



## CLIMATE RISK IN THE SEACOAST

*Assessing Vulnerability of Municipal Assets and  
Resources to Climate Change*

Rollinsford • Dover • Madbury • Durham • Newmarket • Newfields • Exeter • Stratham • Greenland • Newington

# TOWN OF STRATHAM, NEW HAMPSHIRE

## Vulnerability Assessment

of projected impacts from sea-level rise and coastal storm surge flooding



Prepared by the  
Rockingham Planning Commission

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Paul Deschaine, Town Manager

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Cover Photo: Squamscott River, Chapmans Landing at King Tide

Photo Credit: William Meserve; Theresa Walker

### Notes on Use and Applicability of this Report and Results:

The purpose of this vulnerability assessment report is to provide a broad overview of the potential risk and vulnerability of state, municipal and public assets as a result of projected changes in sea-levels and coastal storm surge. This report should be used for preliminary and general planning purposes only, not for parcel level or site specific analyses. The vulnerability assessment performed was limited by several factors including the vertical accuracy of elevation data (derived from LiDAR) and the static analysis applied to map coastal areas subject to future flooding which does not consider wave action and other coastal dynamics. Also, the estimated flood impacts to buildings and infrastructure are based upon the elevations of the land surrounding them, not the elevation of any structure itself.

## PLANNING TO REDUCE RISK AND VULNERABILITY

New Hampshire's economy and quality of life have historically been linked to its shores, its vast expanses of productive saltmarshes and sandy beaches. Increased flooding has the potential to place coastal populations at risk, threaten infrastructure, intensify coastal hazards and ultimately impact homes, businesses, public infrastructure, recreation areas, and natural resources. Accounting for changes in sea level and coastal storms will help lead to informed decisions for public and private investments by minimizing risk and vulnerability.

### What is a Vulnerability Assessment?

A vulnerability assessment identifies and measures impacts of flooding from sea level rise and storm surge on built structures, human populations and natural environments. Factors that influence vulnerability include development patterns, natural features and topography. The assessment evaluates existing and future conditions such as:

- inland extent and depth of flooding
- impacts to natural and human systems
- changes in impacts between different flood levels

*New Hampshire seacoast municipalities are confronted by land use and hazard management concerns that include extreme weather events, storm surges, flooding and erosion. These issues are only intensified by recent increases in the frequency and intensity of extreme storm events and increases in sea level.*

### How can the vulnerability assessment be used?

Information from a vulnerability assessment can help guide common sense solutions, strategies and recommendations for local governments, businesses, and citizens to enable them to adopt programs, policies, business practices and make informed decisions.

Planning for the long-term effects of sea level rise may also help communities better prepare in the short-term for periodic flooding from severe coastal storms. Results from a vulnerability assessment can be incorporated into various municipal planning, regulatory and management documents.

### How will the vulnerability assessment benefit the community?

The Climate Risk in the Seacoast assessment is intended to assist coastal NH communities to take actions to prepare for increase flood risk, including:

- Enhance preparedness and raise community awareness of future flood risks.
- Identify cost-effective measures to protect and adapt to changing conditions.
- Improve resiliency of infrastructure, buildings and investments.
- Protect life, property and local economies
- Protect services that natural systems provide
- Preserve unique community character

Zoning Ordinance

Land Conservation Plan

Capital Improvement Plan

Site Plan Regulations

Master Plan

Roadway Management

Subdivision Regulations

Hazard Mitigation Plan

Facilities Management Plan

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Project Partners:



## MAPPING AND ASSESSMENT METHODS

### Vulnerability Assessment: Sea Level Rise and Storm Surge Scenarios

The *Climate Risk in the Seacoast* (C-RiSe) vulnerability assessment project produced maps and statistical data about the potential impacts to New Hampshire's seven coastal municipalities from sea-level rise and storm surge to infrastructure, critical facilities transportation systems, and natural resources. As shown in Figure 1, three sea-level scenarios were evaluated accounting for a range from the intermediate-low to the highest projected sea-levels at the year 2100.

FIGURE 1: Sea-Level and Storm Surge Scenarios

Sea Level (SLR) Scenarios	SLR Intermediate Low 2100	SLR Intermediate High 2100	SLR High 2100	SLR + storm surge 2100	SLR + storm surge 2100	SLR + storm surge 2100
Sea Level Rise	1.7 feet	4.0 feet	6.3 feet	--	--	--
Sea Level Rise + Storm Surge	--	--	--	1.7 feet + storm surge	4.0 feet + storm surge	6.3 feet + storm surge

Note: Storm surge is the area flooded by the 100-year/1% change storm event

Baseline: Flooding from the sea-level rise scenarios and sea-level rise plus storm surge scenarios evaluated in this study were mapped from Mean Higher High Water (MHHW) which is 4.4 feet in the coastal region of NH. *Mean Higher High Water is the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. The National Tidal Datum Epoch (NTDE) refers to the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken. The present NTDE is 1983 through 2001 and is considered for revision every 20-25 years (the next revision would be in the 2020-2025 timeframe).*<sup>1</sup>

#### *Sea-Level Rise Scenarios*

The sea-level rise projections used in this study are based on an earlier study completed in 2011 by Wake et al are similar to a more recent report issued by the NH Coastal Risks and Hazards Commission's Science and Technical Advisory Panel in 2014. As shown in the graphics below, while slightly different than the scenarios cited in the 2014 report, the sea level rise scenarios used in the *Climate Risk in the Seacoast*

<sup>1</sup> NOAA website at [http://tidesandcurrents.noaa.gov/datum\\_options.html](http://tidesandcurrents.noaa.gov/datum_options.html)

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assessment yield coverage estimates of flooding that are within the mapping margin of error for the scenarios in both the 2011 and 2014 reports.<sup>2</sup>

Figures 2 and 3 below document how the scenarios used in this report relate to 2011 by Wake et al but are similar to a more recent report issued by the NH Coastal Risks and Hazards Commission's Science and Technical Advisory Panel in 2014

Figure 2: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)

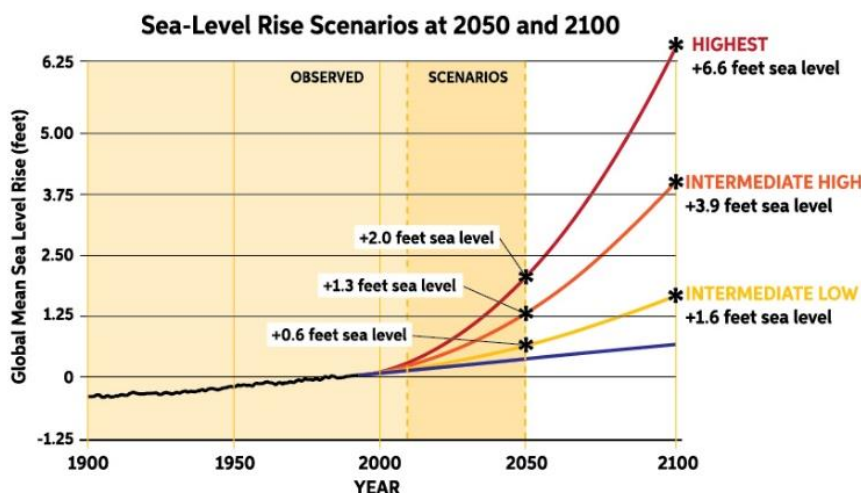
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW <sup>a,b</sup>	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
<b>Total Stillwater Elevation<sup>a,c</sup></b>	<b>13.2</b>	<b>14.7</b>	<b>13.9</b>	<b>18.5</b>

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. Preliminary estimates of future 100-year flood Stillwater elevations at the Fort Point Tide gauge under lower and higher emission scenarios (feet relative to NAVD<sup>a</sup>).

Source: Wake CP, E Burakowski, E Kelsey, K Hayhoe, A Stoner, C Watson, E Douglas (2011) *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future*. Carbon Solutions New England Report for the Great Bay (New Hampshire) Stewards.

Figure 3: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)



Source: Wake CP, Kirshen P, Huber M, Knuuti K, and Stampone M (2014) *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends*, prepared by the Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

<sup>2</sup> For more information about how these sea-level rise scenarios were mapped, visit: [http://granitweb.sr.unh.edu/MetadataForViewers/NHCoastalViewer/RelatedDocuments/Sea\\_Level\\_Rise\\_Narrative\\_rev20150106\\_Final\\_Report/pdf](http://granitweb.sr.unh.edu/MetadataForViewers/NHCoastalViewer/RelatedDocuments/Sea_Level_Rise_Narrative_rev20150106_Final_Report/pdf)

## Assets and Resources Evaluated

Storm Surge: *Storm surge is the rise of water level accompanying intense coastal storm events such a tropical storm, hurricane or Nor'easter, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm event.*<sup>3</sup> Storm surge is mapped using the 100-year/1% chance flood events from the Preliminary Flood Insurance Rate Maps (FIRMs) released by FEMA in 2014. The preliminary FIRM's account for the limit of moderate wave action in coastal areas, however this assessment does account for additional flooding and impacts related to more severe wave action, wind action, erosion and other dynamic coastal processes.

