CLIMATE RISK IN THE SEACOAST

Assessing Vulnerability of Municipal Assets and Resources to Climate Change

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CITY OF DOVER, NEW HAMPSHIRE

Vulnerability Assessment

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

Prepared by the

Strafford Regional Planning Commission

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Cover Photo Credit: Perry Plummer, Former Fire Chief, City of Dover

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 its inland coastal rivers and estuaries. 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 risk and vulnerability.

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 intensified by recent increases in the frequency and intensity of extreme storm events and increases in sea-level.

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

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 in order to enable them to adopt programs, policies, and business practices to make informed decisions (see below).

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, by:

- Enhancing preparedness and raise community awareness of future flood risks
- Identifying cost-effective measures to protect and adapt to changing conditions
- Improving resiliency of infrastructure, buildings and investments
- Protecting life, property and local economies
- Protecting services that natural systems provide
- Preserving unique community character

Master Plan	Capital Improvement Plan	Land Conservation Plan
Zoning Ordinance	Site Plan Regulations	Subdivision Regulations
Roadway Management	Stormwater Management 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 ten inland coastal municipalities from sea-level rise and storm surge to infrastructure, critical facilities transportation systems, and natural resources. Three sea-level scenarios were evaluated, accounting for a range from the intermediate-low to the highest projected sea-levels at the year 2100.

TABLE 1: Sea-Level and Storm Surge Scenarios in Dover

Sea-Level Rise (SLR) Scenarios	SLR	SLR	SLR	SLR + storm surge	SLR + storm surge	SLR + storm surge
Sea-Level Rise	1.7ft	4.0ft	6.3ft	--	--	--
Sea-Level Rise + Storm Surge	--	--	--	1.7ft + storm surge	4.0ft + storm surge	6.3ft + 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 (NTDE). The National Tidal Datum Epoch 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).*[1]

Storm Surge: *Storm surge is the rise of water level accompanying intense coastal storm events such as 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.*[2] 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 FIRMs account for the limit of moderate wave action in coastal areas. This assessment does not take into account additional flooding and impacts related to more severe wave action, wind action, erosion and other dynamic coastal processes.

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 and are similar to a more recent report issued by the NH Coastal Risks and Hazards Commission's Science and Technical Advisory Panel in 2014.

[1] NOAA website at http://tidesandcurrents.noaa.gov/datum_options.html
[2] EPA website at http://epa.gov/climatechange/glossary.html

As shown in Figures 1 and 2 and 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 assessment yield coverage estimates of flooding that are within the mapping margin of error for the scenarios in both the 2011 and 2014 reports.

Figure 1: 2014 Sea-Level Rise Scenarios (based on greenhouse gas emissions)

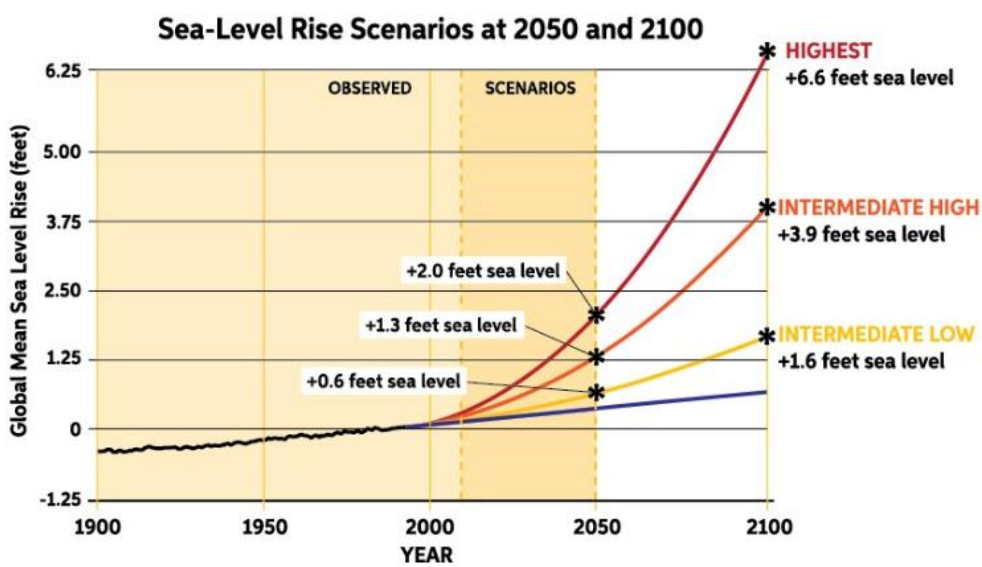
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW[a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation[a,c]	**13.2**	**14.7**	**13.9**	**18.5**

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. 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[a]).

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 2: 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.

Data, Methods, Calculations, and Results of Hydrologic and Hydraulic Modeling for Road Crossing

The C-Rise project assessed both aquatic organism passage capacity and hydraulic flow capacity of ten road crossings in each of the ten inland 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.

