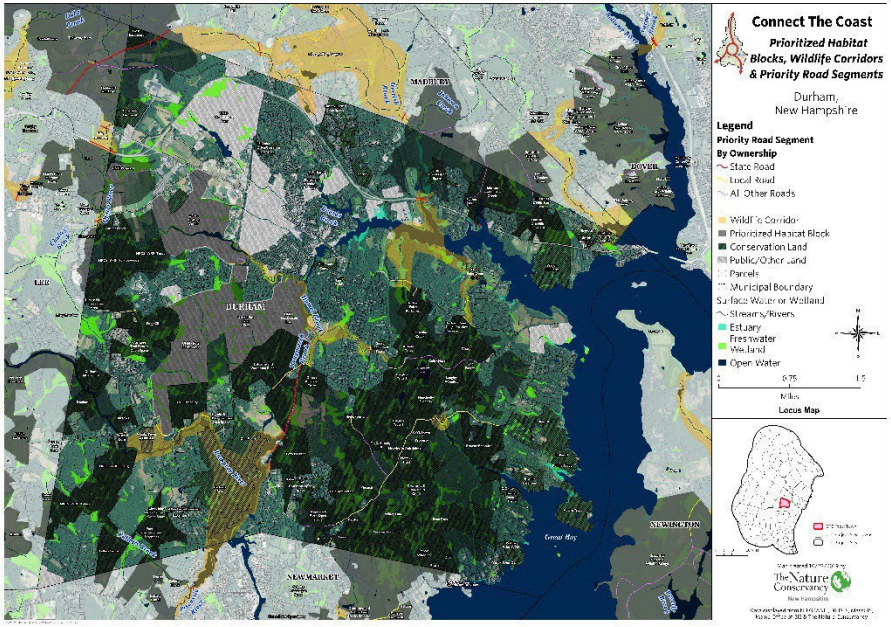
Sea level rise is causing salt water to move into freshwater habitat, which can be a barrier to species that don't have saltwater tolerance. While SLR may impact those freshwater habitats in Durham that are closest to the coastline, the communities, and habitats further inland are more likely to be impacted by freshwater flooding and groundwater rise discussed earlier in this chapter. Other coastal changes that may affect wildlife include deeper waters, increased temperature and salinity, and lower ocean pH (ocean acidification). While some habitat could successfully migrate inland, development and infrastructure could inhibit the ability of plants and animals to move inland.

Storms and Flooding

According to the NH Wildlife Action Plan, storms and flooding are the natural disasters that affect the greatest number of species and habitats. Extreme storms can disrupt bird migrations and make their breeding and nesting sites along the banks of the streams, rivers, and marshes uninhabitable. Floodplain habitats may experience more significant flooding events and be affected by an increase in summer droughts. Greater flood risks can result in more sediment and debris discharge and run-off that pollutes streams, rivers, lakes, ponds, and changes aquatic habitats. One of the greatest impacts of storm water is the destruction of stream crossings, disruptions in watershed connectivity and the impeding on aquatic species' movement.

Wildlife Corridors

Conserving wildlife corridors in rural and urban areas is essential for ensuring habitat for many species. Wildlife corridors are valuable buffers along streams and rivers and provide important linkages between open spaces. While undeveloped areas are ideal for providing habitat for many species, the town lacks an interconnected protected network allowing for wildlife habitat connectivity. Wildlife corridors provide migratory routes and travel ways for species. The Nature Conservancy-NH created maps identifying prioritized habitat blocks, wildlife corridors, and priority road segments in the Connect the Coast project. Durham's map shows seven wildlife corridors. Securing wildlife connectivity pathways is a critical need for the state's wildlife. While meaningful protection is happening within the town, focused and deliberate protection of a connected network of lands across municipalities is needed for sustainable wildlife populations.



Prioritized Habitat Blocks, Wildlife Corridors, and Priority Road Segments (Connect the Coast, 2019)

Droughts

Droughts will most significantly affect aquatic species, but all wildlife are affected by lack of availability of drinking water. Reduced river volumes and warmer temperatures due to shallow depths will directly threaten cold-water fish species. Reduced river volumes will also affect the ponds, lakes, and wetlands they flow into. While some fish species may adapt more easily, cold water species will face competition with warm water species as the fresh waters continue to warm up and their habitats will become more intermingled.

The pressures of drought and increased temperatures will also promote the distribution of invasive species such as the hemlock woolly adelgid. As hemlocks are lost to infestation, young trees are slower to grow in their place due to the dry conditions. The invasive spongy moth will thrive in drought conditions, which will affect oak trees and acorn production, an important food source for a variety of wildlife species.

Land Conservation Efforts

The Town has taken a proactive approach to land conservation to protect its natural resources from further development and contamination and to prepare for changes to the ecosystems caused by global warming. While achieving a balance between development and conservation can be challenging, climate-readiness and mitigation may present more viable and sustainable solutions. The Town and university own additional, undeveloped lands that have the potential to be permanently conserved and continue to provide ecosystem services and keep the balance in check. When combined, the university's undeveloped lands, the Town-owned land or other protected land total roughly 6,400 acres (about ~45%) of the Town's land area). These areas are currently under some type of development curtailment. However, only about 30% of that land is permanently protected, meaning that there is a potential for conversion to other uses by their current owners or upon a land transaction to a new owner.

Community

Community identity is tied to the natural and built environment and corresponds to the human and cultural capital that gives it a meaning. Durham's unique community character is shaped by the people who work, live, and recreate here – creating a sense of place that draws people in. UNH's presence unquestionably contributes to the community character of Durham and adds cultural, academic, and economic resources that enrich the Town's vibrancy. Climate change may threaten and change the character of Durham's community and change the very essence of this quintessential New England town.

The vision for the future must consider the effects of climate change such as migration and displacement, changing demographics, environmental, social, and economic impacts, and plan for an equitable future for all.

Did you know?

Plans for how to successfully integrate residents from diverse backgrounds into the community that include:

- Context specific engagement, communication, and establishing meaningful partnerships.
- Partnerships between community actors in different spheres: religion, government, education, refugee-focused groups, businesses, etc.
- Engaging climate refugees in planning to understand their needs and expectations, as well as what their lived experiences translate to in their new community.

Local Economies

Durham enjoys a high quality of life thanks to a variety of industry sectors and employment opportunities. The University, being the largest employer with over 4,000 employees, provides a skilled and educated workforce and contributes to the local and regional economy. In addition to the University, most commercial activity is located along Main Street where mixed-used development allows for a more walkable and diverse downtown.

The state of the local economy and further economic development are likely to experience the impacts of climate change in one way or another. Businesses are increasingly under more pressure from climate-related threats that might have immediate or long-term effects on their operations. Some of the most obvious impacts include droughts, extreme precipitation, and coastal flooding. Businesses may face serious disruptions to their operations including increasing costs associated with supply chain shortages, rising insurance costs, and worker challenges. To prepare for and mitigate the effects of climate change, the Town will need to build a resilient economy that will be able to withstand the hardships and provide the community with continuous support and resources while protecting the environment.

Local Businesses

Local businesses are crucial to Durham's community character and overall economic resiliency as they provide jobs, services and goods, and financial security. Businesses work and collaborate with each other and provide support in various areas, such as worker training and the sharing of resources and ideas. They aid with the development of social networks and capital and foster connections that create an environment for business hubs. As of March 2020, there are 533 registered businesses in good standing.

While most businesses in Durham are not susceptible to flooding from sea level rise, other hazards including power outages from high winds, heavy snow, or ice; road closures and commuter disruptions due to flooding from extreme precipitation events;

or water restrictions from long-term drought may result in business owners halting operations.

It will be important for the Town to partner with local businesses and provide resources to encourage companies to align their business models and operations with sustainability goals. For example, reducing carbon emissions and investing in energy efficiency measures such as LED lighting and solar, and purchasing locally grown food. It may be difficult for businesses to implement some of these measures in the short-term due to budget constraints; however, the Town should advocate for and raise awareness about the benefits of long-term resilience planning. Most businesses are starting to feel the pressure to adapt and adjust their operational models to be more environmentally conscious, mainly from customers, employees, and clients, but also regulators who have the authority to impose certain performance standards on commercial development. Striving to achieve business sustainability through long-term planning will avoid larger expenses in the future.

Nature-Based Economy

In addition to local businesses, Durham's natural resources contribute as an economic driver through tourism by attracting visitors looking for agritourism activities such as the annual Durham Farm Day, pick your own fruit at Emery Farm, and recreational opportunities such as hiking, fishing, and biking. However, the environment that nature-based economy relies on is increasingly under more threat and has become vulnerable to the effects of climate change.

Public Health

The most vulnerable populations are those that have a limited ability, either physical or financial, to fight off existing or emergent diseases, are unable to relocate or receive timely and proper care. The consequences of climate change, including air pollution, heat waves, food insecurity, access to clean drinking water, floods, extreme weather patterns and wildfires, has and will continue to exacerbate health conditions for children, elderly persons, those with pre-existing conditions or disabilities, and pregnant women. Impacts to at-risk populations are compounded, and disproportionately incurred, when there is limited access to medical care due to language barriers, financial insecurity, and lack health insurance or transportation. While a small percentage of the overall population, linguistically isolated households' vulnerability is compounded when critical information is not available in their native language. Low-income populations are the most likely to be disproportionately affected, and 25.9% of Durham's population are individuals below the poverty level.

Rising atmospheric carbon dioxide levels—the highest ever recorded at 419 parts per million in May 2021, with predicted future increases—will intensify climate-related health impacts such as asthma, heat stress and death, mental health issues, allergies, and the spread of airborne and waterborne diseases, as well as virus-related illnesses.

Heat Waves and Associated Health Impacts

Annual temperatures are 1.3-1.7 degrees Fahrenheit warmer than in 1970 and each of the past four decades has been successively warmer than any decade prior to 1850. The frequency and length of the heat waves, which have both increased over the past decades, contribute to the severity and intensity of population health impacts. Durham, along with other Great Bay communities, is experiencing an increase of 0.2 – 0.6 days over the past six decades in the number of days with extreme warm nighttime temperatures in summer, a strong indicator of heat waves. This can result in fewer cool nights or respite for those who suffer from heat-related stress during the day.

Ground-level ozone increases with the temperatures creating smog and pollution exacerbating symptoms and increasing hospital visits for those suffering from asthma, chronic obstructive pulmonary disease (COPD) or lung cancer. Moreover, research has shown that the longer growing seasons are closely linked to longer pollen seasons and increased pollen levels as pollen is heat sensitive. The rate of people suffering from or developing allergies as a result of climate change is therefore likely to increase as temperatures continue to rise.

Hospital and emergency room visits typically increase during heat waves as people experience dehydration, heat strokes, heat cramps, and a cascading list of side effects including fainting, dizziness, exhaustion, headache, muscle pain, excessive sweating, and confusion, among many others. Extreme heat waves can result in fatalities, but there is also evidence that heat waves can cause or lead to injuries, kidney failure, electrolyte imbalance, sickness, and inflammation.

These symptoms can be exacerbated for older populations that also experience dementia, cardiovascular diseases, respiratory problems, compromised immune system, limited mobility, and diabetes, among other conditions. One of Durham's Census Tracts is home to a concentration of older adults where 20.8% of the population is over the age of 64. Moreover, 576 people in Durham have some form of disability that prevents them from being able to take care of themselves and require assistance. Young children are at higher risk of dehydration as they are often not aware of the feeling of dehydration or overheating. Approximately 2% of the Town's population is under the age of five.

As both day and night temperatures continue to rise throughout the year, we can expect to experience longer, warmer, and muggier summers and milder winters. In fact, by 2050, New Hampshire might experience more than 40 days of extreme heat waves and the scorching sun will become the new normal.