Figure 4 contains a detailed list of the assets and resources evaluated as part of the Climate Risk in the Seacoast vulnerability assessment. The assets and resources evaluated are listed in subsequent tables in this report only if they are affected by one or more of the sea-level rise and/or coastal storm surge scenarios.

FIGURE 4: Assets and Resources Evaluated for the Vulnerability Assessment

Category	Assets and Resources
State and Municipal Infrastructure	Municipal culverts (10 selected sites) Federal and State Historic Register Properties Other Assets: graveyards, water access, transmission lines
Municipal Critical Facilities	Municipal Critical Facilities and Assets
Transportation Assets & Roadways	State and Local Roadways Bridges Regional and Municipal Evacuation Routes Urban Compact Areas NHDOT Transportation Infrastructure NHDOT Ten-year and Long Range Plan Projects
Natural Resources	Freshwater and Tidal Wetlands Aquifers and Wellhead Protection Areas Wildlife Action Plan – Tier 1 and Tier 2 habitats Floodplains
Land Use	Residential structures

<sup>3</sup> EPA website at <http://epa.gov/climatechange/glossary.html>





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## Data, Methods and Results of Hydrologic and Hydraulic Modeling for Road Crossings – Climate Ready Culverts

The hydrologic and hydraulic modeling of crossings was complete by the University of New Hampshire Stormwater Center. The C-Rise project assessed both aquatic organism passage capacity and hydraulic flow capacity of ten (10) road crossings in each of the ten Great Bay coastal municipalities. The assessment was based on runoff associated with the current 10-, 25-, 50- and 100-year storm events. For each storm, each crossing was assigned a hydraulic rating and an *aquatic organism passage (AOP)* rating; both ratings are described in greater detail below.

CRiSe Culvert/Crossing ID	
Grid Key:	
10-YR Rating	25-YR Rating
50-YR Rating	100-YR Rating
10-YR: Rating for the water's surface elevation at the inlet for the 10-yr flood flow 25-YR: Rating for the water's surface elevation at the inlet for the 25-yr flood flow 50-YR: Rating for the water's surface elevation at the inlet for the 50-yr flood flow 100-YR: Rating for the water's surface elevation at the inlet for the 100-yr flood flow	




The AOP rating is labeled by color; Red, Orange, Gray, and Green. Ratings of Red and Orange mean that there is estimated to be little to no AOP at that crossing, with Red being no AOP for all species and Orange meaning no AOP for all species except for adult Salmonids.

Aquatic Organism Passage (AOP) Key	
	No AOP
	No AOP - Adult Salmonids
	Reduced AOP
	Full AOP

A rating of Gray means that there is reduced AOP at the crossing for all species. A rating of Green means that AOP is expected to be possible for all species.

The AOP ratings were developed using the New Hampshire protocol for assessment, which was borrowed directly from the Vermont Culvert Aquatic Organism Passage Screening Tool. This tool uses physical data collected at each crossing and may be used to rate each culvert at a crossing for AOP. At a crossing with multiple culverts, if one culvert is more passable than another, then that culvert is considered to be the path that organisms would utilize. Thus, the best rating for a culvert at a crossing is used as the rating for the crossing as a whole.

The hydraulic rating is color-coded similar to the AOP rating. The peak flows of the 10-, 25-, 50-, and 100-year storm events were used to assess the ability of the culvert to pass the flow (measured by the depth of water upstream of the culvert – known as the headwater depth)

Hydraulic Ranking Key:	
	Pass: Headwater stage is below the lowest top of top of 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

was determined and compared to culvert and road elevations. The ratings for hydraulics are: Pass (green), Transitional (yellow), and Fail (red). These ratings describe the depth of the water at the inlet (the Headwater) for the flows for each of the selected storm events compared to culvert and road elevations. A rating of Pass means that the headwater depth is below the lowest top-of-pipe elevation of any culvert at

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the crossing; a rating of Fail means that the headwater depth is above the road surface; and a rating of Transitional means that the headwater depth is somewhere between these two elevations.

The hydraulic ratings describe the headwater depth (upstream of the culvert) for each storm event flood (see Figure 5). The headwater depths are calculated using field-collected culvert and crossing data. The flood flows were calculated by one of two methods: runoff from rainfall or regression equation. For all watershed areas smaller than one square mile, the Curve Number<sup>4</sup> method was used; and for watersheds larger than one square mile, flows were calculated using the Regression Equations<sup>5</sup> published by the USGS for New Hampshire. Once the flows at each crossing were calculated, they were input into the Federal Highway Administration's free culvert analysis software, HY-8, along with the necessary culvert and crossing data collected at each location. The program then calculated the headwater depth for each of the flows at each of the sites. This headwater depth is what is shown in the results, and are compared to the pipe crown and roadway elevations to determine the Hydraulic Ratings.

FIGURE 5: Example of how the hydraulic rating is applied to a culvert evaluation.



## Map Design and Organization

The Climate Risk in the Seacoast map set is comprised of two components: a map depicting the extent of projected flooding from the three sea-level rise scenarios in shades of green, and a map depicting the three sea-level rise plus storm surge scenarios in shades of pink. Each of the asset categorized evaluated are displayed on these two maps. Examples of the two scenario maps are shown in Figures \_\_\_\_\_.

<sup>4</sup> A curve number is a number from zero to 100 that describes how much rainfall runs off versus how much is lost to infiltration. A high curve number implies most of the rainfall runs off.

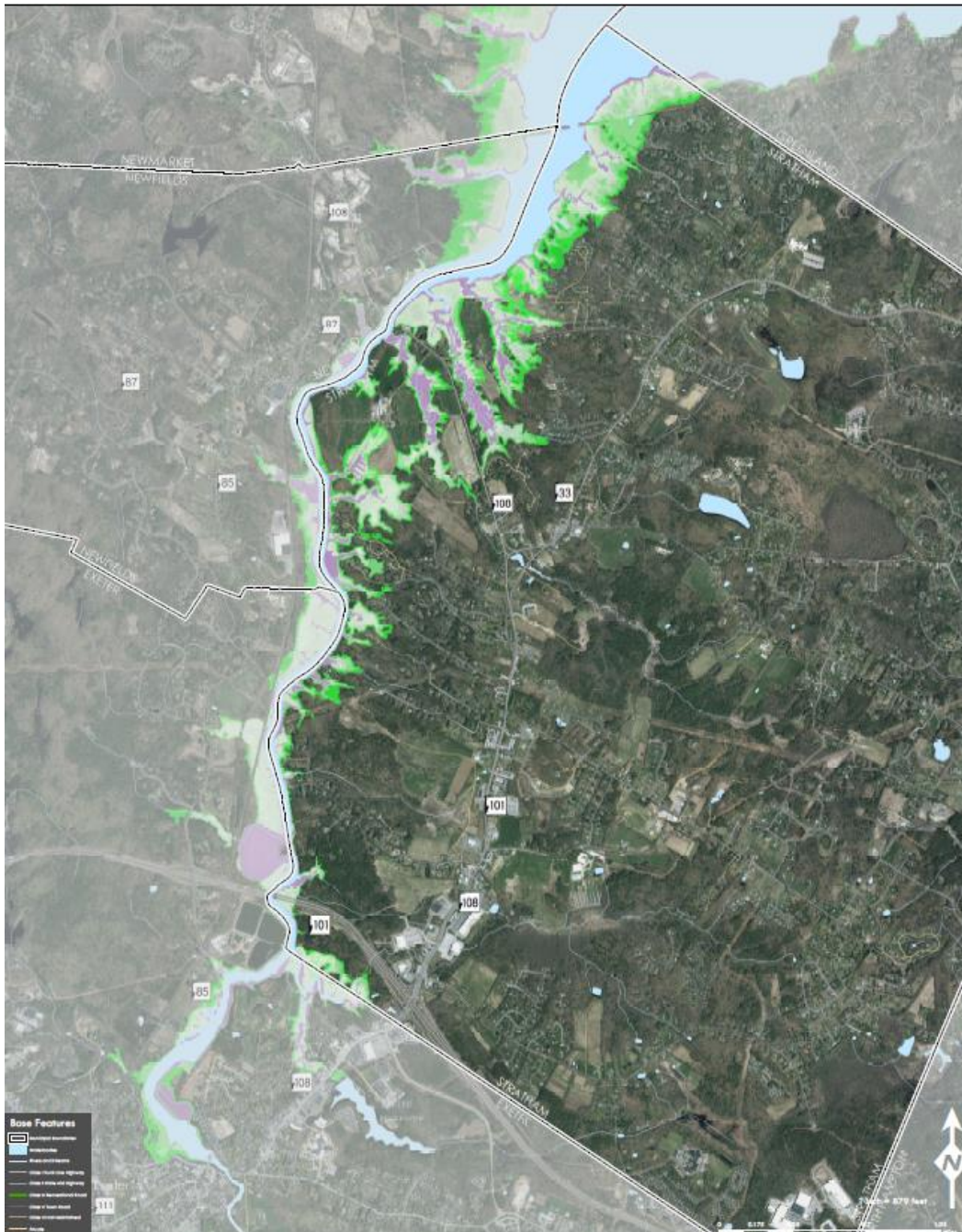
<sup>5</sup> A regression equation describes a mathematical relationship between two variables in which one variable is used to predict the other.