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. 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) and 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 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. 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[3] method was used; and for watersheds larger than one square mile, flows were calculated using the Regression Equations[4] published by the USGS for New Hampshire. Once the flows at each crossing were calculated, they were fed 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.

[3] A number from zero to 100 that describes how much rainfall runs off versus is lost to infiltration: a high curve number implies most of the rainfall runs off.

[4] An equation that describes a mathematical relationship between two variables in which one variable is used to predict the other.

Assets and Evaluation of Resources

Table 2 includes the five major categories and 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.

TABLE 2: Assets and Resources Evaluated for the Vulnerability Assessment

Category	Assets and Resources
State and Municipal Infrastructure	Climate Ready Culverts Federal and State Historic Register Properties Other Assets: graveyards, water access, transmission lines
Municipal Critical Facilities	Municipal Critical Facilities (as identified in Hazard Mitigation Plans)
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 Uplands Floodplains Wildlife Action Plan – Tier 1 and Tier 2 habitats Land Conservation Plan – Conservation focus areas (not mapped)
Land Use	Residential structures

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 on the following page.

Extent of Flooding from Sea-Level Rise and Storm Surge

The green and pink color schemes are arranged from lightest to darkest with increasing flood levels and extents.

Figure 3: Sea-Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft

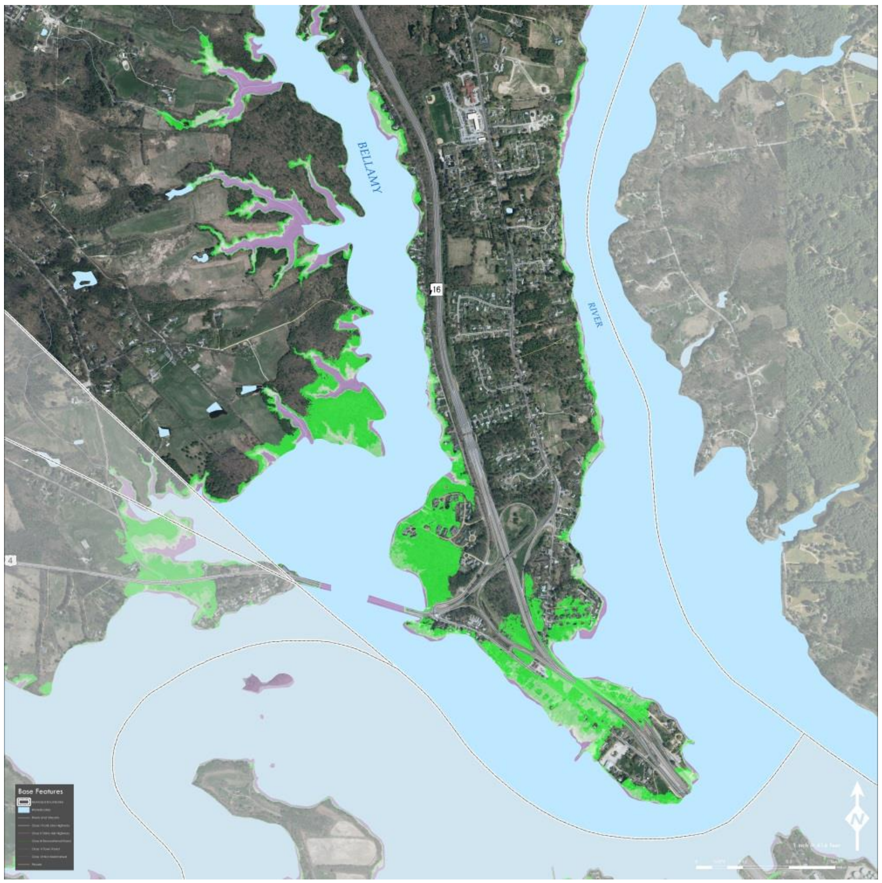
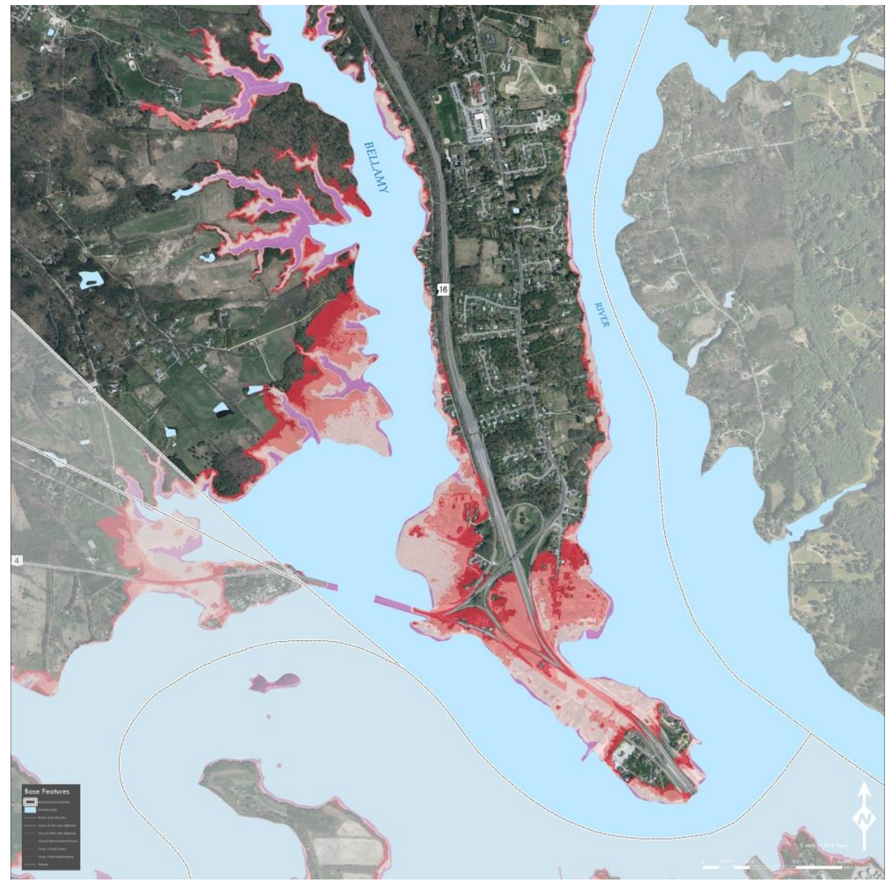