Mental Health

The stress inflicted by loss of lives, property, lack of access to food and clean drinking water and limited ability to adapt to rapid change will most severely impact people suffering from mental health challenges, disabilities, or social isolation, and further compounded for those that may be disproportionately impacted.

Children are more likely to experience injuries, loss of family members, death, displacement, or educational disruptions during the extreme weather events that may lead to long-term developmental and mental health impacts resulting in lowered performance outcomes or social skills, increased anxiety, post-traumatic stress, or depression. Similarly, elderly populations, and socially or linguistically isolated individuals may experience disrupted or decreased access to resources, health care, and social capital.

People living with low income who are unable to adequately plan and prepare for displacement experience additional stress that can be exacerbated when caring for another family member. Homeless people who experience a high risk of exposure to dangerous conditions caused by air pollution, heat waves, intense storms and extreme temperatures are more likely to suffer extreme stresses that will cause or worsen their mental health conditions. Nearest services for women with children experiencing homelessness is My Friend's Place in Dover. The limited number of regional homeless

shelters, none of which are in Durham, have decreased capacity due to the Covid-19 pandemic.

Water Quality

In addition to the sea level and groundwater rise related hazards previously discussed in this chapter, the associated flooding and saltwater intrusion impacts to water quality pose public health implications to food security, fresh water sources, failure of septic systems and further contamination from disposal sites, flooding of basements, and increased inland inundation and groundwater discharge into the freshwater surface water bodies.

The risk of water contamination becomes especially crucial for water bodies which are used for leisure activities such as swimming, fishing or are a sources of local drinking water. The unintended consequences of compromising local water systems include the spread of viruses, bacteria, and parasites that cause diarrhea, such as giardia or campylobacteriosis. Sea level rise is predicted to inundate 385.81 acres of the coastal areas in Durham according to the 6.3ft Sea level rise and storm surge scenario. Many of these areas are currently developed and the rate of ocean pollution is going to grow rapidly as these low-lying coastal communities experience more frequent flooding from storm surges and high tides. Research shows that the post-flood debris of garbage, plastic, oil, access nutrients and other toxins commonly found on the ground, are eventually carried back into the bay and the ocean as the waters recede, further contributing to ocean pollution. Additional water quality contamination results from stormwater runoff pollutants such as nitrogen and ammonium that are carried into the bay and leaching of toxins and sewage into the groundwater systems.

Agricultural Resources

Durham has a rich agricultural history predating the Town's incorporation, which is threatened by the impacts of climate change. Average temperatures have risen three degrees since 1900, average rainfall has increased 19% since 1985, extreme rain events have increased 140% since 1950, warmer winters and increased rain l the winter and spring means a longer mud season and delayed planning, and sea levels have risen eight inches since 1980. These trends are only going to intensify and will have implications for the current food system supporting residents of Durham.

Did You Know?

A 2015 Climate Change Vulnerability Assessment by the USDA lists these vulnerabilities for the Northeast:

- Extreme precipitation shifts planting and harvesting times, causes floods which compact soil, damages crops, lowers grain and vegetable yields.
- Frosts after early spring led to loss of crops, especially perennials.
- Warmer average temperatures impact growth patterns, shorten the cold crop season, and increase pest, disease, and weed issues.
- Rising ocean temperatures decrease livable habitat for fish and shellfish.
- An increase in frost-free days could create opportunity for a longer growing season and increased food production.
- Durham should enable local food production by supporting the construction of greenhouses and hoop houses as well as food storage such as inground root cellars or basement root cellars. These storage solutions require little energy input and will support increased food production, while also providing backup resources in the case of supply chain shocks.

There are multiple farms established in the town, including UNH research-based farms, multi-generational farms such as Tecce Farm, Emery Farm, LaRoche Farm, backyard farms, community gardens, home gardens, and aquaculture operations. On a larger scale, New Hampshire as a state has fallen behind in its commitment to local food, dropping from #5 on the Locavore Index in 2015 to #16 in 2019.

Longer supply chains are more vulnerable to the impacts of climate change; increasing local food production can mitigate disruptions like those seen during peak Covid-19 periods. Agricultural resources and local food production in Durham are impacted by sea-level rise, drought, storms, and flooding, strengthening the case for the conservation of undeveloped land to increase food production.

Preserving farmland from development, mitigating flood risk, and preparing for habitat changes, pests, and disease is vital to increasing local food production and protecting the town's agricultural economy.

According to a 2008 farmland soils map developed by the Strafford Regional Planning Commission, around 10% of these farmland soils are currently in conservation. It is crucial the Town work with landowners and conservation organizations to conserve undeveloped land and enable that land to be used for food production. Durham should actively establish and encourage food production by individuals, neighborhood collaboration, community wide efforts, and small-scale farming operations, to reduce reliance on food produced elsewhere. Preventing urban sprawl will help the town adapt to a changing climate by building resilience into the food system, development patterns, and preserving ecosystem services.

New England is especially vulnerable to supply chain shocks and food shortages, as it is at the end of the supply chain and geographically distant from large food production centers. The issues and goals presented in the Town's 2015 Master Plan update are pertinent to the discussion around agriculture and climate change and aim to develop a framework for a resilient agricultural economy. Durham is heavily dependent on food grown outside of the region, the Town's most productive soils have been lost to development, there is no more than a three-day supply of fresh food in New England at any one time, and agriculture will be impacted by but can also help mitigate climate change impacts. Goals to address these issues suggest: encouraging agriculture to contribute to the Town's working landscape, identify and maintain productive agricultural and forestland in Durham, support the development of food hubs in Strafford, Rockingham, and York counties, and increase access to local and regional food supplies to reduce reliance on fossil fuels.

Did You Know?

Durham's aquaculture industry provides important ecosystem services for the Town. Oyster farming in Great Bay helps to filter nutrients and improve water quality. Livestock not only provide food, fiber, and other important byproducts, they are essential players in resilient and regenerative agricultural systems.

Durham has a vibrant local food economy. Key players in the local food system include Farmer's Markets organized by seacoast Eat Local and Seacoast Grower's Association, farm markets, and restaurants which source ingredients grown in Town and the wider region such as the Works and UNH Dairy Bar. Producers and distributors working in the local food economy created a vital support system when the Covid-19 pandemic began impacting supply chains. Producers quickly responded with food delivery services to accommodate stay at home orders and met the needs of restaurants when national food supplies were disrupted. Building off this ability to mend gaps in the food system will only further protect the Town against future disruptions.

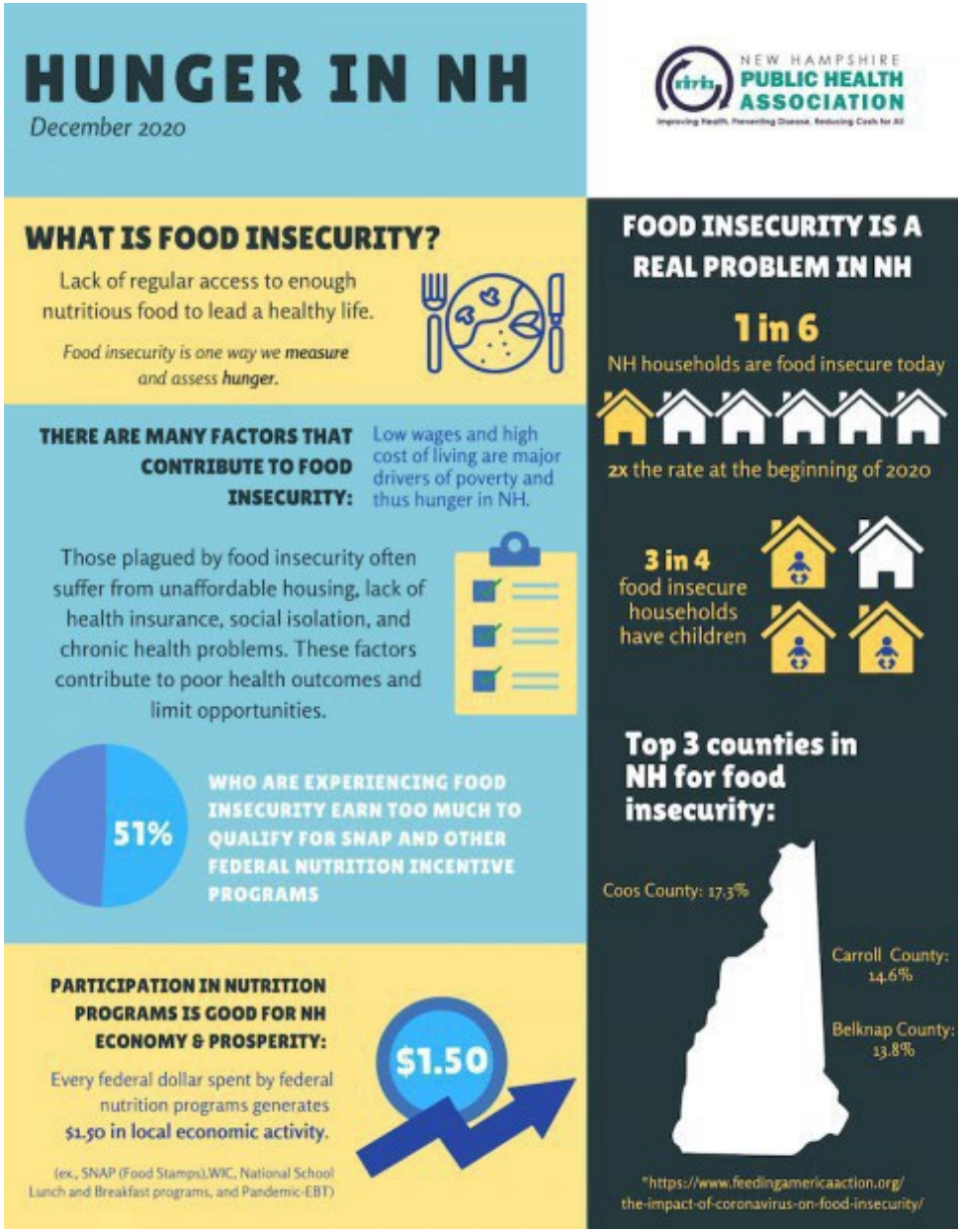
Since the 2015 Master Plan update, the town has achieved elements of its agricultural vision. An update to the Agricultural Zoning Ordinance in February 2021 allows for expansive agricultural activities as residential accessory uses including beekeeping, animal husbandry, and aquaculture. Principal agricultural uses in the rural zone were expanded even further. This amendment will allow non-commercial supplements to the local food system, and enable residents to develop a more regenerative approach to home gardening. Regenerative Agriculture places a focus on soil and ecosystem health and generally includes practices like cover cropping, crop diversification, no or low-till, composting, and animal integration to preserve and rebuild the soil microbiome. Promoting regenerative practices for local food production is an approach to agroecological resilience that aligns human-centered and nature-based goals.

Food Insecurity

Food insecurity is a complex issue but can generally be defined as an economic and social condition of limited or uncertain access to adequate food. a prevalent issue which has been exacerbated by the Covid-19 crisis according to recent research. One projection by Feeding America indicates a jump in the overall food insecurity rate in Strafford County from 9.1% in 2019 to 12.1% in 2020. What's more, a 2015 survey of University of New Hampshire students reported 25% of students to be food insecure and an additional 9.6% of students experienced marginal food insecurity. Emergency supplemental services exist in Durham to support residents having trouble, such as the UNH program "swipe it forward" which allows students to donate to a bank of meal swipes. Even still, qualifying for such programs through evidence of need can be a barrier for many, and relying on emergency food sources is not a resilient method of support.