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### Extent of Flooding from Sea Level Rise and Storm Surge

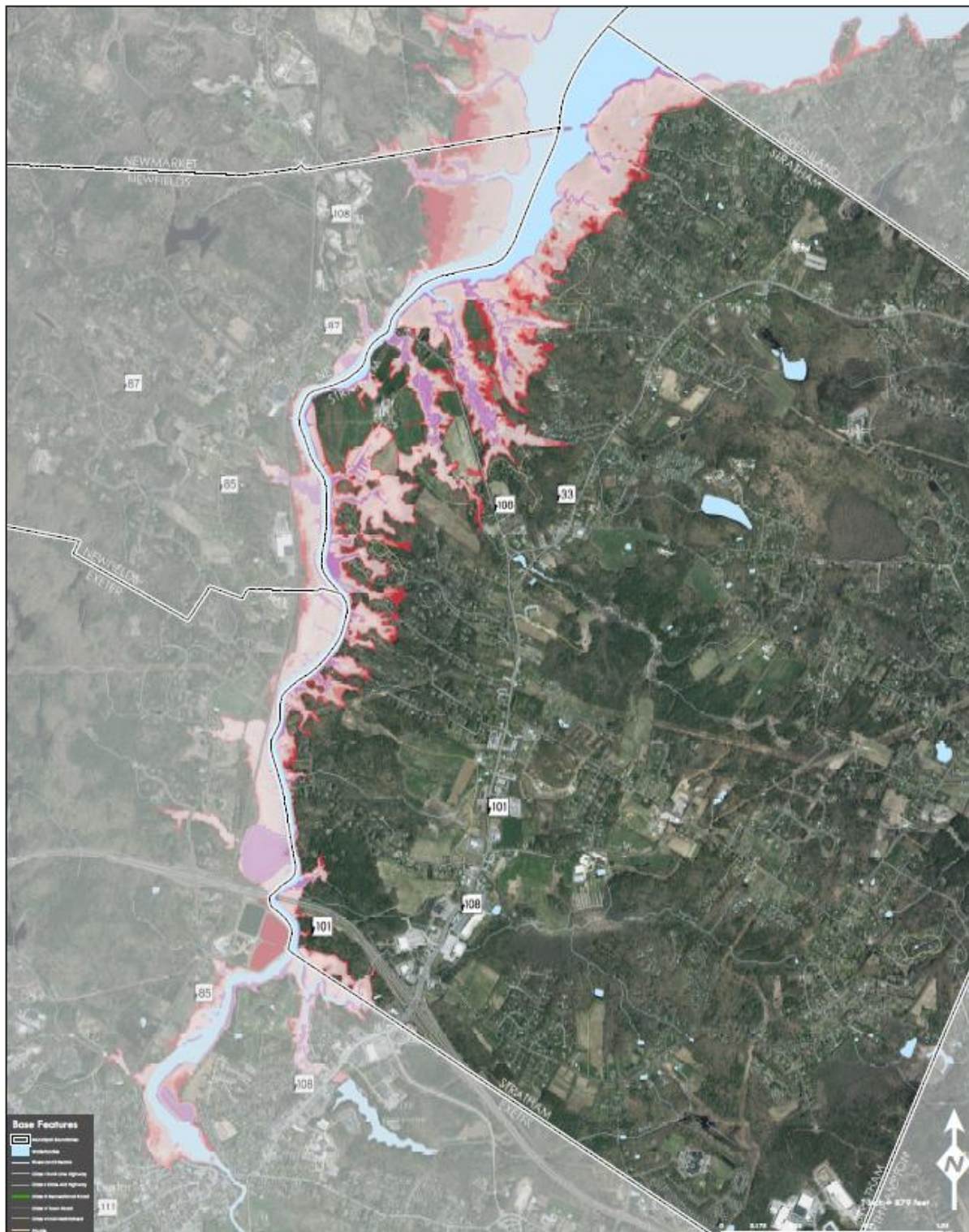
The green and pink color schemes shown in Figures 5 and 6 are arranged from lightest to darkest with increasing flood levels and extents. The complete C-RiSe map set for Stratham is available on the Rockingham Planning Commission website at <http://www.rpc-nh.org/regional-community-planning/climate-change/resources>.

FIGURE 5: Sea Level Rise Scenarios 1.7 feet, 4.0 feet, and 6.3 feet at year 2100.



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FIGURE 6: Sea Level Rise Scenarios 1.7 feet, 4.0 feet, and 6.3 feet + storm surge at year 2100. Note: Storm surge = 100-year/1% chance storm event and flood elevation.



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## Report Acronyms

AOP	Aquatic Organism Passage
CAPE	Climate Adaptation Planning for Exeter
CAW	NH Coastal Adaptation Workgroup
C-RiSe	Climate Risk in the Seacoast
FEMA	Federal Emergency Managmenr Agency
FIRMs	FEMA Flood Insurance Rate Maps
HY-8	Federal Highway Administration's free culvert analysis software
LiDAR	Li(ght) + (ra)DAR – a mapping tool that uses infrared laser light
MHHW	Mean Higher High Water
NTDE	National Tidal Datum Epoch
Salmonids	family of fish including salmon, trout, chars and white fish
SLAMM	Sea Level Affecting Marshes Model

## Glossary

### *100-year Coastal Floodplain*

Includes flood hazard areas subject to tidal flooding and storm surge and identified on the FIRMs as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. In coastal areas, these SFHAs are defined as specific zones on the FIRM's: In most communities, there are two areas or flood zones within the SFHA:

- A zone – an area subject to a 1 percent annual chance of a flood event but does not have a mapped elevation and;
- AE zone – an area that has the same 1 percent annual chance of a flood event and a corresponding mapped flood elevation of 9 feet.

### *Accommodate*

Measures that manage risk by requiring development to be built and retrofitted to be more resilient to impacts and by limiting certain types or all development in highest risk areas, favoring adaptive uses (i.e. passive uses such as recreation) and gradual modification of structures and uses as conditions change over time.

### *Adaptation*

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic change and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

[<http://unfccc.int/focus/adaptation/items/6999.php>]

### *Climate Change*

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.

[EPA <http://epa.gov/climatechange/glossary.html>]

### *Coastal Flooding*

Upland areas inundated by tides, storm surge, and projected sea-level rise.

### *Mean Higher High Water (MHHW)*

The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. The National Tidal Datum Epoch (NTDE) refers to the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken. The present NTDE is 1983 through 2001 and is considered for revision every 20-25 years (the next revision would be in the 2020-2025 timeframe).

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*Resilience*

A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

[EPA <http://epa.gov/climatechange/glossary.html>]

*Retreat*

Often the last action before abandonment, retreat follows an incremental path of planning for the eventual relocation of structures to upland areas as properties become threatened or directly impacted by rising sea level, erosion and coastal storms. Such measures may include rolling setbacks and buffers, transfer of development rights, and property acquisition/buyout programs.

*Riverine (and Freshwater) Flooding*

Areas inundated adjacent to freshwater drainage systems not affected by coastal flooding, including the 100-year flood plain and other areas subject to flooding from precipitation and snow melt.

*Sea-level rise*

Sea level is measured in various ways. Relative Sea Level refers the measurement of sea level at a local tide gauge station which is referenced relative to a specific point on land. These measurements at any given local tide gauge station include both measurements of global sea-level rise and local vertical land movement, such as subsidence, glacial rebound, or large-scale tectonic motion. Because the heights of both the land and the water are changing, the land-water interface can vary spatially and temporally and must be defined over time. The term Mean Sea Level (MSL) refers to a tidal datum (which a frame of vertical reference) defined by the average tide over a specific period of time. Global Sea-level rise (or eustatic sea-level rise) refers to the increase currently observed in the average Global Sea Level Trend, which is primarily attributed to changes in ocean volume due to two factors: ice melt and thermal expansion.

[NOAA <http://www.tidesandcurrents.noaa.gov/est/faq>]

*Storm Surge*

Storm surge is the rise of water level accompanying intense events such a tropical storm, hurricane or Nor'easter, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm event.

[EPA <http://epa.gov/climatechange/glossary.html>]

*Vulnerability Assessment*

An evaluation of the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. [[www.ipcc.ch/pub/syrgloss.pdf](http://www.ipcc.ch/pub/syrgloss.pdf)]

## PURPOSE AND APPLICATIONS OF THE VULNERABILITY ASSESSMENT

The *Climate Risk in the Seacoast* (C-RiSe) vulnerability assessment project produced maps and statistical data about the potential impacts from sea-level rise and storm related flooding to infrastructure, critical facilities transportation systems, and natural resources. in New Hampshire's 10 Great Bay coastal municipalities. As shown in Figure 7, the assessment evaluated flood impacts from six sea-level rise and storm surge scenarios - 1.7 feet (intermediate-low), 4.0 feet (intermediate), and 6.3 feet (highest) sea-level rise projections at the year 2100 and these sea-level rise projections with the 100-year storm surge. These scenarios capture a range of plausible projections of sea levels at 2100, from the intermediate-low to the highest scenarios.