Figure 4: Sea-Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft + storm surge



Note: Storm surge = 100-year/1% chance flood.

COMMUNITY PROFILE

The City of Dover is located in southeastern NH within Strafford County at the center of the Seacoast region and is the easterly gateway to the White Mountains and Lakes region via Route 16. It is bounded by the City of Somersworth to the northeast; Eliot (ME) to the east, from which it is separated by the eastern branch of the Piscataqua River; and the Town of Madbury to the southwest. Dover's land area covers roughly 26.7 square miles and a water area of 2.3 square miles. With an estimated population of 30,275 (2013), Dover is the most populated municipality in Strafford Regional Planning Commission's (SRPC) coastal region. The inland coastal portion of Dover that is most susceptible to coastal flooding is located in low areas along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay. Many of 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.

Completed and Ongoing Efforts

Starting in the fall of 2012, Dover was chosen as one of four National Estuarine Research Reserve (NERR) sites to partner with the Massachusetts Institute of Technology Science Impact Collaborative and the Consensus Building Institute to test new and innovative ways to increase public awareness about climate change risks and adaptation opportunities.

In 2014, with the help of climate scientists at the University of New Hampshire, Dover engaged more than 100 participants, during which attendees participated in a mock decision-making process about how to deal with increasing stormwater flooding risk in a fictional coastal community similar to the City of Dover. This effort culminated in the release of the New England Climate Adaptation Project report, which summarized the key findings of the City's public engagement process.

In 2015, Dover made the decision to enforce regulations that exceed the National Flood Insurance Program minimum standards by adopting freeboard regulations, which require the lowest floor of residential and non-residential structures that are new construction or substantial improvements to be elevated two feet above base flood elevation.

In 2016, Dover participated in a training workshop conducted by the New Hampshire Office of Energy and Planning, NH GRANIT, and the Strafford Regional Planning Commission. The purpose of this workshop was to provide an introduction to the FEMA's Flood Risk Products, present community-specific flood risk data and information, and show how the flood risk data and information can be used in planning initiatives to increase flood resiliency.

In 2017, the City of Dover, in partnership with the Strafford Regional Planning Commission, UNH Cooperative Extension, and NH Sea Grant, will work to develop a Climate Adaptation Chapter to be included in the City's Master Plan. The Climate Adaptation Chapter will build off existing partnerships and data, and provide adaptation strategies and recommendations to protect vulnerable areas and key infrastructure and resources that may be prone to flooding resulting from increased precipitation and sea-level rise.

VULNERABILITY ASSESSMENT RESULTS

Key findings for the City of Dover are reported in the tables below, based on evaluation of the 1.7 feet (intermediate-low), 4.0 feet (intermediate), and 6.3 feet (highest) sea-level rise projections at the year 2100 and with the 100-year storm surge. Table 3 provides data on the total acreage of each sea-level rise scenario. Table 4 provides a summary of assessment data that was analyzed as part of this project.