Food Security versus Food Sovereignty

It is important to maintain a distinction between meeting the basic needs of Durham's residents, versus developing an environment that leads to the enrichment of their lives. Although much of the resources and data around hunger in the United States is approached from a food security context and while it is appropriate to acknowledge and uses as a basis for policy change and decision making, approaching solutions to this issue through the food sovereignty lens will ultimately build a more resilient future for the town of Durham. Where food security promotes medium scale production in support of the agrochemical industrial complex, which is known to degrade land, and views local production as supplemental to the industrial complex, food sovereignty centers local production in its definitions. The food sovereignty lens discourages agricultural practices that are harmful to land preservation while encouraging agroecological local production. It positions food and clean water as a human right and defines sovereignty as having access to locally and sustainably produced, culturally appropriate, and independent of the larger food system context that is highly vulnerable to climate change impacts.

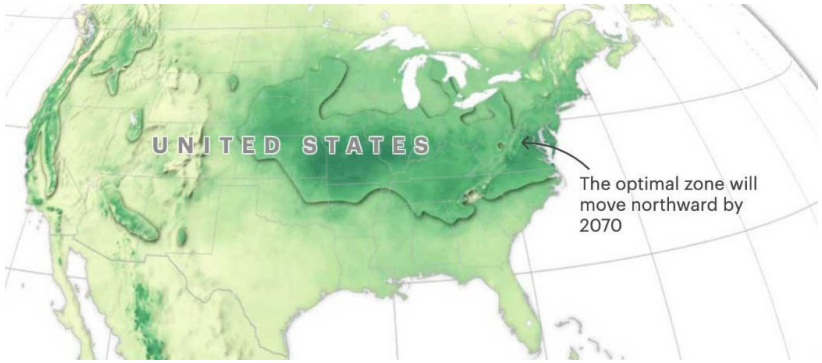


Resources

Resources based at the University of New Hampshire such as the NH Food Alliance, Food Solutions New England, and the Northeast Climate Hub at Woodman Horticultural Research Farm provide the town connective points to climate-based research and food systems network partners. Food Solutions New England envisions a future where 50% of the region's food is produced within New England. The Durham Agricultural Commission, UNH Agricultural Experiment Station, and USDA Northeast Climate Hub are also critical resources in the local-regional food systems context. Leveraging these partnerships and resources to drive this vision on a municipal scale reinforces collaboration and community building.

Food Access in NH

A 2019-2021 Food Insecurity Project by UNH students found that one of the greatest barriers for food insecure students, which can be applied to the wider population of people who are food insecure, is searching for resources and proving need. Effective communication of information and reaching those in search of resources is crucial to improving access to food. UNH Cooperative Extension has developed a New Hampshire Food Access Map that is frequently updated with new sites. The directory includes food pantries and meals, local discounts and benefits, nutritional assistance, and summer meals. Seacoast Eat Local's Seacoast Harvest Guide is another source for food pantries, SNAP farm stands, and other valuable services. Through gleaning from community gardens and home gardens in Durham, local community members also play an important role in improving access for food insecure households.



New Climate Maps Show a Transformed United States (ProPublica: Climate Migration)

Climate Migration

Research suggests climate hazards will incite migration patterns across the country, and even internationally. There are many drivers of this migration that are important to analyze to fully understand the impacts this may have. Climate migration can be simply described as displacement caused by the impacts of climate change, though the nexuses between the impacts of climate change, economic strife, and violence complicate the definition of a climate migrant. In the United States, the increasing frequency of extreme weather events have intensified a cause for concern among homeowners. In 2019, almost one million Americans were displaced from their homes due to disasters, and in 2020 that number grew to over one million seven hundred thousand people. Multiple counties in Vermont, Maine, Massachusetts, and New Hampshire appear on a list of the top 150 counties in the country for climate resilience based on a tool developed by the EPA called the Climate Resilience Screening Index (CRSI), which uses socio-ecological indicators to measure a community's resilience.

On the state level, some New Hampshire residents living on the coast, especially those living in areas like Hampton that are already experiencing the impacts of climate change via flooding from storms and sea level rise will be looking to migrate inland away from the immediate coastline. New Hampshire saw a glimpse of what climate migration is going to look like when the Covid-19 pandemic influenced people to move to their second homes for greater portions of the year, even permanently, in the state. On top of this, the state was dealing with a climate-induced drought. Municipal infrastructure and community services have become strained due to this combination in some areas only equipped to handle predictable vacation populations.

Lastly, it is important to consider that climate migrants will also be seeking refuge from outside of the United States, as similar extreme weather events are impacting areas in other parts of the world even more severely than the U.S. One example of this trend can be seen in the influx of immigrants from Puerto Rico to Nashua, N.H. after Hurricane Maria in 2017.

Potential Benefits

Because of the warming climate, the northeast may see an increase in agricultural yields, which is beneficial to developing the regional food system for a growing population. Climate migration could help to diversify New Hampshire's population, introduce new cultural identities and skill sets, strengthen the workforce, and revitalize rural areas.

Possible Challenges

If our communities and infrastructure aren't built to support a growing population, when issues arise such as evictions, not enough space in hospitals, and unbearable traffic and our resources become strained, tension may build between existing residents and new community members displaced from their previous homes. Additionally, people migrating to rural areas are often younger than the existing population. The changing demographic and introduction of new perspectives and backgrounds can be cause for further tensions between new and long-time residents. Climate migrants may have new ideas of what made their previous community thrive to which Durham could adapt, and it is important to consider their lived experiences in planning for the future.

Economic Implications

To prepare for this shift, it is critical that the town invest in infrastructure planning which looks to the future. The ability of a person or family to move away from unsuitable living conditions largely relies on their financial means. As people relocate, the threat of urban sprawl may intensify while the divide between the rich and poor expands. Bolstering municipal infrastructure in preparation for sea level rise and flooding scenarios will prepare potential receptor sites to house a growing population while mitigating hazards. This includes investing in affordable housing, a topic of interest identified in the 2015 Master Plan update as well as ensuring adequate transportation, water and sewer systems, and appropriate food access that can support a growing population.

Affordable Housing and Density

A crucial element of infrastructure to fortify for incoming climate migrants and a growing population is the town's housing stock. Many residents have expressed dismay with the Town's housing options in terms of affordability. Comments regarding the lack of workforce housing, housing for young adults and new families, and a desire for intergenerational developments have surfaced in community forums. Planning for Smart Growth in Durham will require affordability and use considerations, as well as an understanding of which demographics are being pushed out of the housing market.

Did You Know?

The EPA's Planning for Smart Growth publication includes actions to promote a more resilient future land use patterns including:

- Enact an adequate public facility ordinance (APFO). An APFO helps ensure that infrastructure for schools, road, sewers, and fire protection exists to accommodate new development.
- Establish urban service areas or boundaries as part of the overall master facilities plan to help phase development in coordination with infrastructure.
- As part of detailed area plans, rezone designated growth areas (e.g., around transit stops or regional activity centers) to allow denser development."
    - Allowing for denser development in areas planned for growth will also help to preserve open space and important farmland soils.

III. Planning for a Resilient Future

Specific criteria were developed to evaluate a comprehensive list of recommended actions to help guide Durham in addressing climate change.

Goals and Recommendations

This section outlines the goals and recommendations associated with the findings of the chapter and are intended to strategically guide the Town's adaptation and resilience efforts over the coming decades. It's important to note that the goals and recommendations below are not prioritized.

LU Land Use Recommendation

BI = Built Infrastructure, **NWL** = Natural & Working Lands, **C** = Community

Issue: Solving climate change requires global scale solutions; however, Durham can take steps to reduce its carbon footprint.

Goal: Lower total amount of greenhouse gas emissions (BI)

Recommendations

Planning

1. Implement emission reduction strategies set forth in the Town's Carbon and Nitrogen Inventory (i.e., transition the municipal fleet to hybrid-electric vehicles and exercise the buy-out options for the Town's solar power purchase agreements)
2. Identify ways to begin shifting from natural gas to electric energy powered by renewable sources
3. Explore additional options to increase energy efficiency and the use of renewable energy sources by residents and business owners in Durham

Partnerships, Collaboration, and Resource Sharing

Support actions set forth in the University's Climate Action Plan (WildCAP 2021), particularly those where the Town is listed as a partner

Transportation Alternatives

1. Increase number of local destinations connected by sidewalks, safe bike routes, and accessible public transportation
2. Increase the frequency, dependability, and use of public transit particularly for year-round residents

Regulation/Policy

LU 1. Amend land use regulations and policies to increase the use of efficient electric vehicle technology (i.e., revise parking requirements in the Zoning Ordinance to require that a percentage of spaces be electric vehicle ready, create a fee structure that would allow for the Town to purchase additional charging stations for public use, etc.)

LU 2. Review the zoning ordinance to ensure it does not place unnecessary restrictions or barriers on residential/small business renewable energy installations and identify opportunities to encourage these types of installations, while preserving the Town's aesthetics

Goal: Accomplish objectives set forth in the Global Covenant of Mayors agreement (BI)

Recommendations

Planning

1. Report community wide GHG inventories regularly to track Durham's emissions and progress towards emission reduction
2. Prioritize reducing emissions from Durham's highest emitting sectors: transportation and the built environment
    a. Increase energy efficiency and shift from fossil fuels to electric energy powered by renewable sources
    b. Encourage no and low-carbon modes of transportation, such as walking, biking, and use of public transportation
3. Promote forest and tree conservation and avoid forest fragmentation
4. Create an updated forest inventory of high-quality lands and forests to determine ways to optimize forest sequestration and determine best forest management scenarios to improve resilience to climate change
5. Increase the resiliency of Durham's sustainability efforts by ensuring a steady funding source and designating staff to oversee the efforts

Partnerships, Collaboration, and Resource Sharing

1. Leverage community involvement to promote social equity regarding land use and involve community members in the development of the Town's Climate Action Plan

Issue: Building climate resilience is necessary to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate change.

Goal: Increase resilience of the built environment (BI)

Recommendations

Planning

1. Conduct an update to the sea level rise scenarios and floodplain analysis on the tidal portion of the Oyster River
2. Evaluate options to reduce impacts from sea-level rise and storm surge flooding to sections of roadway on Back River Road and Cedar Point Road
3. Investigate the feasibility of a stormwater utility program
4. The sea level rise impacts on groundwater levels and water quality final non-technical report should be consulted during future planning efforts

Capital Improvements

LU 1. Ensure that capital improvement projects (i.e., drainage system improvements, street reconstruction, culvert/bridge design, water/sewer pipe replacement, etc.) are evaluated for climate impacts, using the NH Coastal Flood Risk Summary, Part II: Guidance for Using Scientific Projects (2020, and as updated)

2. Prioritize culverts identified in the C-RiSe Assessment and the NH Tidal Crossing Project for more immediate replacement/resizing schedules in the capital improvements program to mitigate future flooding

3. Evaluate adaptation options to address vulnerable infrastructure identified in the C-RiSe Assessment, including sewer and water pipes, the lift station near Beards Creek, and Beards Creek dam

LU 4. Use Groundwater Vulnerability Analysis and Planning Study as a guide to implement actions to mitigate groundwater rise impacts

Transportation Alternatives

1. Research and promote the use of pavement materials that are more resilient to climate impacts, including extreme heat, groundwater rise, increased freeze/thaw cycles, and more extreme precipitation

Partnerships, Collaboration, and Resource Sharing

1. Encourage NHDOT to use the NH Coastal Flood Risk Summary, Part II: Guidance for Using Scientific Projections when designing future road/bridge improvement projects along Route 4 in areas vulnerable to projected sea level rise and storm surge

Regulation/Policy

LU 1. Reevaluate Shoreland Protection and Wetlands Overlay Districts to incorporate data on sea-level rise projections and potential impacts

LU 2. Provide information and resources for green infrastructure developments that may encourage developers to go beyond minimum design requirements. Provide information and resources for residents to implement green infrastructure on their properties.