FIGURE 7: Sea-Level and Storm Surge Scenarios at year 2100

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
Sea Level Rise	1.7 feet	4.0 feet	6.3 feet	--	--	--
Sea Level Rise + Storm Surge	--	--	--	1.7 feet + storm surge	4.0 feet + storm surge	6.3 feet + storm surge

Note: Storm surge is the area flooded by the current 100-year/1% chance storm event as depicted on the FEMA Flood Insurance Rate Maps (preliminary maps, 2014).

The results of this vulnerability assessment can be incorporated into existing municipal plans including the Master Plan, Hazard Mitigation Plan, Road Improvement Plan, Infrastructure Management Plan, and Capital Improvement Plan. These results can also inform zoning amendments such as floodplain development standards and natural resource protection, and land development standards in site plan review regulations and subdivision regulations.

## OVERVIEW OF STRATHAM

The Town of Stratham is located along the Squamscott River, a tidal tributary of the Great Bay. Stratham's land area covers roughly 15.1 square miles (9,664) and 0.4 square miles of inland water area (256 acres). With an estimated population of 7,303 (2014), Stratham is the eight most populated municipality in the Rockingham Planning Commission region. The inland coastal portion of Stratham that is most susceptible to coastal flooding is located in lowlands adjacent to and within floodplain of the Squamscott River and its tributaries. Although confined in extent, these low-lying areas, containing a mix of residential and commercial development and the infrastructure that services them, are particularly vulnerable to flooding from seasonal high tides, sea-level rise and coastal storms. Other flood impacts include:

- Chapmans Landing water recreation access and parking lot.
- Stuart Farm and Scamman Farm bordering the Squamscott River.

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- Reduced hydraulic capacity of four culverts on Squamscott Road.
- Well-head protection areas for residential developments west of Route 33
- 128 parcels valued at \$40.6 million and 6 residential structures valued at \$2.5 million.

## DETAILED FINDINGS OF THE VULNERABILITY ASSESSMENT

### Land Area Affected

Figure 8 provides data on the total acres of land and water affected for each sea-level rise and storm surge scenario. Areas affected by flooding in all scenarios evaluated represent a very small percentage of the total area of the town.

FIGURE 8: Total Acreage Affected by Sea Level Rise Scenarios (acres)

Municipality	Sea-Level Scenarios					
	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	1.7 feet SLR + storm surge (acres)	4.0 feet SLR + storm surge (acres)	6.3 feet SLR + storm surge (acres)
Stratham	191.6	325.9	452.6	383.0	489.6	593.5
% total	1.9	3.3	4.6	3.9	4.9	6.0

Total area of Stratham = 9,920 acres

### Assets and Resources

Stratham's impacts from sea-level rise and storm related flooding are located exclusively on the west side of town adjacent to the Squamscott River floodplain and the river's tidal and freshwater tributaries. The affected lands are zoned residential-agricultural, and developed with a mix of commercial uses, single-family homes and active agriculture, including portions of the Scamman Farm and Stuart Farm. Portions of the Scamman Farm impacted by flooding are permanently protected by a conservation easement held by the Southeast Land Trust. Six residential properties are affected at the highest flood scenario of 6.3 feet sea-level rise plus storm surge.

Figure 9 reports summarizes impacts to assets and resources for each sea-level rise and coastal storm surge scenario. Fortunately, most of Stratham's roads, stormwater infrastructure and critical facilities are located outside areas affected by future sea-level rise and storm related flooding. Infrastructure and critical facilities affected by 6.3 feet sea-level rise and 6.3 feet sea-level rise plus storm surge include a handful of culverts on Squamscott Road, water lines, isolated local road segments serving residential developments, two small dams, and two water access points. Refer to Figures 11, 12 and 13 for detailed impact data for each asset and resource type.

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In Stratham, portions of 12 wellhead protection areas serving residential and condominium developments, commercial uses and a church are located within areas subject to sea-level rise and storm related flooding. This assessment did not evaluate or quantify the degree of impact this flooding may have on the wellhead protection areas, however salt water intrusion and rising groundwater levels due to sea-level rise could be of concern in the future. In addition, a number of wellhead protection areas in Newfields extend into Stratham within the high risk flood areas, including the Newfields Village Water and Sewer District, Ship to Shore restaurant and Great Bay Camping facility. Refer to Figure 14 for a complete listing of affected wellhead protection areas.

Within rising sea levels, freshwater wetlands located in the upper reaches of Jewell Hill Brook, Mill Brook, Parkman Brook and several unnamed tributaries may be impacted by saltwater inundation. This change in hydrology may result in the conversion of these freshwater wetlands to brackish systems, altering their species composition and habitat types over time.

**FIGURE 9: Summary of Asset and Resources Impact Data**

<b>Sea Level (SLR) Scenarios</b>	<b>SLR 1.7' Intermediate Low 2100</b>	<b>SLR 4.0' Intermediate High 2100</b>	<b>SLR 6.3' High 2100</b>	<b>SLR 1.7' + storm surge 2100</b>	<b>SLR 4.0' + storm surge 2100</b>	<b>SLR 6.3' + storm surge 2100</b>
<b>Municipal, State and Private Assets</b>						
Infrastructure (# of sites)	n/a	n/a	7	n/a	n/a	7
Critical Facilities (# of sites)	n/a	n/a	7	n/a	n/a	7
Transportation Assets (# of sites)	n/a	n/a	0	n/a	n/a	6
Residential Structures (# of homes)	n/a	n/a	0	n/a	n/a	6
Roadways (miles)	0.2	0.3	0.6	0.5	0.6	0.9
Historic/Recreational Sites	na	na	2	na	na	2
<b>Natural Resources</b>						
Freshwater Wetlands (acres)	5.5	19.2	30.4	25.7	32.9	39.6
Tidal Wetlands (acres)	158.8	181.8	183.7	182.9	183.9	184.3
Stratifies Drift Aquifers (acres)	0	0	0	0	0	0
Wellhead Protection Areas (acres)	217.7	368.8	579.9	454.8	649.8	858.3
Conserved and Public Lands (acres)	98.6	168.2	218.9	191.2	232.1	263.7
Wildlife Action Plan (acres)	177.9	287.8	377.5	329.3	402.2	469.9
100-year Floodplain (acres)	191.6	321.9	339.7	335.8	341.0	342.4

Notes: Storm surge is the area flooded by the 100-year/1% chance storm event. n/a = not assessed

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The complete detailed vulnerability assessment information and recommendations are provided in the following sections of this report.

## DETAILED VULNERABILITY ASSESSMENT RESULTS BY ASSET TYPE

### Culvert Assessment

*Map: Culvert Assessment* show the hydraulic and aquatic organism passage function of culverts under existing precipitation conditions for the 10-year, 25-year, 50-year and 100-year storm event. Figure 10 reports the functional hydraulic status and Aquatic Organism Passage rating for each culvert.

Of the ten culverts analyzed for hydraulic rating, five pass, 2 are transitional, and three fail under the 10-year storm event. Culverts #82, #83, #84 and #85 are impacted by sea-level rise and storm surge flooding. For Aquatic Organism Passage, one culvert has full capability, and fourteen are reduced or have no capability.

FIGURE 10: Assessment of Culvert Hydraulic and Aquatic Organism Passage (AOP) Function

Crossing #	Location	Hydraulic Rating				AOP Rating	
		10-yr	25-yr	50-yr	100-yr	Color	Rating
82	Squamscott Road	Pass	Transitional	Transitional	Transitional	GREEN	Full AOP
83	Squamscott Road	Transitional	Transitional	Fail	Fail	GRAY	Reduced AOP
84	Squamscott Road	Fail	Fail	Fail	Fail	GRAY	Reduced AOP
85	Squamscott Road	Pass	Transitional	Transitional	Fail	GRAY	Reduced AOP
86	Route 33 @ Chisholm Road	Transitional	Transitional	Transitional	Fail	GRAY	Reduced AOP
87	Route 33 @Chase Lane	Pass	Transitional	Transitional	Fail	RED	No AOP
88	Birnum Woods	Fail	Fail	Fail	Fail	GRAY	Reduced AOP
89	Winnicut Road@ Barker Lane	Pass	Pass	Pass	Pass	GRAY	Reduced AOP
90	Route 108 @ West Road	Pass	Pass	Pass	Pass	RED	No AOP
91	Stratham Heights Road	Fail	Fail	Fail	Fail	GRAY	Reduced AOP

A rating of **Pass** means that the headwater depth is below the lowest top-of-pipe elevation of any culvert at the crossing; a rating of **Fail** means that the headwater depth is above the road surface; and a rating of **Transitional** means that the headwater depth is somewhere between these two elevations.