TABLE 3: Total Acreage of Sea-Level Rise Scenarios in Dover

	Sea-Level Scenarios					
Community	1.7ft SLR (acres)	4.0ft SLR (acres)	6.3ft SLR (acres)	1.7ft SLR + storm surge (acres)	4.0ft SLR + storm surge (acres)	6.3ft SLR + storm surge (acres)
Dover	50.97	137.77	310.74	225.16	390.66	536.53

TABLE 4: Summary of Assessment Data

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Infrastructure (# of sites)	4			4		
Critical Facilities (# of sites)	7			11		
Transportation Assets (# of sites)	6			6		
Residential Structures (# of homes)	0	14	74	44	109	185
Uplands (acres)	25.58	100.03	261.26	181.27	337.56	476.61
Roadways (miles)	0.00	0.31	1.83	0.91	3.05	5.54
Freshwater Wetlands (acres)	13.86	21.61	36.99	26.52	48.13	70.18
Tidal Wetlands (acres)	23.14	36.26	42.06	40.19	43.70	45.34
Aquifers (acres)	39.74	120.69	287.09	204.40	364.68	506.00
Wellhead Protection Areas (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Conserved and Public Lands (acres)	14.65	37.76	102.48	70.13	115.34	166.39
Wildlife Action Plan (acres)	37.46	86.78	166.12	127.10	197.07	266.65
Conservation Focus Areas (acres)	28.94	66.70	140.71	102.61	171.76	241.98
100-year Floodplain (acres)	46.46	106.37	133.50	127.40	138.83	143.82

Notes: Upland refers to land above mean higher high water (highest tidal extent). Storm surge is the area flooded by the 100-year/1% chance storm event.

The data indicates that Dover's aquifers, uplands, floodplains, conserved lands, and lands identified as important habitat (Wildlife Action Plan) are the most vulnerable to flooding from sea-level rise and coastal storm surge. In Dover, current floodplains provide moderate relief from flooding due to sea-level rise. Roughly 43% of the highest sea-level rise scenario (6.3ft) occurs within the existing FEMA 100-year floodplain. The City can expect to see further flooding impacts from sea-level rise when there is a storm surge on top of the 4.0ft and 6.3ft scenarios. When a storm surge is added to the 4.0ft and 6.3ft scenarios, only 36% and 27% of the impacts occur within the floodplain.

Another consideration is the City's groundwater resources – over 500 acres of stratified drift has been identified as important aquifer recharge areas that may experience future issues. While this study did not analyze the potential impacts from salt water intrusion, this may be a future challenge the City wishes to investigate. Compared to other municipalities in the inland coastal region, Dover's infrastructure, community assets, and natural resources are at the most risk.

As shown in *Maps 1 and 2 Extent of Projected Tidal Flooding*, Dover can expect to see impacts along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay. There are a handful of critical facilities impacted, including water and sewer pipes, transmission lines, 7 pump stations, and two dams. Several transportation assets are impacted, including evacuation routes on Routes 16 and 4, future NHDOT projects, and local urban compact areas that should also be considered during long-term planning efforts. Dover also can expect to experience impacts to residential homes on Spur Road, Boston Harbor Road/Dover Point Road, and Wentworth Terrace.

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

SUMMARY OF VULNERABILITY ASSESSMENT RESULTS BY ASSET TYPE

Infrastructure

Maps 3 and 4 Critical Facilities and Infrastructure show state and municipal infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 5 reports when specific infrastructure types are affected by each sea-level rise and coastal storm surge scenario.

TABLE 5: Infrastructure

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
State and Municipal Infrastructure (miles & # of facilities)						
Transmission Lines (miles)	0.05	0.10	0.16	0.13	0.18	0.24
Total miles impacted	0.05	0.10	0.16	0.13	0.18	0.24
Water Access (#)	2			2		
Graveyards (#)	0			0		
Historic sites (#)	1			1		
Total # of Sites	4			4		

There are four municipal infrastructure assets identified as being vulnerable from either projected sea-level rise or coastal storm surge flooding. They include stretches of transmission lines over the Bellamy River, Varney and Canney Brooks, and the Cochecho River; two water access points at Hilton Park along the Piscataqua River and Little Bay Marina; and the Back River/Samuel Emerson Farm on Bay View Road, which is a historic registry site.

Municipal 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. Table 6 reports when specific municipal critical facilities are affected by each sea-level rise and coastal storm surge scenario.

TABLE 6: Municipal Critical Facilities

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Municipal Critical Facilities (miles & # of facilities)						
Sewer Pipes (miles)	0.00	0.28	1.74	0.84	2.92	5.39
Water Pipes (miles)	0.00	0.02	0.05	0.05	0.06	0.06
Total miles impacted	0.00	0.30	1.79	0.89	2.98	5.45
Pump Stations (#)	4			7		
Dams (#)	1			2		
Total # of Sites	7			11		

NOTE: Municipal Critical Facilities as identified in the City's Hazard Mitigation Plan.