LU 3. Review both subdivision and site plan regulations that are key to climate change adaptation.

Goal: Improve local hazard mitigation and emergency operations planning (BI)

Recommendations

Emergency Planning

1. Determine which populations are highly dependent on certain transportation infrastructure (roads, public transportation, etc.) to address how disruptions in the system will affect their safety and well-being
2. Use scenario planning (i.e., traffic demand model) to determine how potential infrastructure failures at certain points in the network would affect emergency response and evacuation processes
3. Update the Town's Hazard Mitigation plan to include a co-occurrence map showing natural disasters and extreme events and the compounding effects on the community, environment, and infrastructure
4. Conduct tabletop or scenario training in departments responsible during emergency response situations

Partnerships, Collaboration, and Resource Sharing

1. Ensure that evacuation plans are completed in coordination with surrounding towns and agencies in the coastal region to implement timely and comprehensive planning and notification for coastal storm events; routes should be reviewed periodically to evaluate risk and consider long-term planning efforts.
2. Investigate opportunities to share costs, at the regional level, of infrastructure resilience improvements that benefits multiple communities or agencies

Outreach and Engagement

1. Identify opportunities to improve emergency communications between the Town and residents
2. Increase awareness of municipal resources available to support residents sheltering in place during storms
3. Mark evacuation routes with signage and communicate routes to the public

Issue: More frequent and intense drought, storms, heat waves, and rising sea levels will impact wildlife and the environments in which they live.

Goal: Protect wildlife habitat and manage natural resources (NWL)

Recommendations

Land Protection Efforts

1. Conserve and restore corridors between habitat block to facilitate wildlife movement, and minimize future loss or fragmentation of habitat
2. Protect areas identified in the sea-level marsh migrating model (SLAMM) as opportunities for salt marsh migration and where possible, remove physical barriers to salt marsh migration
3. Revise criteria in the Guidelines for Acquiring Legal Interest in Conservation/Open Space Land document to include carbon sequestration, air pollution reduction, and flood storage
4. Consider the merits of establishing permanent conservation status on publicly owned, but not currently permanently protected lands, so their integrity and ability to provide ecosystem services remains unchanged

Planning

1. In suitable areas, install living shorelines along the coastal banks to prevent erosion and stabilize the shoreline
2. Improve the condition of stream crossings that have restricted aquatic organism passage

Regulation/Policy

LU 1. Consider minimum density requirements, especially in areas such as mixed-use zones to encourage development patterns that minimize impacts on open space and important natural resources

Goal: Improve resilience to invasive species (NWL)

Recommendations

Planning

1. Implement strategies from the Town's Integrated Pest Management Approach and continue to improve, adapt, and respond to invasive plant management
2. Use prevention, early detection, and rapid response to reduce the impacts of invasive plants on Town-owned land
3. Continue to survey, map, and monitor current and potential invasive plants and select control methods (i.e., cultural, mechanical, or chemical) based on science and current technology to eradicate the known invasive species and reduce the environmental impacts they cause

Outreach and Education

1. Conduct education, including workshops, and outreach efforts that increase invasive plant awareness among the public, volunteers, and the Town staff

Goal: Ensure the long-term sustainability of the Town's working lands (NWL)

Recommendations

Planning

1. Use sustainable forest management practices on Town-owned forests and incorporate a climate lens into forest management plans

Outreach and Engagement

1. Conduct education and outreach to raise awareness about the effects of climate change on working and natural lands
2. Work with private landowners to support conservation of undeveloped lands for long-term sustainability

Regulation/Policy

1. Explore regulatory options or best management practices that would reduce point- and nonpoint sources of pollution from roads, lawns, septic systems, agricultural fields, and residential and commercial development

Issue: Impacts of climate change will be felt in many different sectors of society, including local economies, food systems, housing conditions, and food production.

Goal: Ensure the Town's local economy and social capital is resilient to a changing future (C)

Recommendations

Planning

1. Ensure all staff positions are equipped to respond to planning and development activities through a resilience and adaptation lens
2. Prepare for a likely increase in climate in-migration (i.e., support additional municipal services and affordable housing stock, ensure future development is guided out of vulnerable areas, plan to be a welcoming community for newcomers)

Partnerships, Collaboration, and Resource Sharing

1. Connect local businesses to available resources to assist them in implementing climate adaptation measures and emergency preparedness planning
2. Support local businesses to assess supply chain impacts and vulnerabilities and identify strategies to improve resilience
3. Support student/youth engagement in climate action and municipal decision making, and ensure at-risk populations are engaged in all planning processes

Outreach and Engagement

1. Consider sharing relevant information on climate action legislation from the Coastal Adaptation Workgroup in weekly Durham Friday updates.

Regulation/Policy

LU 1. Ensure land use regulations allow for compact, mixed-use, low-impact developments in the downtown to extend walkability and areas for unplanned social interaction

Goal: Improve existing food, public health and safety, and housing conditions (C)

Recommendations

Planning

1. Incorporate additional trees and native vegetation, while also preserving mature trees, into the downtown landscape and other Town-owned properties to help lower surface and air temperatures by providing shade
2. Work to prevent the stress on and loss of native species in landscapes owned by the Town
3. Identify buildings in greatest need of weatherization services and support households to access these services

Outreach and Engagement

1. Make resources for residents experiencing food insecurity more readily available via the Durham town website
2. Provide information about vectors and vector-borne diseases to the public, offer tips on how residents can protect themselves with a focus on children
3. Provide education and outreach to ensure that residents are made aware of emergency resources the Town provides, including temporary shelters during large scale disasters and warming/cooling shelters during times of extreme temperatures or during power outages
4. Educate residents on managed retreat from the shoreline and flood-prone areas.
5. Encourage the use of energy efficiency/renewable energy/weatherization products and services by raising awareness of available financing/rebate options

Regulation/Policy

LU 1. Connect local food producers and retailers, while ensuring local food purchasing of nutritious, affordable items is accessible especially to vulnerable populations.
LU 2. Explore creative ways to promote and secure affordable housing options to make available to a diverse demographic of students, young professionals, and seniors (i.e., requiring that for new developments of a certain size, a percentage of the rental units must remain at the HUD rental rate, allowing multiple accessory dwelling units on a single lot in some zoning districts, etc.)

Goal: Increase local food production (C)

Recommendations

Planning

1. Identify town owned land suitable for community gardens and food and fiber production
2. Improve equitable access to healthy, fresh, locally sourced and produced, culturally appropriate foods
3. Assess vulnerability to sea level rise and storm surge of prime farmland soils and soils of local and statewide importance
4. Include local farms and food producers in economic development planning
5. Ensure new conservation easements enable agricultural activity, where appropriate
6. Review existing conservation easement language for Town owned properties to identify land that may be used for food production.
7. Enable the growing of food at a neighborhood and collaborative scale.

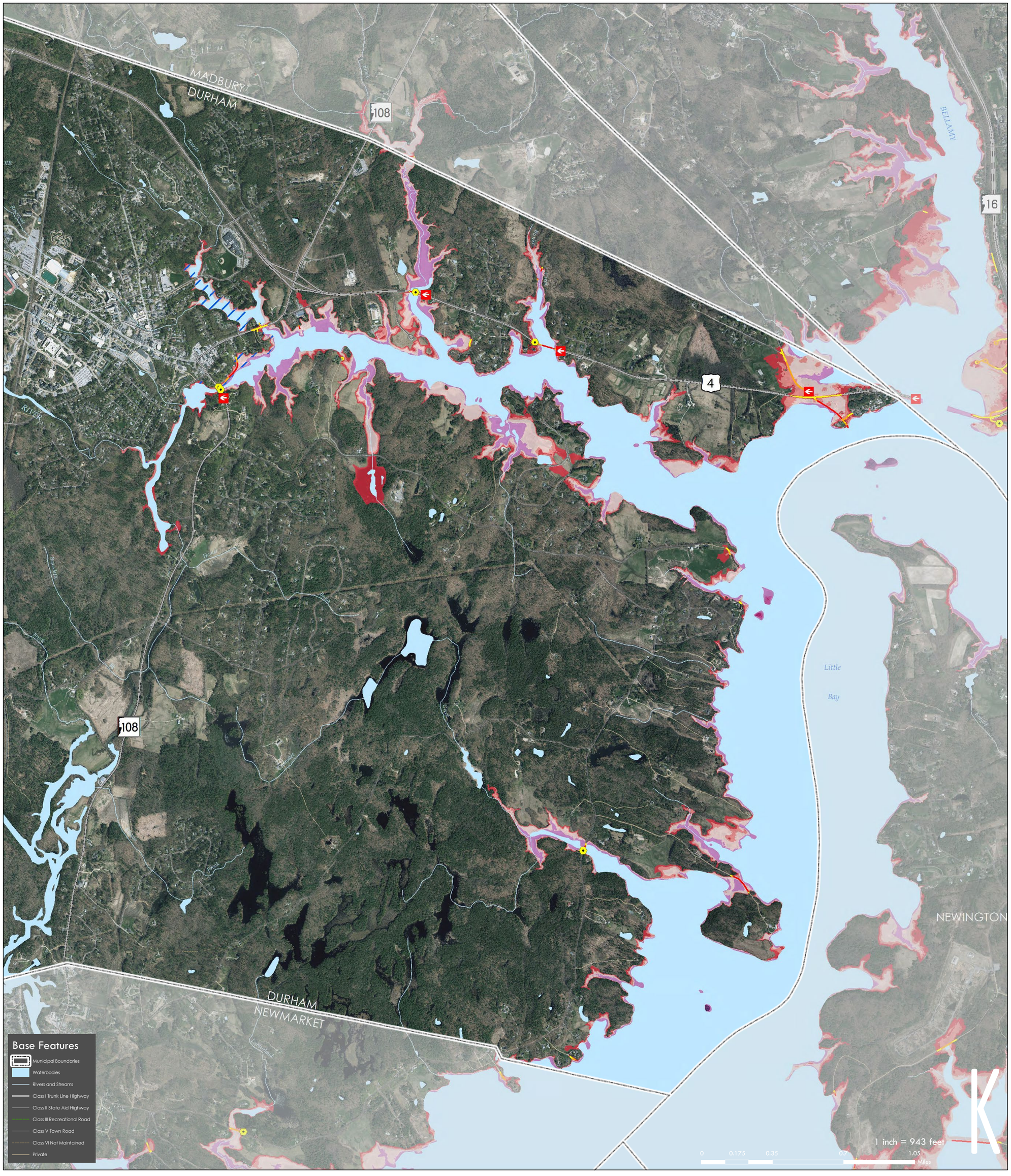
Education and Outreach

1. Build awareness of the local food system in Durham and surrounding towns
2. Conduct education and outreach on food production, processing, preservation, and storage, seed saving, animal husbandry and processing, as well as processing and use of their biproducts
3. Provide outreach on the benefits of encouraging local food production of all food groups; fruits, vegetables, grains, dairy, protein (both animal and plant based) as well as animal feed and forage.

Regulation/Policy

LU 1. Consider ways to reduce development on prime farmland soils
LU 2. Consider regulations that would reduce or prohibit chemical fertilizer, herbicides, pesticides in agriculture, landscaping, and by individual property owners
LU 3. As appropriate, support neighborhood scale, individual and cooperative gardens

Map Appendix begins on the next page.