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**\*AOP = Aquatic Organism Passage** is the degree to which aquatic organisms are able to pass through a crossing. Green = Full AOP, Gray = Reduced AOP, Pink = No AOP, for all species except Adult Salmonids, Pink = No AOP, for any species including Adult Salmonids.

## Municipal and Critical Facilities

*Maps 3 and 4 Critical Facilities and Infrastructure* show the municipal critical facilities affected by sea-level rise and coastal storm surge flooding. Figure 11 reports when specific municipal critical facilities are affected by each sea-level rise and coastal storm surge scenario.

**FIGURE 11: Municipal Critical Facilities (# of facilities)**

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
Sewer Pipes	0.00	0.00	0.00	0.00	0.00	0.00
Water Pipes	0.03	0.03	0.07	0.05	0.08	0.11
Transmission Lines	0.00	0.02	0.03	0.02	0.05	0.09
<i>Analysis below for SLR 6.3 feet and SLR 6.3 feet + storm surge only</i>						
Culverts	Squamscott Road at three locations over Jewell Hill Brook			Squamscott Road at three locations over Jewell Hill Brook		
Dams	Winding Brook Condo Detention Pond Turnberry Condo: Wildlife Pond			Winding Brook Condo Detention Pond Turnberry Condo: Wildlife Pond		
Residential Structures*	0 structures			6 structures		
Water Access	Stratham Town Landing: Squamscott River Chapman's Landing: Squamscott River			Stratham Town Landing: Squamscott River Chapman's Landing: Squamscott River		

\* Building data points shown on this map indicate the relative location of existing structures.

## Transportation

*Maps 5 and 6 Road and Transportation Assets* show the state and municipal roadways affected by each sea-level rise and coastal storm surge scenario. Figure 12 reports the miles of state and local roadways affected by each flood scenario. Less than one mile of flood impacts are reported under all scenarios for local and state roads in Stratham.

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FIGURE 12: State and Municipal Roadways and Infrastructure (miles)

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
<b>Roadway Type</b>						
State	0.18	0.24	0.39	0.32	0.33	0.48
Local	0.00	0.07	0.15	0.12	0.17	0.27
Private	0.00	0.00	0.08	0.02	0.09	0.18
<b>Total Road Miles</b>	<b>0.18</b>	<b>0.31</b>	<b>0.62</b>	<b>0.46</b>	<b>0.59</b>	<b>0.93</b>
<i>Analysis below for SLR 6.3 feet and SLR 6.3 feet + storm surge only</i>						
<b>Urban Compact Areas</b>	0			0		
<b>Evacuation Routes</b>	NH Routes 108 and 101, Squamscott Road			NH Routes 108 and 101, Squamscott Road		
<b>Bridges</b>	Route 101 over Squamscott River			Route 101 over Squamscott River		
<b>NHDOT Projects</b>	Squamscott Road metal pipe replacement; Route 108/Stratham Circle to Squamscott River; NH 101 earth embankment at Squamscott River			Squamscott Road metal pipe replacement; Route 108/Stratham Circle to Squamscott River; NH 101 earth embankment at Squamscott River		

*Maps: Transportation Assets* and Figure 13 report the miles of local roads impacted by each sea-level rise and coastal storm surge scenario. Stratham's municipal roadway network is not particularly sensitive to sea-level rise and coastal storm flooding with only small segments impacted under the highest flood scenarios.

FIGURE 13: Impacts to State, Municipal and Private Roadways (miles)

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
Butterfield Lane (local)	na	na	0	na	na	0.01
Chisholm Farm Drive (local)	na	na	0	na	na	0.01
College Road (state)	na	na	0.01	na	na	0.01
Dunbarton Oaks Ext. (local)	na	na	0.15	na	na	0.18
Morning Star Drive (local)	na	na	0	na	na	0.07
NH Route 101 East (state)	na	na	0.09	na	na	0.09
NH Route 101 West (state)	na	na	0.10	na	na	0.10
No Name (local)	na	na	0.08	na	na	0.14
Squamscott Road (state)	na	na	0.20	na	na	0.28
Wingate Court (private)	na	na	0	na	na	0.05

na = not assessed

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Culverts are supporting infrastructure for the roadway network that are also highly susceptible to flooding impacts. As sea levels rise in the future, some tidal culverts may become submerged by flooding even at low tide and freshwater culverts will be influenced by tidal flooding, creating hydrologic conditions these drainage systems were not designed for.

## Natural Resources

*Maps: Conservation Areas* and *Maps: Wetlands, Aquifers, Wellhead Protection Areas* show natural resources affected by sea-level rise and coastal storm surge flooding. Figure 14 reports the number of acres by natural resource type affected for each sea-level rise and coastal storm surge scenario. The greatest impacts to wetland systems are in the tidal systems. Over time, low marsh may convert to mud flats and high marsh may convert to low marsh as these systems are inundated by rising seas. Significant acres of high quality habitat and natural resources identified in the NH Wildlife Action Plan and Coastal Conservation Plan, and Conserved lands may be impacted by future flooding. These natural shorelands can act as critical flood storage areas to protect infrastructure and private property from rising seas and storm events. No impact to designated wellhead protection areas, and although minimal impacts are reported for stratified drift aquifers, the assessment did not evaluate potential impacts to private drinking water wells from salt water intrusion as sea-level rises.

Lowlands on the Stuart Farm and Scamman farm used for hay and crop production and cattle grazing are impacted under both sea-level rise and storm surge scenarios. Inundation of these lands by tidal and storm related flooding could introduce pollutants from fertilizer, pesticides and animal waste into the Squamscott River and the Great Bay.

FIGURE 14: Natural Resources (acres)

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
Wellhead Protection Areas (acres)	217.7	368.8	579.9	454.8	649.8	858.3
Stratified Drift Aquifers	0.00	0.00	0.00	0.00	0.00	0.00
Freshwater Wetlands (total)	5.5	19.2	30.4	25.7	32.9	39.6
Freshwater Emergent Wetland	1.0	1.6	2.3	2.0	2.4	2.6
Freshwater Forested/Shrub Wetland	4.3	14.8	22.5	18.4	24.8	31.2
Freshwater Pond	0.2	2.8	5.6	5.3	5.7	5.8
Lake	0.0	0.0	0.0	0.0	0.0	0.0
Riverine	0.0	0.0	0.0	0.0	0.0	0.0

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<b>Sea Level (SLR) Scenarios</b>	<b>SLR 1.7 feet Intermediate Low 2100</b>	<b>SLR 4.0 feet Intermediate High 2100</b>	<b>SLR 6.3 feet High 2100</b>	<b>SLR 1.7 feet + storm surge 2100</b>	<b>SLR 4.0 feet + storm surge 2100</b>	<b>SLR 6.3 feet + storm surge 2100</b>
Tidal Wetlands (total)	158.8	181.8	183.6	182.9	183.9	184.3
Estuarine and Marine Deepwater	0.01	0.02	0.04	0.02	0.04	0.04
Estuarine and Marine Wetland	158.8	181.8	183.6	182.9	183.8	184.2
Wildlife Action Plan – Tier 1 and Tier 2 habitat	177.9	287.7	377.5	329.3	402.2	469.9
Coastal Conservation Plan Focus Area: Squamscott River	163.0	268.1	358.3	309.5	382.9	446.9
Conserved and Public Lands	98.6	168.2	218.2	191.2	232.1	263.7
Wellhead Protection Areas (total from sites below)	217.7	368.9	579.9	454.8	649.8	858.3
Chisholm Farm: Chisholm Farm Drive	129.8	207.8	319.4	255.0	355.3	460.8
Exeter Water Department: Portsmouth Ave	2.3	4.0	5.1	4.5	5.3	5.9
Jewett Hill: Tansy Ave, Winnicutt Road	1.3	1.4	1.5	0.0	0.0	0.1
Newfields Village Water and Sewer: District, Route 85	8.7	18.2	29.3	1.5	1.6	1.8
Pennisula at Winding Brook: 78 Penninsula Drive, Winding Brook	0.3	1.1	1.9	21.7	33.8	52.0
RCN Condos: 4 West Road	0.0	0.0	0.1	1.6	2.1	2.5
Salt River Condos	12.3	24.1	31.0	0.0	0.2	2.4
Stratham Crossing 7621: 100 Shaws Lane	29.7	50.7	78.0	27.1	32.9	37.5
Stratham Green Condos: Route 108	13.48	23.84	36.81	61.47	88.04	122.91
Stratham Woods: Butterfield Lane	19.9	37.7	76.9	28.5	41.6	59.9
Turnberry: Squamscott Road, Route 108	129.8	207.8	319.4	53.4	88.9	112.3

FIGURE 15: Conservation Lands and Wildlife Action Plan (acres)