There are eleven municipal critical facilities identified as being vulnerable from either projected sea-level rise or coastal storm surge flooding. They include impacts to sewer pipes located downstream of the dam on the Cochecho River, Dover Point Road over Canney Brook, and areas along Spur Road, Boston Harbor Road/Dover Point Road, and Wentworth Terrace; minor impacts to water pipes off Park Road; seven pump stations on Eagles Bay Drive, Hilton Park Road, Gerrish Road, Mill Street, Boston Harbor Road, Heaphy Lane, and Washington Street; and two dams located at the Tuttle Market Gardens Farm Pond and Boulanger Farm Pond.

Transportation

Maps 5 and 6 Road and Transportation Assets show the state and municipal roadways affected by sea-level rise and coastal storm surge flooding. Table 7 reports the miles of state and local roadways affected by each flood scenario. Table 8 provides greater detail as to which roads are impacted. Table 9 details other transportation assets, including information on urban compact areas, evacuation routes, and future NHDOT projects.

TABLE 7: State and Municipal Roadways and Infrastructure (miles)

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Roadway Type						
State	0.00	0.01	0.27	0.06	0.79	1.85
Local	0.00	0.12	0.88	0.48	1.35	2.22
Private	0.00	0.18	0.68	0.37	0.91	1.47
Not Maintained	0.00	0.00	0.00	0.00	0.00	0.00
Total Road Miles	0.00	0.31	1.83	0.91	3.05	5.54

The total number of miles impacted under the 6.3ft of sea-level rise with a storm surge scenario is 5.54, which is the highest amount in the region. No roadways in the City are projected to be impacted under a low sea-level rise scenario; however the medium and higher scenarios depict impacts to all roadway types except those classified as not maintained. Local roadways are the most sensitive to sea-level rise and coastal storm flooding in Dover. Some of the most vulnerable areas are located just before the Little Bay bridges. This area is currently under construction and part of a much larger NHDOT project.

TABLE 8: Dover’s Road Asset Impacts

Sea-Level Rise (SLR) Scenarios		SLR 6.3ft	SLR 6.3ft + storm surge
Road Name	Road Class	Miles Impacted	Miles Impacted
Bayview Road	Private	-	0.02
Boston Harbor Road	Local/State	0.01	0.31
Center Road	Private	-	0.07
Clearwater Drive	Private	0.03	0.38
Cocheco Street	Local	-	0.04
Cote Drive	Local	0.09	0.26
Deborah Lane	Private	-	0.03
Dover Point Road	State	0.29	0.66
Dover Point One-Way	State	-	0.04
Eagle’s Bay Drive	Private	-	0.13
General Sullivan Bridge Road	Private	0.01	0.04
Gulf Road	State	0.00	0.06
Heaphy Lane	Local	0.02	0.03
Henry Law Ave	Local	-	0.01
Hilton Park Road	Local/Private	0.38	0.54
Hilton Road	Local	-	0.06
Mill Street	Local	0.03	0.04

Sea-Level Rise (SLR) Scenarios		SLR 6.3ft	SLR 6.3ft + storm surge
Road Name	**Road Class**	**Miles Impacted**	**Miles Impacted**
No Name	Private	0.45	0.64
Old Dover Point Road	Local	-	0.02
Ramp from Spaulding to N Rd.	State	-	0.02
River Street	Local	-	0.12
Spaulding Turnpike N	State	0.03	0.40
Spaulding Turnpike NB Exit 5 off ramp	State	0.06	0.16
Spaulding Turnpike NB Exit 6 on ramp	State	-	0.05
Spaulding Turnpike S	State	0.15	0.61
Spur Road	Local	-	0.29
US 4 on ramp	State	-	0.10
US 4 WB off ramp	State	-	0.00
Washington Street	Local	-	0.03
Wentworth Terrace	Local/Private	0.25	0.34
Young Street	Local	-	0.01
Total Road Miles	-	1.80	5.54

This analysis determined that, in Dover, there are approximately 1.8 miles of roadway (a total of 14 different roads) vulnerable to the high sea-level rise scenario and a total of 5.54 miles of roadway (an additional 18 different roads) vulnerable to sea-level rise with a storm surge. Roadways that experience the largest stretches of inundation over at least a half-mile, include sections of Boston Harbor Road, Dover Point Road, Hilton Park Road, and the Spaulding Turnpike, as well as various "no-name" private roads. Maps 5 and 6 provide a visual representation of these impacts.

TABLE 9: Dover's Other Transportation Asset Impacts

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Roadway Type						
Urban Comact Areas (acres)	8.0			23.8		
Evacuation Routes (# of sites)	2			2		
NHDOT Projects (# of sites)	3			3		

The table above provides detail on other transportation related assets that are vulnerable to sea-level rise and coastal storm flooding, including: parts of the City's urban compact zone located in the downtown along the Cochecho River waterfront; two evacuation routes along Route 16 and Route 4; and three NHDOT future/ongoing planning projects on Spaulding Turnpike/General Sullivan Bridge; Scammell Bridge over the Bellamy River; and Gulf Road over the Salmon Falls River.