C-RiSe

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TOWN OF DURHAM

Map 6: Roads and Transportation Assets
Sea-Level Rise + Storm Surge 1.7', 4.0', 6.3'

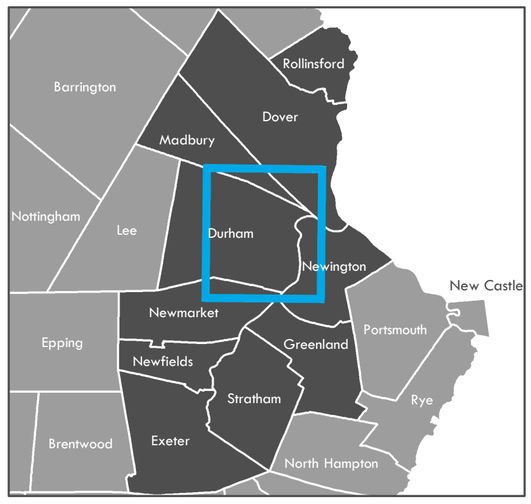
SLR Legend

- Extent of Sea-Level Rise of 1.7' with Storm Surge
- Extent of Sea-Level Rise of 4.0' with Storm Surge
- Extent of Sea-Level Rise of 6.3' with Storm Surge
- Approximate Mean High High Water Level

Impact Legend

- DOT Projects
- Evacuation Routes
- Impacted Urban Compact Area
- Roads Impacted By SLR of 1.7 Feet w/ Storm Surge
- Roads Impacted By SLR of 4.0 Feet w/ Storm Surge
- Roads Impacted By SLR of 6.3 Feet w/ Storm Surge

Disclaimer:
NHDOT projects were derived from various sources within the New Hampshire Department of Transportation and may have been updated at different times and with varying levels of accuracy. Given redundancies and the need to provide meaningful maps for planning purposes, SRPC generalized projects according to vulnerable areas. A more comprehensive list of impacted projects can be viewed within the community's vulnerability assessment chapter.



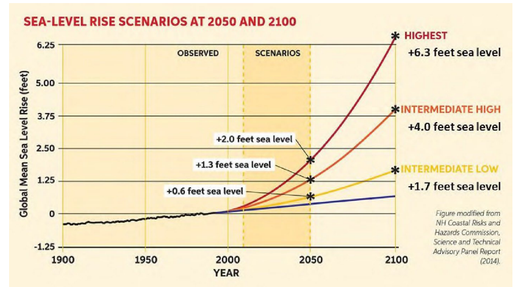


Figure modified from NH Coastal Risks and Hazards Commission, Science and Technical Advisory Panel Report (2014).

Sea-Level Rise Scenarios

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	2050		2100	
	Lower	Higher	Lower	Higher
Current Elevation of MHHW a,b	4.4	4.4	4.4	4.4
100-Year Flood Height	6.8	6.8	6.8	6.8
Subsidence	0.0	0.0	0.0	0.0
Eustatic SLR	1.0	1.7	2.5	6.3
Total Stillwater Elevation a,c	**12.2**	**12.9**	**13.7**	**17.5**

a - NAVD: North American Vertical Datum of 1988
b - MHHW: Mean Higher High Water at Fort Point, NH
c - Total Stillwater Elevation may not equal total of components due to rounding

Table 13. Estimates (in feet) of future 100-year flood Stillwater elevations at Fort Point under lower and higher emission scenarios (relative to NAVD88) based on the statistical analysis presented in this report.

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Path: M:\Region\Project_Special_Merit\Mapping\Final_Maps_By_Community\Durham\Durham_Transportation_4_6.mxd

Data Sources:
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Road Asset Impacts: Town of Durham

Road Name	Road Class	Miles Impacted	Road Name	Road Class	Miles Impacted	Road Name	Road Class	Miles Impacted
Adams Point Road	Private	0.12	Piscataqua Road	State	0.39			
Back River Road	Local	0.30	Riverview Road	Local	0.03			
Bay Road	Local	0.03	Watson Road	Local	0.01			
Bunker Lane	Not maintained	0.02						
Cedar Point Road	Local	0.24						
Colony Cove Road	Private	0.01						
Dover Road	State	0.08						
Jacksons Landing	Local	0.01						
Newmarket Road	State	0.01						
No Name	Private	0.17						
Old Landing Road	Local	0.14						

Note: Total miles impacted per road were calculated using the greatest sea-level scenario (6.3') extent + storm surge.

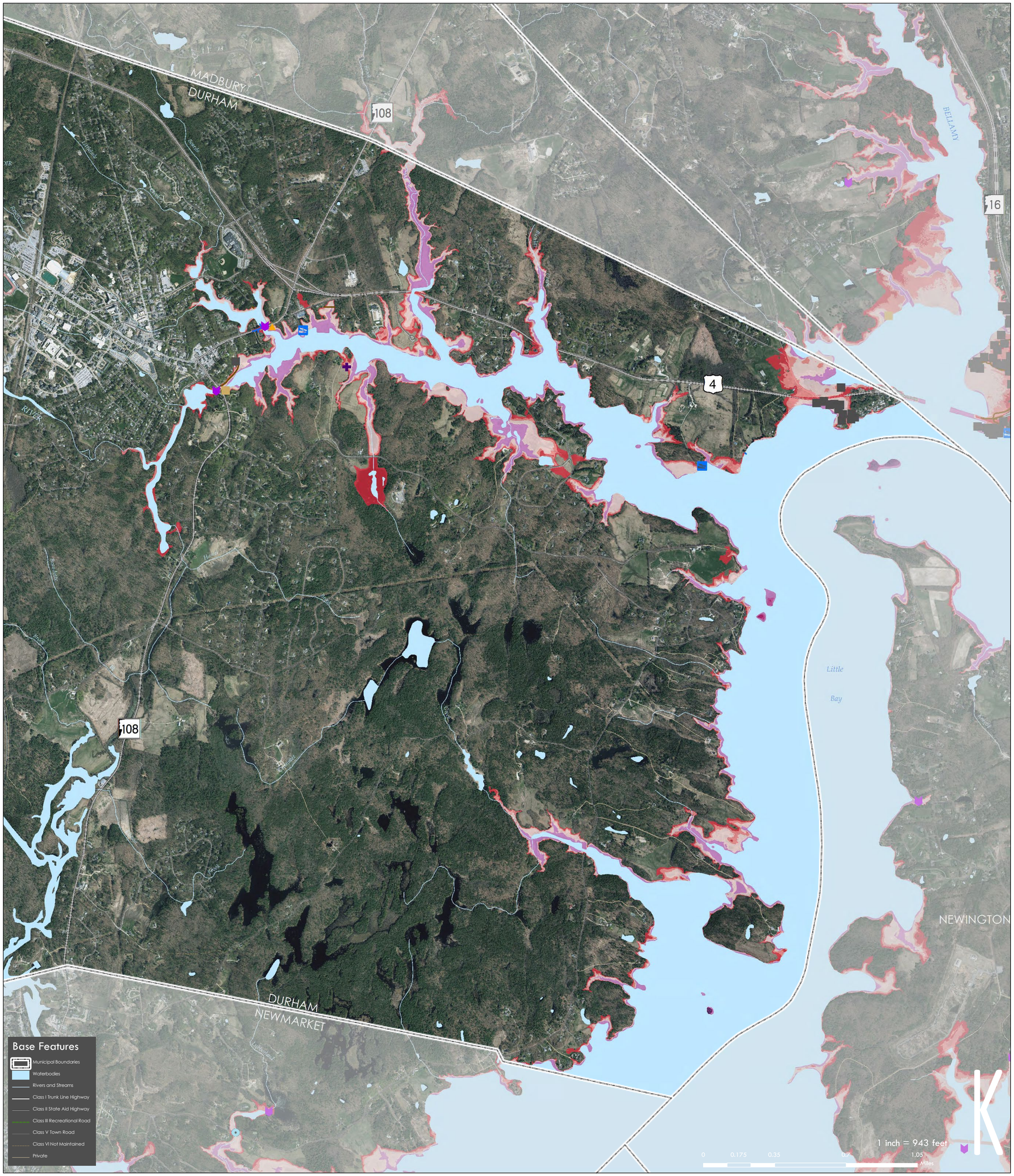
State & Municipal Roadways (miles)

Roadway Type	Sea Level + Storm Surge Scenarios		
	1.7 feet	4.0 feet	6.3 feet
State	0.05	0.10	0.48
Local	0.24	0.58	0.77
Private	0.11	0.16	0.30
Not Maintained	0.01	0.01	0.02
Total Road Miles	0.41	0.85	1.57

Other Transportation Asset Impacts: Town of Durham

Impacted Asset	Metric	Metric Impact	General Location and Name
Urban Compact Areas	Acres	24.4	Neighborhoods near Route 108 along Oyster River and Beards Creek
Evacuation Routes	#	3	Route 4
			Route 108
			Back River Road
NHDOT Projects	#	5	Bay Road over Great Bay inlet
			Route 4 over Johnson Creek
			Route 4 over Bunker Creek
			Route 108 bridge replacement over Oyster River
			Route 108 bike shoulder construction

Note: Total number of impacted assets were calculated using the greatest sea-level scenario (6.3') extent + storm surge.



C-RiSe

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TOWN OF DURHAM

Map 4: Extent of Projected Tidal Flooding Sea-Level Rise 1.7', 4.0', 6.3' + Storm Surge

SLR Legend

- Extent of Sea-Level Rise of 1.7' with Storm Surge
- Extent of Sea-Level Rise of 4.0' with Storm Surge
- Extent of Sea-Level Rise of 6.3' with Storm Surge
- Approximate Mean High High Water Level

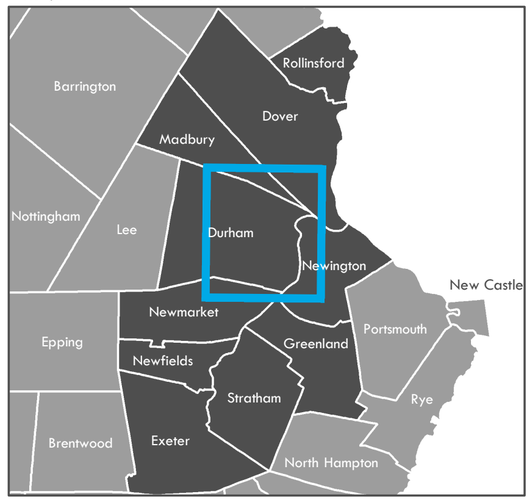
Impact Legend

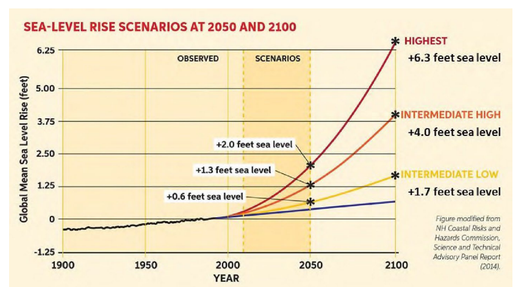
- Critical Facilities
- Culverts
- Dams
- Graveyard
- Houses
- National Register of Historic Places
- Public Water Access Sites
- Sewer Pipes
- Water Pipes

Base Features

- Municipal Boundaries
- Waterbodies
- Rivers and Streams
- Class I Trunk Line Highway
- Class II State Aid Highway
- Class III Recreational Road
- Class V Town Road
- Class VI Not Maintained
- Private

Disclaimer:
The building data points shown on this map indicate the relative location of existing structures to the flood scenarios displayed. For the purpose of the C-RiSe assessment, the severity, type, or impact of flooding on these structures was not evaluated.