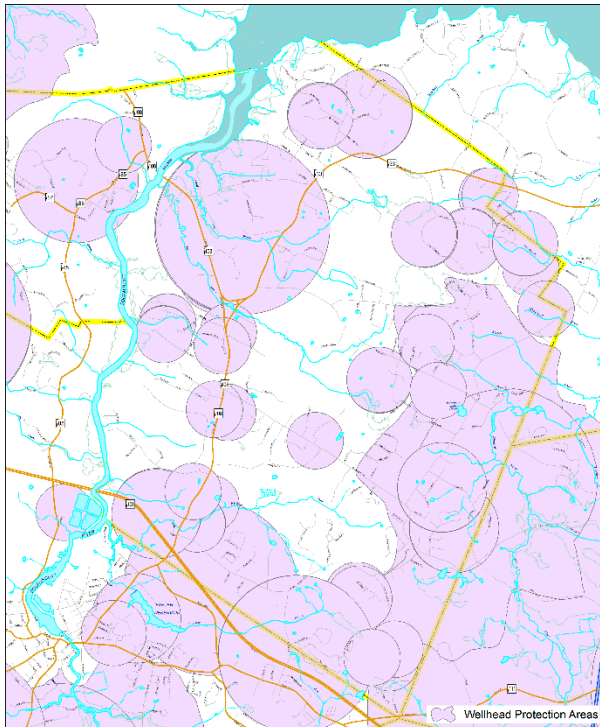


Figure 15 shows the spatial extent of wellhead protection areas in Stratham which serve as public water supplies for multi-family and condominium developments. [Note the Squamscott River is the boundary between Stratham, Newfields and Exeter.]

Although most of these wellhead protection areas are not inundated by sea-level rise or storm surge, rising sea level can result in rising groundwater levels and saltwater intrusion which could influence the quality and quantity of these drinking water sources.

Figure 16 reports the acres of conservation lands (by named easement) and high value habitats from the NH Wildlife Action Plan impacted for each sea-level rise and coastal storm surge scenario. Over time, coastal flooding may impact sensitive habitats identified in the Land Conservation Plan for NH's Coastal Watersheds (2006) and the NH Wildlife Action Plan (updated in 2015). Such habitats include nesting and breeding sites for shorebirds, tidal wetlands and saltmarsh, freshwater wetlands, vernal pools, forests, and scrub-shrub and meadow landscapes. The ability of these habitats to accommodate changing environmental conditions will depend variables such as the rate and extent of change, competition with invasive species, and soil and landscape conditions.

Figure 17 report acres of conservation lands, NH Wildlife Action Plan high value habitat and Land Conservation Plan for NH's Coastal Watershed – Focus Areas affected by each of the sea-level rise and storm surge scenarios. The riparian corridors and shorelands in these habitats and focus areas will serve to accommodate flood waters and rising seas over time which will greatly reduce impacts to public and private assets. Based on the assessment, tidal marshes along the Squamscott River may become open water as sea level rises, unless the marshes are able to keep pace by building upward. A marsh migration model would need to be done to more accurately predict the condition of tidal marshes under different sea-level rise scenarios. Over time, coastal flooding may impact sensitive habitats identified in the Land Conservation Plan for NH's Coastal Watershed (2006) and the NH Wildlife Action Plan (updated in 2015). Such habitats include nesting and breeding sites for shorebirds, tidal and freshwater wetlands, vernal pools, forests, scrub-shrub and meadow landscapes.

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FIGURE 16: Conservation Lands and Wildlife Action Plan (acres)

Resource Name	Sea-Level Rise			SLR + Storm Surge		
	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
<b>Conservation Lands</b>						
Barker A/B (Great Bay NERR WMA)	4.2	4.2	4.2	4.2	4.2	4.2
Chapmans Landing (Great Bay NERR WMA)	5.5	6.1	6.6	6.3	6.7	7.5
Gowen (Great Bay NERR WMA)	5.8	5.9	5.9	5.9	5.9	5.9
Harmon/Knight (Great Bay NERR WMA)	3.3	6.9	9.9	8.4	10.7	12.7
Hill	0.2	0.8	1.5	1.1	1.8	2.3
Monahan Tract (Great Bay NERR WMA)	4.7	4.8	4.9	4.9	4.9	4.9
Parsonage Hill (Great Bay NERR WMA)	0.01	0.6	7.2	2.2	9.9	14.4
Railroad Crossing (Great Bay NERR WMA)	0.3	6.2	7.2	6.9	7.4	7.4
Salt River	19.3	34.5	37.3	36.3	37.7	38.8
Sandy Point	37.4	62.2	77.2	69.7	80.3	83.7
Scamman Trust (Woodland)	0.4	0.8	1.4	1.0	1.7	2.0
Starry Brook	0.1	0.1	0.1	0.1	0.1	0.1
Strathlorne Tract	1.7	3.1	3.9	3.4	4.1	5.1
Stuart - Agric. Pres. Rest.	8.4	20.2	31.4	25.2	34.6	46.0
Wiggin Tract (Great Bay NERR WMA)	5.0	8.0	11.6	9.8	12.8	17.3
Zarnowski Tract	2.2	3.8	8.4	5.7	9.2	11.4

FIGURE 17: Wildlife Action Plan and Coastal Conservation Plan (acres)

Resource Type		Sea-Level Rise (SLR)			SLR + Storm Surge		
		SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet +storm surge 2100	SLR 4.0 feet +storm surge 2100	SLR 6.3 feet +storm surge 2100
Wildlife Action Plan	Tier 1 habitat	168.2	260.2	317.9	289.5	331.4	361.3
	Tier 2 habitat	4.7	13.5	26.1	18.4	31.0	47.6
	Tier 3 habitat	5.0	14.0	33.4	21.4	39.8	61.0
Focus Areas - Land Conservation Plan for NH's Coastal Watershed	Squamscott River	163.0	268.1	358.3	309.5	382.9	446.9

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## Land Use

*Maps: Extent of Sea-Level Rise and Sea-Level Rise + Storm Surge Flooding* show upland affected by sea-level rise and coastal storm surge flooding above mean higher high water. Figure 18 reports the number of acres of upland affected for each sea-level rise and coastal storm surge scenario. Under the 6.3 feet sea-level rise scenario, flooding is confined to lowland areas and floodplain of the Squamscott River and its tributaries Hill Brook, Mill Brook and several unnamed tributaries. Under the 6.3 feet sea-level rise plus storm surge scenario, additional upland impacts include inundation of upper portions of the freshwater drainages systems, neighborhood roads and culverts, and increased interior flooding at the sites already impacted under the 6.3 feet sea-level rise scenario.

**FIGURE 18: Uplands (acres)**

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
Acres	78.1	182.5	297.9	232.9	333.2	433.6
% Upland	0.8	2.0	3.2	2.5	3.6	4.7

Total Upland in Stratham = 9,207 acres. Upland refers to land above mean higher high water (highest tidal extent).

## Parcels and Assessed Value

Figure 19 reports the number of parcels affected for each sea-level rise and coastal storm surge scenario and the aggregated assessed value of these parcels. The degree to which the parcel and any development on the parcel is affected by sea-level rise or storm related flooding was not analyzed. Affected parcels were identified based on their location either partially or fully within the extent of the scenarios evaluated. The data may include a number of high value parcels under state and municipal ownership.

**FIGURE 19: Parcels and Assessed Value by Scenario**

Sea Level Rise (SLR) Scenarios	Number of Parcels Affected by Scenario	Aggregate Value of Affected Parcels	Percent Total Assessed Value
1.7 feet SLR	85	\$25,198,948	2.05
4.0 feet SLR	102	\$31,024,048	2.5
6.3 feet SLR	112	\$35,444,548	2.9
1.7 feet SLR + storm surge	105	\$33,354,348	2.7
4.0 feet SLR + storm surge	114	\$36,318,948	2.9
6.3 feet SLR + storm surge	128	\$40,604,748	3.3
The total assessed land and property value for Stratham = \$1,230,389,707 (2016 town report)			

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Assets in Stratham are only impacted by the two highest flood scenarios - 4.0 feet sea-level rise plus storms surge, and 6.3 feet sea-level rise plus storm surge. Impacts to assessed value from flooding are minimal, however there is a 500 percent increase in the number of affected parcels and approximately a \$2.1 million increase in assessed value from the 4.0 feet to the 6.3 feet sea-level rise plus storm surge scenario. Figure 20 reports the number of homes affected by each of the sea-level rise and storm surge scenarios and the aggregated percent assessed value of these homes.

FIGURE 20: Residential Structures and Assessed Value by Scenario

Sea Level Rise (SLR) Scenarios	Number of Homes Affected by Scenario	Aggregate Value of Affected Parcels	Percent Total Assessed Value
1.7 feet SLR	0	\$0	0
4.0 feet SLR	0	\$0	0
6.3 feet SLR	0	\$20	0
1.7 feet SLR + storm surge	0	\$0	0
4.0 feet SLR + storm surge	0	\$0	0
6.3 feet SLR + storm surge	6	\$2,473,822	0.20
The total assessed property value for Exeter = \$1,230,389,707 (2016 town report)			

## FEMA Flood Hazard Areas

*Maps: Preliminary FEMA Flood Hazard Areas* show areas within the 100-year floodplain affected by sea-level rise and coastal storm surge flooding. Figure 21 reports the acreage within the current 100-year floodplains affected for each sea-level rise and coastal storm surge scenario.