Natural Resources

Maps 7 and 8 Land Resources and *Map 9 and 10 Water Resources* show natural resources affected by sea-level rise and coastal storm surge flooding. Table 10 reports the number of acres for each natural land resource affected by each sea-level rise and coastal storm surge scenario. Table 11 reports the number of acres for each water resource.

TABLE 10: Natural Land Resources (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Natural Land Resources (acres)						
Conservation Lands	14.65	37.76	102.48	70.13	115.34	166.39
Wildlife Action Plan	37.46	86.78	166.12	127.10	197.07	266.65
Conservation Focus Areas (acres)	28.94	66.70	140.71	102.61	171.76	241.98
Total land resources	81.05	191.24	409.31	299.84	484.17	675.02
* As part of this analysis, conservation focus areas were calculated; however due to their overlap with data from the Wildlife Action Plan, they were not mapped.						

A total of 23 protected properties (includes land protected as public land and/or conservation easement), are sensitive to sea-level rise and coastal storm flooding; however, the acres of impacted land vary significantly by property and range from less than one acre to as much as 47.57 acres. Some of the largest tracts of land include Bellamy River WMA – West, Bellamy River Wildlife Sanctuary, Huggins Easement, and the Nute/Whitehouse tract. Conservation focus areas identified in the Land Conservation Plan for NH's Coastal Watersheds (Bellamy River, Fresh Creek, Garvin Brook, and Lower Cochecho River), as well as lands identified in the Wildlife Action Plan along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay are also vulnerable.

TABLE 11: Natural Water Resources (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Natural Water Resources (acres)						
Wellhead Protection Areas	0.00	0.00	0.00	0.00	0.00	0.00
Estuarine and Marine Wetlands	23.14	36.26	42.06	40.19	43.70	45.34
Freshwater Wetlands	13.86	21.61	36.99	26.52	48.13	70.18
Stratified Drift Aquifers	39.74	120.69	287.09	204.40	364.68	506.00
Total water resources	76.74	178.56	366.14	271.11	456.51	621.52

Dover's water resources, which include freshwater and tidal wetlands, and stratified drift aquifers, are vulnerable to sea-level rise. While the impacts to tidal wetlands stay relatively consistent between the highest scenario and the highest scenario with a storm surge, the impacts to freshwater wetlands nearly double. Another consideration is the City's groundwater resources – there are roughly 500 acres of stratified drift aquifers that have been identified as areas that may experience future issues. While this study did not analyze the potential impacts from salt water intrusion, this may be a future challenge the City wishes to investigate.

Land Use

Maps 1 and 2 Extent of Projected Tidal Flooding show upland affected by sea-level rise and coastal storm surge flooding above mean higher high water. Upland refers to land above mean higher high water (highest tidal extent). Table 12 reports the number of acres of upland affected by each flood scenario.

TABLE 12: Uplands (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Uplands (acres)						
Acres	25.58	100.03	261.26	181.27	337.56	476.61
% Upland	0.15	0.60	1.56	1.08	2.01	2.84

Total Upland in Dover = 16,791 acres

Nearly 3% of Dover's uplands are impacted by the SLR 6.3ft + storm surge scenario. Dover's inland coastal area has some low lying areas, mainly along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay. Many of these areas have experienced riverine flooding in the past.

Parcels and Assessed Value

Table 13 reports the number of parcels affected by each of the six scenarios and the aggregated assessed value of these parcels. The degree to which each parcel and any development on the parcel are 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. Table 14 reports the number of residential structures affected by each of the six scenarios and the aggregated assessed value of these homes.

TABLE 13: Parcels and Assessed Value by Scenario

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Parcels and Assessed Value						
Parcels Affected (# of parcels)	354	387	432	404	448	476
Aggregate Value of Parcels ($ value)	$194,954,460	$201,690,560	$213,379,960	$205,761,060	$216,670,960	$235,961,200

In Dover, there was an incremental increase in the number of parcels impacted by each of the different scenarios. The total number of impacted parcels ranges from 354 to 476 with aggregated values of $194,954,460 to $235,961,200 respectively.

TABLE 14: Residential Structures and Assessed Value

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Residential Structures and Assessed Value						
Structures Affected (# of homes)	0	14	74	44	109	185
Assessed Value of homes ($ value)	$0	$5,310,239	$28,864,002	$16,978,780	$45,510,216	$70,658,867

Dover does not experience any residential impacts under the first sea-level rise scenario; however, significant impacts in the medium (4.0ft) and high (6.3ft) scenarios can be expected. Adding a storm surge to these scenarios more than doubles the number and estimated losses of affected homes. Assessed values of homes range from roughly $5.3 million to $70.7 million.

Climate Ready Culverts

Maps 11 and 12 Climate Ready Culverts Maps show areas within the 100-year floodplain affected by sea-level rise and coastal storm surge flooding. Table 15 reports the hydraulic and aquatic organism passage ratings for the twelve culverts chosen for this analysis.