Sea-Level Rise Scenarios

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	2050		2100	
	Lower	Higher	Lower	Higher
Current Elevation of MHHW a,b	4.4	4.4	4.4	4.4
100-Year Flood Height	6.8	6.8	6.8	6.8
Subsidence	0.0	0.0	0.0	0.0
Eustatic SLR	1.0	1.7	2.5	6.3
Total Stillwater Elevation a,c	**12.2**	**12.9**	**13.7**	**17.5**

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Infrastructure Asset Impacts: Town of Durham

Impacted Asset	Metric	Sea Level Scenarios			General Information
		1.7 feet	4.0 feet	6.3 feet	
Sewer Pipes	Miles	0.13	0.19	0.26	Critical Municipal Infrastructure
Water Pipes	Miles	0.01	0.01	0.11	Critical Municipal Infrastructure
Transmission Lines	Miles	0.00	0.00	0.00	Critical Municipal Infrastructure

Other Infrastructure Assets: Town of Durham

Impacted Asset	Metric	Metric Impact	General Location and Name
Primary Sewer Lift Station	#	1	Near Beards Creek Dam
Dams	#	1	Beards Creek Dam
		1	Mill Pond Dam
Graveyards	#	1	Durham Point Road
Durham Historic District	#	1	Main Street/Newmarket Road
Residential Structures	#	14	Building data points shown on this map indicate the relative location of existing structures
Water Access	#	1	Jackson's Landing
		1	Wagon Hill

Note: Total number of impacted assets were calculated using the greatest lea-level scenario (6.3')

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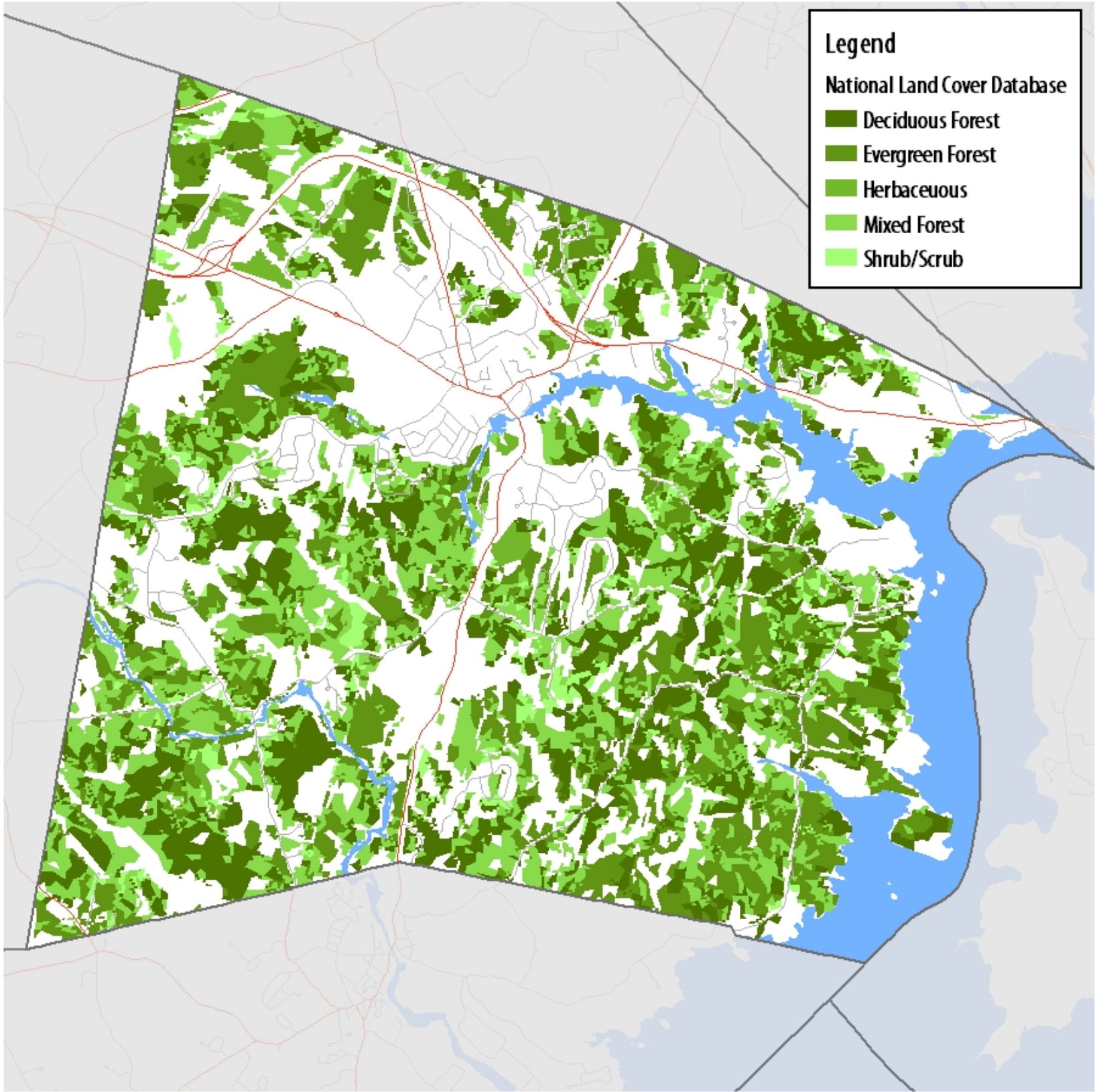
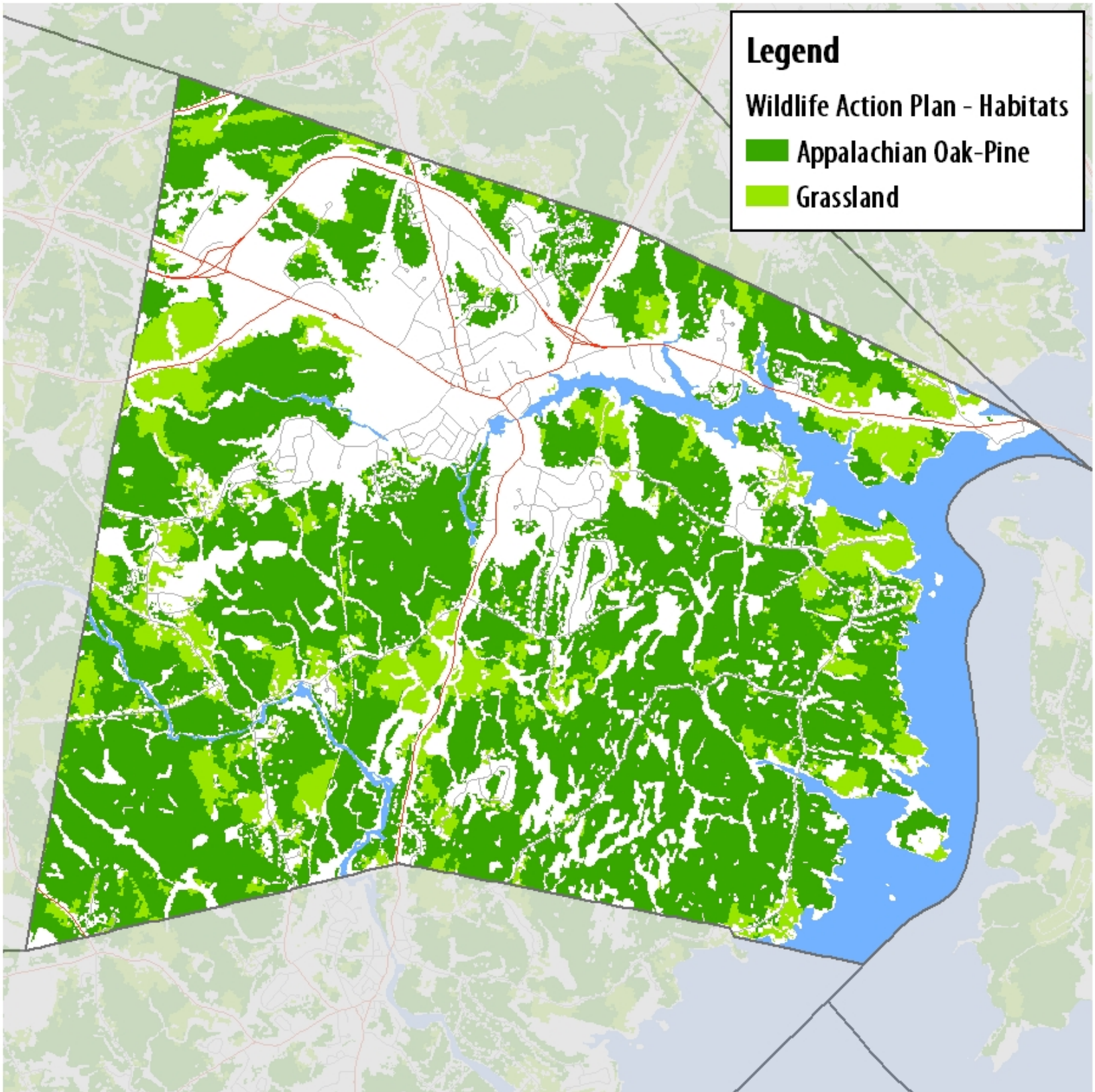
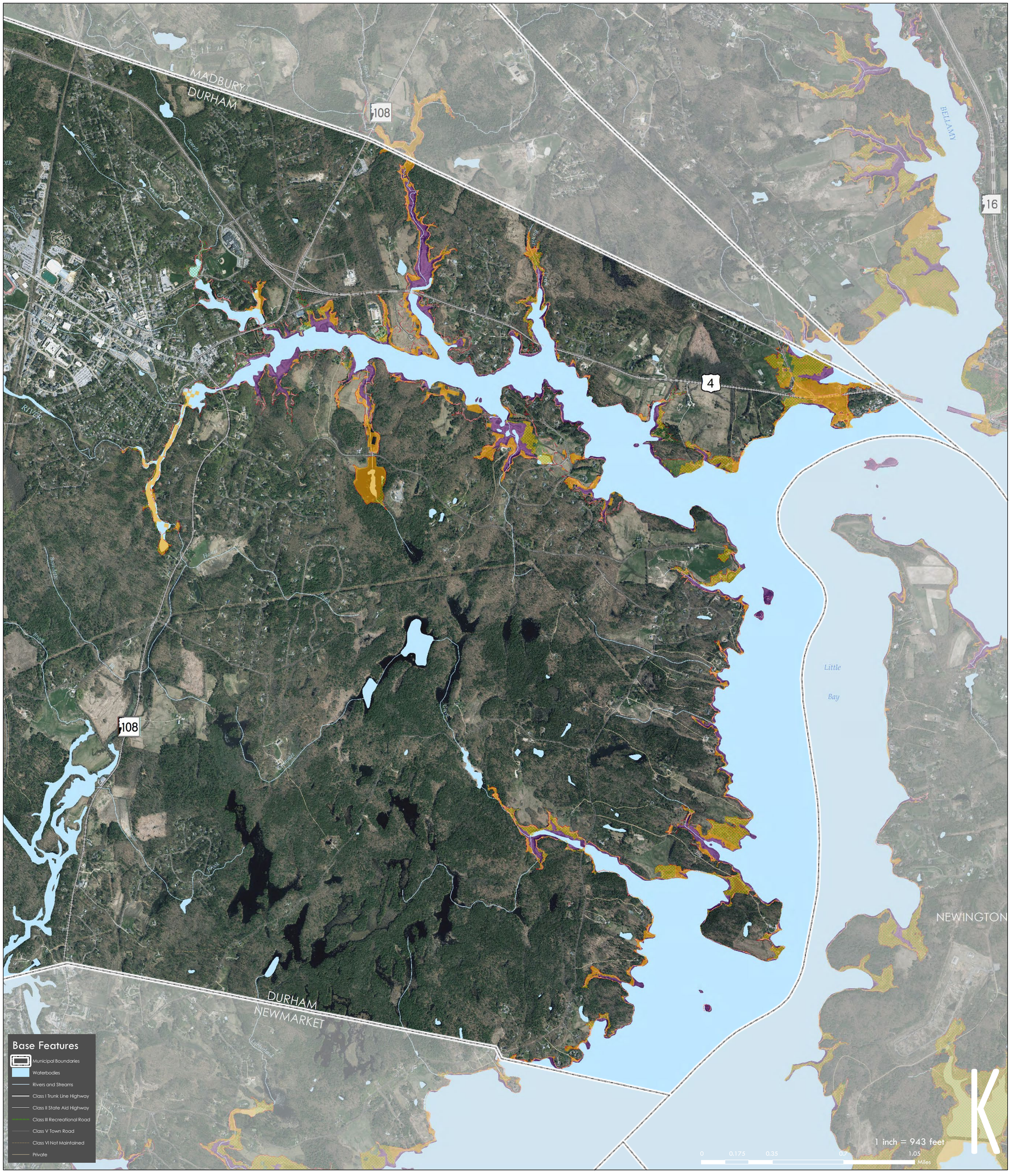