*From a floodplain management perspective, creating more resilient development within the current 100-year floodplain will provide protection against flood impacts from long term sea level rise.*

FIGURE 21: FEMA Flood Hazard Areas (acres)

Sea Level (SLR) Scenarios	SLR 1.7 feet Intermediate Low 2100	SLR 4.0 feet Intermediate High 2100	SLR 6.3 feet High 2100	SLR 1.7 feet + storm surge 2100	SLR 4.0 feet + storm surge 2100	SLR 6.3 feet + storm surge 2100
100-year floodplain	191.6	321.9	339.7	335.8	341.0	342.4
Percentage of SLR within 100-year floodplain (FP)	100%	99% (4 acres beyond FP)	75% (113 acres beyond FP)	88% (47 acres beyond FP)	70% (148 acres beyond FP)	58% (251 acres beyond FP)

*Floodplain assessment based on Preliminary Flood Insurance Rate Maps (FIRMs) released by FEMA in 2014.*

In Stratham, the 100-year floodplain is highly vulnerable to sea-level rise and storm surge related flooding,. Under the other six scenarios, flooding generally falls within the current 100-year floodplain, extending beyond into the 500-year floodplain in certain areas. From a floodplain management perspective, creating

more resilient development within the current 100-year floodplain will provide protection against flood impacts from long term sea level rise. Under the 6.3 feet sea-level rise plus storm surge scenario, flooding extends well beyond the 100-year floodplain.

## ISSUES AND CONSIDERATIONS

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The following issues and considerations of local and regional importance were identified during project meetings with municipal staff and land use board and commission members.

- Improvements to the state roadway network (elevating, enlarging culvert and bridges) may affect local connector roads, driveway access points and connecting infrastructure and utilities.
- Although roadways, buildings and infrastructure can be protected by raising them above projected sea-level rise elevations, supporting land and land based uses may be impacted by daily tidal flooding from projected sea-level rise.
- Planning for long term sea-level rise can be integrated with existing regulatory and management frameworks for the current 100-year floodplain.
- Ownership of transportation infrastructure and assets by multiple state agencies (roadways, culverts, state parks, parking areas) and town responsibility for management of assets (sidewalks, roads in urban compact areas) creates complexity in comprehensively managing these systems and implementing climate adaptation strategies.
- Flooding from sea-level rise and coastal storm surge impacting the state and local roadway network adjacent to the Route 101 interchange may disrupt the designated evacuation network in Stratham and connections to evacuation routes in adjacent towns.
- Providing information about potential flood hazards to businesses and residents, and early notification of flood risk during a coastal storm event would enhance public safety and preparedness.
- Long term infrastructure management would benefit from an analysis of the costs necessary to improve roads and drainage infrastructure to withstand projected sea-level rise elevations at 2050 and 2100.

## RECOMMENDATIONS

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The following recommendations are short-term climate adaptation actions that can be included in the town's Natural Hazards Mitigation Plans, Master Plan and other planning and policy documents. These actions are focused on strengthening land use development standards, resource protection, municipal policy and plans, and public support to create more resilient development, infrastructure and natural systems. *Refer to Appendix B for an expanded list of climate adaptation strategies.*

### REGULATORY

**R1 - Elevate Structures 2 feet Above Base Flood Elevation.** Adopt standards in floodplain zoning and/or Site Plan Review and Subdivision Regulations that require all new development and redevelopment to be elevated 2 feet above the base flood elevation. Two feet of additional elevation will ensure that structures are protected from flooding based on the highest sea-level rise projection of 2 feet by 2050.

**R2 - Coastal Buffers and Tidal Marshes.** Adopt buffers and setbacks that adequately separate development and infrastructure from tidal wetlands, freshwater wetlands and surface waters to sustain flood storage capacity, and allow for inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems to accommodate projected changes in sea-levels.

### PLANNING AND POLICY

**P1 - Natural Hazards Mitigation Plan.** Incorporate the vulnerability assessment information and recommendations from the Climate Risk in the Seacoast Vulnerability Assessment report and maps in the town's 2015/2016 Natural Hazards Mitigation Plan update. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan.

**P2 - Master Plan Coastal Hazards Chapter.** Adopt a Coastal Hazards Chapter in the town's Master Plan that incorporates information and recommendations from the Climate Risk in the Seacoast Vulnerability Assessment report and maps.

**P4 - Capital Infrastructure and Investments.** Incorporate consideration of impacts from sea-level rise and coastal storm surge flooding in current and future capital infrastructure projects. Incorporate the Climate Risk in the Seacoast vulnerability assessment information into infrastructure management plans and capital improvement plans. Evaluate the extent of sea-level rise and storm surge flooding on individual facilities (e.g. wastewater treatment plant, transfer station, high school).

**P5 - Land Conservation.** Land conservation offers the greatest opportunities to provide for adaptation to the effects of sea-level rise and coastal storm flooding and climate change impacts.

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- Adopt a targeted scoring framework or incorporate new scoring criteria into existing land conservation prioritization efforts that consider climate adaptation benefits when evaluating land for conservation purposes.
- Increase funding and resources for land conservation, land management programs, and land stewardship activities. (Note: Land conservation scores very high as an activity in the FEMA Community Rating System program.)
- Support retreat from high risk areas by buying properties and restoring them to a natural condition.

**P6 - Wetlands Mitigation Site Inventory.** Identify and inventory lands where protection of tidal and freshwater wetlands would provide tangible benefits to protect against flooding, and restoration opportunities to remove barriers to tidal function and marsh and migration. This inventory will allow the town to pre-identify and prioritize sites that can be permanently preserved as a mitigation strategy for wetland impacts from development in high risk coastal areas.

**P7 - Evacuation Planning.** Prepare evacuation plans and coordinate these plans with towns in the coastal region to implement timely and comprehensive planning and notification for coastal storm events. Mark evacuation routes with signage and communicate these routes to the public with information on the town's website and printed maps.

#### COMMUNITY OUTREACH AND ENGAGEMENT

**O1 – NH Coastal Adaptation Workgroup.** The NH Coastal Adaptation Workgroup (CAW) is a voluntary collaborative advocacy group consisting of members from federal and state agencies, regional and non-profit organizations, municipalities, academia, and private businesses. The group's focus is to: 1) pursue activities that improve the resilience of natural systems, infrastructure and development to the impacts of climate change; and 2) facilitate communication and cooperation among stakeholders throughout the coastal watershed, especially with regard to research, programs and other efforts designed to help preserve, protect, and strengthen the Great Bay and Hampton-Seabrook Estuary. CAW can assist the city with outreach, planning and regulatory activities involving climate adaptation implementation.

- Support work of the NH Coastal Adaptation Workgroup in climate adaptation activities that facilitate, coordinate, provide technical information, and convene public outreach events.

**O2 - Implement FEMA's High Water Mark Initiative.** Consider implementing the FEMA High Water Mark Initiative (HWMI) as a public outreach activity. The HWMI provides information on past floods, such as documenting high water marks in public places, and posting maps and photographs of past floods on their websites. High water marks can be displayed on public buildings or on permanently installed markers.

**O3 - Coastal Flood Hazard Overlay District.** Use the Coastal Flood Hazard Overlay District concept as a tool to inform property owners of existing and future risks and hazards based on projected sea-level rise and coastal storm surge flooding.

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**O4 - Living Shorelines and Landscaping.** Maintaining natural shorelines is an effective way to preserve the functions of shoreline systems (marshes, dunes, estuaries) in providing valuable services including flood storage, recreational areas, and commercial harvesting of fish and shellfish.

- Provide information to property owners about living shorelines and the importance of retaining the functions of natural shorelines, and implementing landscaping best practices.
- Implement living shorelines projects on town lands to demonstrate best practices, and the benefits and effectiveness of living shorelines approaches.

*Refer to Stratham's Natural Hazards Mitigation Plan for additional recommendations for outreach and engagement activities.*

### Recommendations from the Coastal Risk and Hazards Commission Final Report (2016)

**CC7. Incorporate coastal hazards, risks and vulnerability in policies, plans and investments.**

**ACTIONS:**

- a. Evaluate deficiencies and barriers in municipal regulations, plans and policies, and their implications for regional vulnerability.
- b. Incorporate coastal hazards and risks assessments, including social vulnerability information, in municipal hazard mitigation plans, natural hazards and climate change adaptation Master Plan chapters, and emergency management plans.
- c. Encourage municipalities to develop detailed preparation, response and recovery plans that build on existing plans and initiatives.
- d. Encourage municipalities to adopt buffers and setbacks that better account for risk and vulnerability of structures, facilities, and natural resources and maintain ecosystem services (e.g. flood storage, storm surge attenuation, reduced impacts to public structures and facilities, and private property).
- e. Incorporate vulnerability assessment information and adaptation strategies for structures and facilities planning and investment for long term capital projects in municipal Capital Improvement Programs (CIPs).
- f. Improve connections between municipal hazard mitigation plans, master plans and capital improvement plans.
- g. Identify and reduce existing inconsistencies between municipal plans and state plans, such as hazard mitigation plans, building codes, design standards, and evacuation plans.
- h. Consider the concepts of uncertainty and risk in decision-making and action planning.
- i. Encourage communities that conduct floodplain management activities that exceed the minimum requirements of the National Flood Insurance Program (NFIP) to consider joining and participating in the Community Rating System (CRS), which provides discounts to annual flood insurance premiums for some residents and businesses as a reward for their communities' activities.