TABLE 15: Climate Ready Culvert Analysis

Culvert Crossing ID & Location	*Precipitation Flood Flow				***Aquatic Organism Passage (AOP) Rating
	10-yr	25-yr	50-yr	100-yr	
	**Hydraulic Rating				
#7: Sixth Street over Blackwater Brook	Pass	Pass	Transitional	Transitional	Full AOP
#8: Long Hill Rd over Reyners Brook	Transitional	Transitional	Transitional	Fail	Full AOP
#9: Sixth Street over Reyners Brook	Pass	Pass	Pass	Transitional	Reduced AOP
#10: County Farm Road over Jackson Brook	Transitional	Fail	Fail	Fail	Reduced AOP
#11: County Farm Road over Reyners Brook	Transitional	Transitional	Transitional	Fail	Reduced AOP
#12: Portland Ave north of Hancock Street	Transitional	Transitional	Transitional	Fail	Reduced AOP
#13: Atlantic Ave east of Magnolia Drive	Fail	Fail	Fail	Fail	No AOP
#14: Private Road over unnamed stream	Pass	Pass	Transitional	Transitional	No AOP
#15: Bellamy Road over Bellamy River	Pass	Pass	Pass	Pass	Reduced AOP
#16: Drew Road over unnamed stream	Fail	Fail	Fail	Fail	Reduced AOP
#17: Garrison Road over unnamed stream	Fail	Fail	Fail	Fail	Reduced AOP
#18: Spur Road over Varney Brook	Transitional	Transitional	Transitional	Transitional	Full AOP

**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*

***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;*

**** No AOP: For all aquatic organisms including adult salmonids; No AOP – Adult Salmonids: For all aquatic organisms except adult salmonids; Reduced AOP: For all aquatic organisms; Full AOP: for all aquatic organisms*

The table above describes the hydraulic component of the analysis. According to this analysis, of the twelve culverts chosen, four were able to pass the 10-yr storm event; three failed; and five were ranked transitional. For the 25-yr storm event, four culverts passed; four culverts failed; and four were ranked transitional. For the 50-yr storm event, two culverts passed; four culverts failed; and six were ranked transitional. For the 100-yr storm event, one culvert passed; seven failed; and four were ranked transitional.

According to the aquatic organism passage component of the analysis, of the twelve culverts chosen, three were able to fully accommodate species to navigate through the culvert; seven were reduced; and two failed to provide the opportunity for species to successfully navigate the culvert.

FEMA Flood Hazard Areas

Maps 11 and 12 Climate Ready Culverts Maps show areas within the 100-year floodplain affected by sea-level rise and coastal storm surge flooding. The three sea-level rise scenarios generally fall within the current 100-year floodplain, extending 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. Table 16 reports the acreage within the current 100-year floodplain affected by each flood scenario.

TABLE 16: FEMA Flood Hazard Areas (acres) Impacted

Sea-Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
FEMA Flood Hazard Areas						
100-yr floodplain impacted (acres)	46.46	106.37	133.50	127.40	138.83	143.82
Percentage of SLR within the floodplain	91.15%	77.21%	42.96%	56.58%	35.54%	26.81%

Floodplain assessment based on Flood Insurance Rate Maps (FIRMs) released by FEMA in September, 2015.

In Dover, the 100-year floodplain is highly sensitive to flooding from sea-level rise mostly along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay. According to this analysis, roughly 43 percent of the highest sea-level rise scenario (6.3ft) falls within the existing FEMA 100-year floodplain. The City can expect to see further flooding impacts from sea-level rise when there is a storm surge on top of the 4.0ft and 6.3ft scenarios. The 4.0ft scenario with a storm surge falls within 36 percent of the floodplain and the 6.3ft scenario with a storm surge falls with 27 percent of the floodplain.

ISSUES AND CONSIDERATIONS

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.

- State and Municipal Infrastructure: Using the results of the Climate Ready Culvert analysis will assist the City during long-term planning decisions in regard to the placement, design, and size of new culverts or when upgrades and repairs are being made to existing culverts.

- State and Municipal Infrastructure: According to the hydraulic component of the analysis, of the twelve culverts chosen, four were able to pass the 10-yr storm event; three failed; and five ranked transitional. The vulnerability and risk of future failure at these locations will become greater with an expected increase in the frequency of extreme precipitation events.

- State and Municipal Infrastructure: Municipal infrastructure identified as vulnerable from either projected sea-level rise or coastal storm surge includes stretches of transmission lines over the Bellamy River, Varney and Canney Brooks, and the Cochecho River; two water access points at Hilton Park along the Piscataqua River and Bay View Marina on Great Bay; and the Back River/Samuel Emerson Farm on Bay View Road, which is a historic registry site.