Legend
National Land Cover Database
Deciduous Forest
Evergreen Forest
Herbaceuous
Mixed Forest
Shrub/Scrub


Legend
Wildlife Action Plan - Habitats
Appalachian Oak-Pine
Grassland



C-RiSe

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TOWN OF DURHAM

Map 8: Land Resources
Sea-Level Rise + Storm Surge 1.7', 4.0', 6.3'

SLR Legend

- Extent of Sea-Level Rise of 1.7' with Storm Surge
- Extent of Sea-Level Rise of 4.0' with Storm Surge
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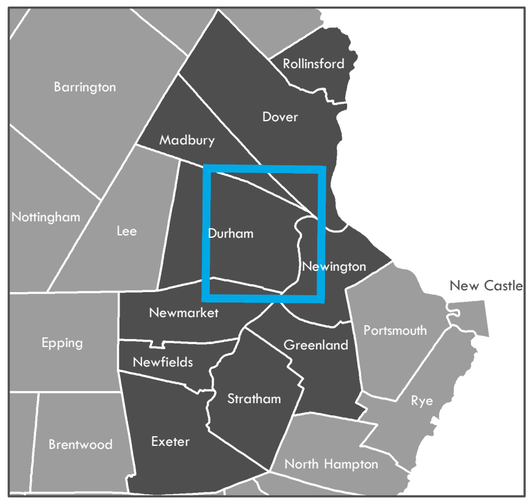
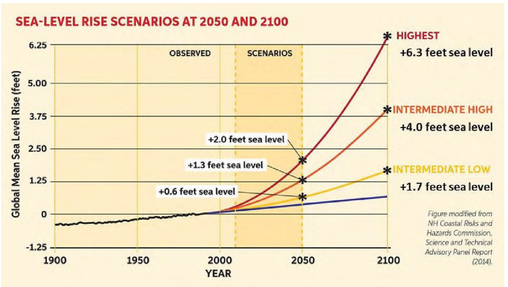
- Approximate Mean High High Water Level

Impact Legend

- Conservation Lands (2015)
- Wildlife Action Plan Tiers 1,2,3 (2015)





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Path: M:\Region\Project_Special_Merit\Mapping\Final_Maps_By_Community\Durham\Durham_LandRes_4_6.mxd

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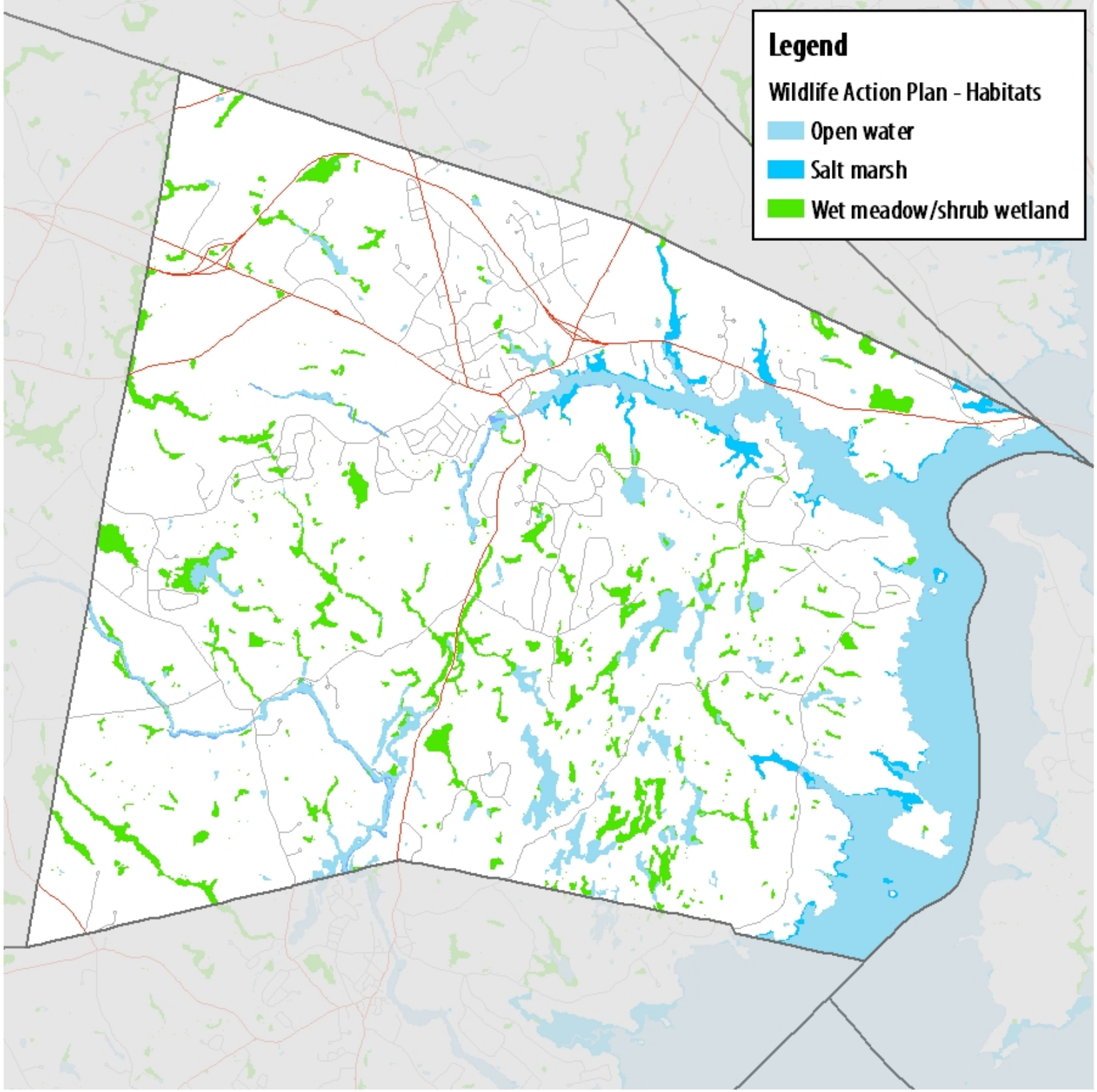
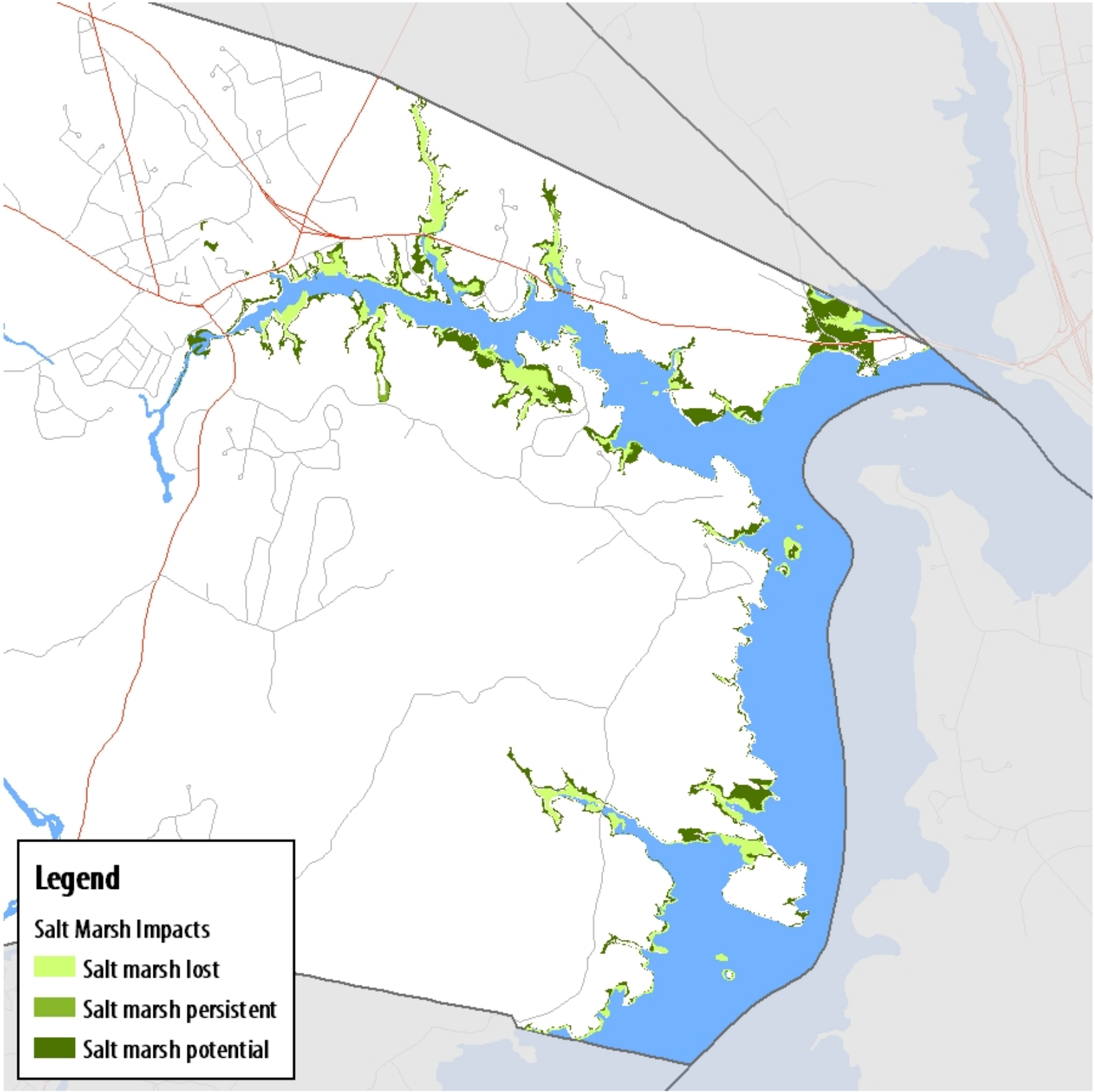
Land Resource Impacts: Town of Durham (acres)