**E2. Incorporate best available climate science and vulnerability assessment information in state, regional, and municipal economic development plans.**

**ACTIONS:**

- a. Encourage private property owners and businesses to incorporate best available climate science and vulnerability assessments in their decision making and preparedness plans.

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- b. Consider vulnerabilities of local tax base, state economic development plan, retention or replacement of economic resources, at risk populations and population migration.
- c. Improve management, coordination and delivery mechanisms to ensure continuity of services to essential facilities, people, businesses and employment centers.
- e. Identify economic assets that are vulnerable to storm surge, sea-level rise, and extreme precipitation; understand the scope of that vulnerability; and evaluate existing statutes, ordinances, rules and regulations, policies, programs, and plans to determine whether changes should be made to reduce

**E3. Use appropriate and available mechanisms, including but not limited to incentives and market-based tools to fund climate adaptation strategies.**

**ACTIONS:**

- a. Align land acquisition and easement programs to transfer vulnerable properties into conservation.
- b. Establish stormwater utilities to fund retrofits to existing development and future improvements.
- c. Develop and utilize tools to identify cost effective strategies and public investments for adapting to increased flood risk in vulnerable areas.
- d. Develop special overlay districts, tax credits and revolving loan funds as mechanisms to discourage development in vulnerable areas.
- e. Implement voluntary transfer of development rights programs and other economic incentives to acquire or conserve property in high risk areas.
- f. Create statewide and municipal funding programs for climate adaptation strategies.
- g. Adapt economic development planning approaches to respond to changing environmental conditions and leverage shifting opportunities.
- h. Promote resilience and sustainability planning as economic development strategies.

**E4. Improve information available to property owners and prospective buyers about coastal hazards and vulnerabilities.**

**ACTIONS:**

- a. Improve consumer protection disclosure of properties vulnerable to coastal flooding.
- b. Distribute flood protection safety information to property owners in high-risk areas.
- c. Encourage homeowners in moderate- to low-risk areas to purchase Preferred Risk Policy.

**BL2. Implement regulatory standards and/or enact enabling legislation to ensure that the best available climate science and flood risk information are used for the siting and design of new, reconstructed, and rehabilitated state-funded structures and facilities, municipal structures and facilities, and private structures.**

**ACTIONS:**

- c. Encourage municipalities to use one of the following three approaches<sup>xiii,xiv,xv</sup> for determining a higher vertical flood elevation and expanded corresponding horizontal floodplain than the current base flood elevation and floodplain to address current and future flood risk for new construction, substantial improvement, or repairs to substantially-damaged municipal and private structures and facilities:
  - i. *Climate-informed Science Approach* – use the best available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science.<sup>xvi</sup>
  - ii. *Freeboard Value Approach* – use the freeboard value, reached by adding an additional two (2) feet to the base flood elevation for non-critical structures and facilities and from adding an additional three (3) feet to the base flood elevation for critical<sup>xvii</sup> structures and facilities.
  - iii. *The 0.2-percent-annual-chance Flood Approach* – use the 0.2-percent-annual-chance flood elevation (also known as the 500-year flood elevation).

<sup>xi</sup> An acceptable source of climate science for New Hampshire includes the Coastal Risk and Hazards Commission Science and Technical Advisory Panel report, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends, as amended.

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xii Any activity for which even a slight chance of flooding would be too great. For expanded description of "critical action" see Part I, Section 6 of Guidelines for Implementing Executive Order 13690.

xiii See Federal Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Input.

xiv See Guidelines for Implementing Executive Order 13690.

xv See [Appendix F](#) for State of New Hampshire comments on Draft Guidelines for Implementing Executive Order 13690.

xvi An acceptable source of climate science for New Hampshire includes the Coastal Risk and Hazards Commission Science and Technical Advisory Panel report, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends, as amended.

xvii Any activity for which even a slight chance of flooding would be too great. For expanded description of "critical action" see Part I, Section 6 of Guidelines for Implementing Executive Order 13690.

## **BL4. Integrate comprehensive land use and environmental planning with floodplain management approaches that prevent and minimize impacts from coastal hazards.**

### **ACTIONS:**

- c. Promote land development regulations that reduce vulnerability and protect ecosystem services (e.g. open space/cluster development).
- d. Prepare watershed-based plans that address comprehensive water resource management principles focused on changes in hydrologic systems resulting from climate change.
- e. Consider prohibiting development in areas destroyed by storms, experiencing repetitive loss of structures, and subject to chronic flooding and erosion. Consider adaptive reuse and/or acquisition of at-risk private properties.

## **NR2. Develop natural resource restoration plans that explicitly consider future coastal risk and hazards, and the ecological services that they provide.**

### **ACTIONS:**

- b. Provide recommendations and incentives for removal or modification of structures and facilities, such as freshwater and tidal crossings, that create barriers to tidal flow and habitat migration, particularly those that will be impaired or severely impacted by sea-level rise, storm surge, or extreme precipitation.
- c. Engage in best practices for invasive species planning and removal and incorporate climate considerations in invasive species removal plans.
- d. Utilize existing funding sources for natural resource restoration (e.g. offset measures, state Aquatic Resource Mitigation fund).

## **NR4. Consider ecosystem services provided by natural resources in land use planning, master plans, and asset decisions.**

### **ACTIONS:**

- b. Implement strategies and tools (such as land regulations, incentives, building regulations) designed to maintain or restore pervious surfaces, provide nutrient barriers, protect vegetated buffers and maintain wildlife passage.
- e. Develop best management practices for shoreline buffers, including information on appropriate use of shoreline hardening, bank stabilization, vegetation restoration and agricultural practices.
- f. Explore options to minimize shoreline hardening and promote natural or hybrid shoreline protection strategies.
- h. Develop guidelines and provide incentives for communities to incorporate climate adaptation actions for wildlife protection in master plans, hazard mitigation plans, and zoning ordinances.

## **H2. Develop plans and implement strategies to prepare and adapt recreational resources based on best available climate science.**

### **ACTIONS:**

- a. Conduct public information hearings to understand the impacts of proposed climate adaptation strategies.
- b. Assess existing and future recreational areas for their potential to provide storage for flood waters and stormwater runoff.
- c. Preserve open space and recreational areas that serve to minimize climate change impacts.

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- d. Integrate recreational and open space planning into climate adaptation planning and the Tidal Shoreline Management Plan.
- e. Integrate protection of recreational resources into land use and management, engineering, regulatory components of state and municipal plans including the Tidal Shoreline Management Plan, hazard mitigation plans, Master Plans, and design standards.

**H3. Identify and survey cultural and historic resources and assess their vulnerability to coastal risk and hazards based on best available climate science.**

**ACTIONS:**

- a. Map all currently surveyed cultural and historical resources.
- b. Identify asset types that may also be cultural and historic resources.
- c. Use reconnaissance level survey and vulnerability assessments to identify high priority areas for intensive survey.

**H4. Develop long-term plans for protecting, adapting, or reducing risk to cultural resources affected by climate change.**

**ACTIONS:**

- a. Create or modify adaptation strategies for cultural and historic buildings affected by climate change, including plans for protecting or relocating resources.
- b. Integrate protection of cultural and historical resources into land use and management, engineering, regulatory components of state and municipal plans including the Tidal Shoreline Management Plan, hazard mitigation plans, Master Plans, and design guidelines.
- e. Create programmatic strategies to compensate for the loss of historic asset types that will be replaced in order to adapt to climate change impacts.

## APPENDIX – MAP SET

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The following recommendations are short-term climate adaptation actions that can be included in the town's Natural Hazards Mitigation Plans, Master Plan and other planning and policy documents. These actions are focused on strengthening land use development

Map - Extent of Projected Tidal Flooding - SLR 1.7', 4.0' and 6.3'

Map - Extent of Projected Tidal Flooding - SLR + Storm Surge

Map - Infrastructure - SLR 1.7', 4.0' and 6.3'

Map - Infrastructure - SLR + Storm Surge

Map - Transportation Assets - SLR 1.7', 4.0' and 6.3'

Map - Transportation Assets - SLR + Storm Surge

Map - Water Resources 1.7', 4.0' and 6.3'

Map - Water Resources - SLR + Storm Surge

Map - Land Resources - SLR 1.7', 4.0' and 6.3'

Map - Land Resources - SLR + Storm Surge