Resource Type	Name	Sea Level + Storm Surge Scenarios 1.7 feet	4.0 feet	6.3 feet
Conservation Lands	Adams Point	5.76	7.55	9.84
	Barbara Cochrane Parcel	0.04	0.11	0.20
	Borner Easement	1.18	2.79	4.05
	Brown and Beckwith	5.38	7.64	9.64
	D. Chase	0.05	0.06	0.08
	Deer Point Open Space	5.62	7.48	8.16
	Durham Open Space	0.03	0.09	0.15
	Durham Point Road Forest	0.00	0.00	1.72
	Durham Pump Station	0.26	0.35	0.49
	Durham Town Land	0.05	0.07	0.39
Conservation Lands	Durham WWTP	1.01	2.57	3.61
	Jacksons Landing	2.38	2.79	4.21
	Johnson and Bunker Creeks	1.68	2.54	3.65
	John Creek Open Space	0.54	0.92	1.41
	Langley Bison Farm	2.89	4.44	8.19
	Mill Pond	0.00	0.15	0.36
	Mill Pond Center	0.00	0.26	0.32
	Milne Tract	0.00	0.18	0.22
	NHFG Fishing Access	0.06	0.13	0.31
	Old Town Landing	1.04	1.20	1.27
Conservation Lands	Oyster River School District	2.36	3.35	1.29
	Palmer Tract	1.40	2.50	3.82
	Rollins II/Rollins Tract	5.50	9.89	13.30
	Smith Trust	10.60	15.61	17.91
	Stolworthy Wildlife Sanctuary	0.01	0.09	0.21
	Town of Durham	0.54	0.91	1.30
	Tuveson	0.00	0.19	2.87
	UNH - MacDonald Lot	0.00	1.24	2.56
	Wagon Hill Farm	8.04	13.23	19.63
	Wilcox Point	0.70	1.74	3.31
Wildlife Action Plan	Name	Sea Level + Storm Surge Scenarios 1.7 feet	4.0 feet	6.3 feet
	Tier 1	76.63	122.01	180.92
	Tier 2	5.26	9.39	15.49
	Tier 3	18.65	32.34	47.73

Land Resource Totals (acres)

Resource Type	Sea Level + Storm Surge Scenarios 1.7 feet	4.0 feet	6.3 feet
Conservation Lands	57.12	90.07	127.56
Wildlife Action Plan	100.54	163.74	244.14
Total(s) Combined	157.66	253.81	371.70


Legend
Wildlife Action Plan - Habitats
Open water
Salt marsh
Wet meadow/shrub wetland

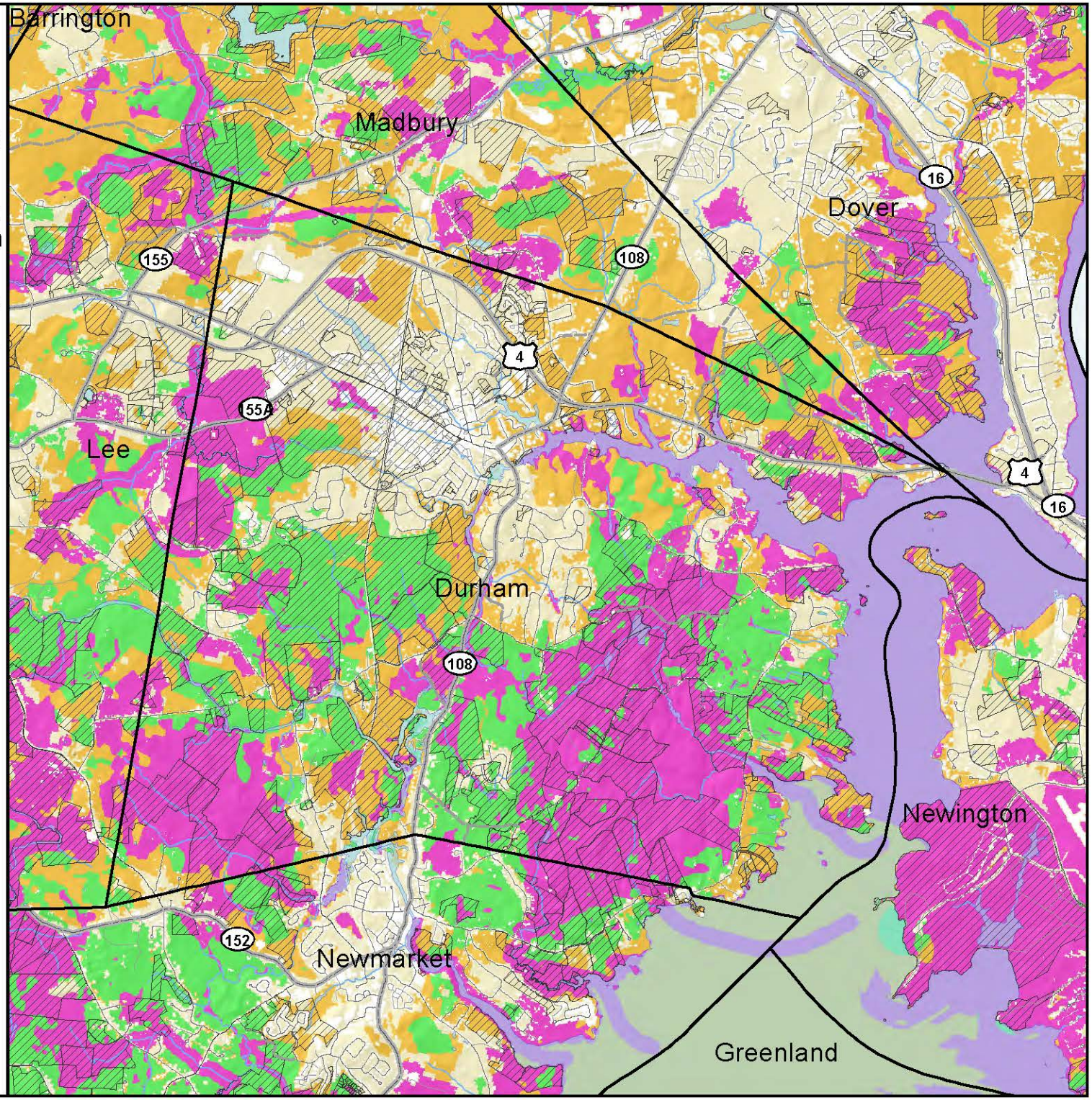

Legend
Salt Marsh Impacts
Salt marsh lost
Salt marsh persistent
Salt marsh potential

2020 HIGHEST RANKED WILDLIFE HABITAT BY ECOLOGICAL CONDITION

- Highest Ranked Habitat in New Hampshire
- Highest Ranked Habitat in the Biological Region

Biological region = TNC ecoregional subsection for terrestrial habitats or Aquatic Resource Mitigation region for wetlands and floodplain forest.

- Supporting Landscapes
- Conservation or public



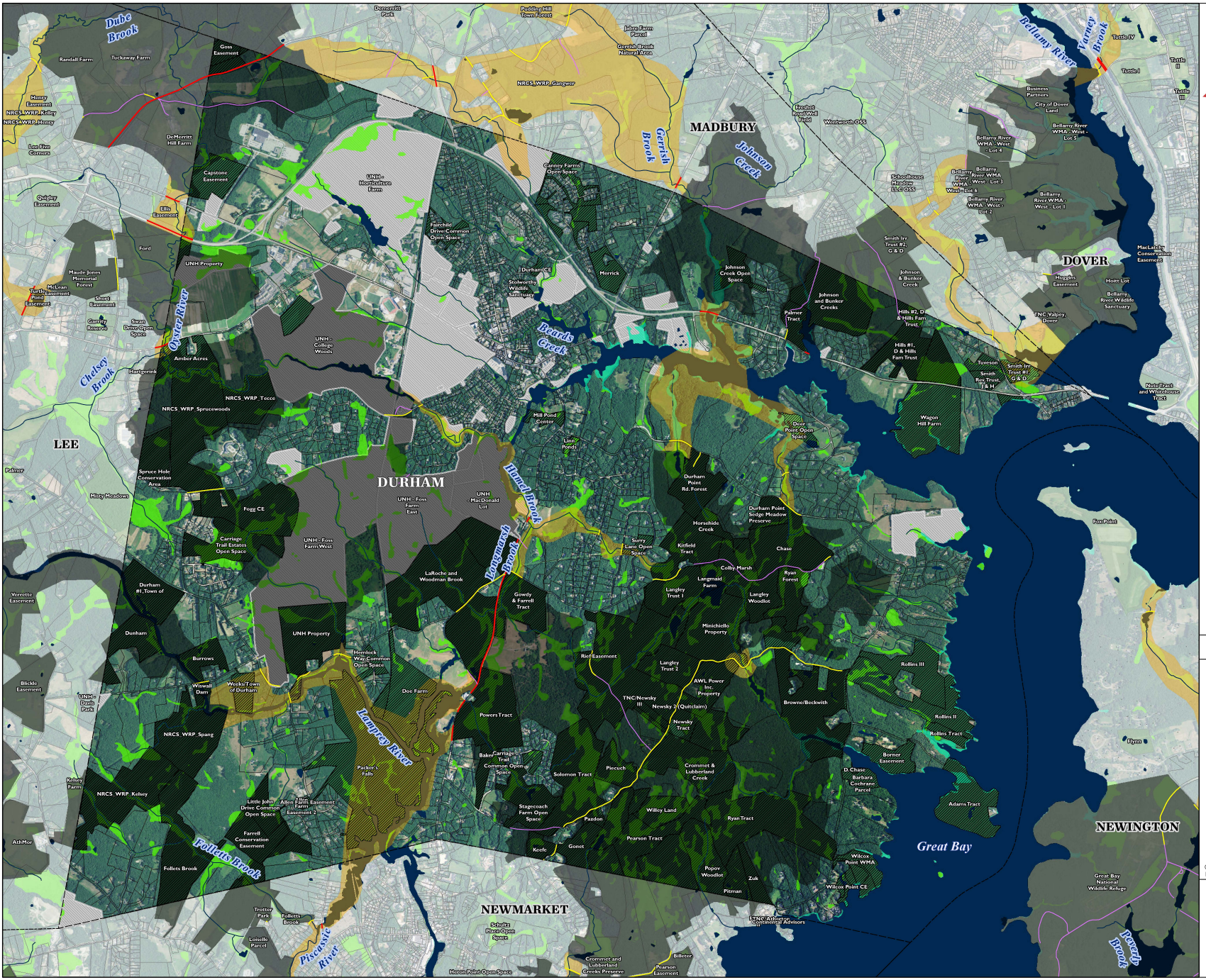
Base map data provided by NH GRANIT at UNH May 2020. Intended for planning use only.

NEW HAMPSHIRE Wildlife Action Plan

Sept. 2015, spatial data Apr. 2020

0 1.5 3 Kilometers

0 1 2 Miles



Connect The Coast

Prioritized Habitat Blocks, Wildlife Corridors & Priority Road Segments

Durham,
New Hampshire

Legend

Priority Road Segment
By Ownership

- State Road
- Local Road
- All Other Roads

- Wildlife Corridor
- Prioritized Habitat Block
- Conservation Land
- Public/Other Land
- Parcels
- Municipal Boundary

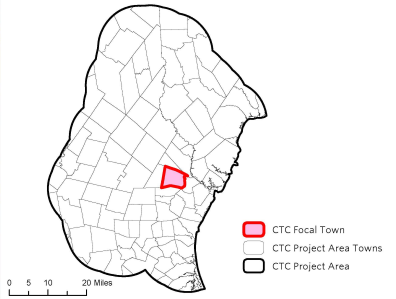
Surface Water or Wetland

- Streams/Rivers
- Estuary
- Freshwater Wetland
- Open Water

N
W E
S

0 0.75 1.5
Miles

Locus Map



Map created 10/28/2019 by:
The Nature Conservancy
New Hampshire

Data displayed from NH GRANIT, NHDES, MassGIS, Maine Office of GIS & The Nature Conservancy.