- Municipal Critical Facilities: Municipal critical facilities identified as vulnerable from either projected sea-level rise or coastal storm surge includes impacts to sewer pipes located downstream of the dam on the Cochecho River, Dover Point Road over Canney Brook, and areas along Spur Road, Boston Harbor Road/Dover Point Road, and Wentworth Terrace; minor impacts to water pipes off Park Road; seven pump stations on Eagles Bay Drive, Hilton Park Road, Gerrish Road, Mill Street, Boston Harbor Road, Heaphy Lane, and Washington Street; and two dams located at the Tuttle Market Gardens Farm Pond and Boulanger Farm Pond.

- Transportation Assets & Roadways: Roadways that can expect to experience the largest stretches of inundation due to flooding from sea-level rise and coastal storm surge include sections of Boston Harbor Road, Dover Point Road, Hilton Park Road, as well as various unnamed, private roads. Areas along Route 16 (Spaulding Turnpike N/S) are expected to experience significant flooding. Flooding to these areas may disrupt local commuting patterns and cause challenges for emergency responders.

- Transportation Assets & Roadways: Other transportation-related assets vulnerable to sea-level rise and coastal storm flooding, include parts of the City's urban compact zone located in the downtown along the Cochecho River waterfront; two evacuation routes along Route 16 and Route 4; and three NHDOT future/ongoing planning projects on Spaulding Turnpike/General Sullivan Bridge; Scammell Bridge over the Bellamy River; and Gulf Road over the Salmon Falls River.

- Natural Resources: Protecting both freshwater and tidal wetlands will improve floodplain storage capacity; assist in adequately separating development and infrastructure from these areas; and allow for the inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems to accommodate projected changes in sea-levels.

- Natural Resources: Land conservation efforts along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River; and along the shores of Little Bay would mitigate future flooding impacts by guiding development away from those areas and increasing flood storage capacity.

- Natural Resources: It is unclear as to the impacts of groundwater intrusion the City may experience due to sea-level rise. This issue needs further study to identify how saltwater is likely to change the salinity of existing freshwater sources along the coast. Additionally, as sea levels rise, groundwater table elevations are pushed upward, resulting in higher groundwater elevations at significant distances from the coast.

- Land Use: 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.

RECOMMENDATIONS

The following recommendations are short-term climate adaptation actions that can be included in Dover's Hazard Mitigation Plan, 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.

REGULATORY

R1 - Coastal Flood Hazard Overlay District. Adopt in the City's zoning ordinance a Coastal Flood Hazard Overlay District that includes performance-based standards that protect against flood impacts from sea-level rise and coastal storm surge. Establish the overlay district boundaries based on current flood hazard areas on FEMA Flood Insurance Rate Maps and projected future high risk flood areas mapped by the C-RiSe Vulnerability Assessment. (Also see similar recommendation in the Community Outreach and Engagement section below.)

R2 - Coastal Buffers and Tidal Marshes. Adopt buffer requirements for setbacks to wetlands that include consideration of climate change in order to protect land that allows coastal habitats and populations to adapt to changing conditions and also provides ecosystem services that protect people, structures, and facilities.

R3 – Culvert Maintenance and Improvement. Adopt ecosystem-friendly approaches in the placement and design of freshwater and tidal stream crossings in order to restore or maintain natural flow regimes to increase ecosystem resilience to extreme weather events and other coastal hazards.

PLANNING AND POLICY

P1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the C-RiSe report into Dover's Hazard Mitigation Plan update. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan as new data and information becomes available.

P2 - Capital Infrastructure and Investments. Incorporate consideration of impacts to municipal infrastructure, including water access at Hilton Park along the Piscataqua River and Little Bay Marina; and the Back River/Samuel Emerson Farm on Bay View Road in current and future capital infrastructure projects. Evaluate the extent of sea-level rise and storm surge flooding on individual facilities, including sewer pipes located downstream of the dam on the Cochecho River, Dover Point Road over Canney Brook, and areas along Spur Road, Boston Harbor Road/Dover Point Road, and Wentworth Terrace; minor impacts to water pipes off Park Road; seven pump stations on Eagles Bay Drive, Hilton Park Road, Gerrish Road, Mill Street, Boston Harbor Road, Heaphy Lane, and Washington Street; and two dams located at the Tuttle Market Gardens Farm Pond and Boulanger Farm Pond.

P3 - 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.

- Incorporate new scoring criteria into existing land conservation prioritization efforts that consider climate adaptation benefits when evaluating land for conservation purposes.
- Support funding and resources for conservation, land management programs, and land stewardship activities.

P4 - Evacuation Planning. Prepare evacuation plans and coordinate these plans with municipalities in the coastal region to implement timely and comprehensive planning and notification for coastal storm events.

- Mark evacuation routes with signage and communicate routes to the public with information on the City's website and printed maps.

P5 – Drinking Water Protection. Conduct an investigation of the vulnerability of public drinking water supplies to salt water intrusion. Ongoing groundwater modeling at the University of New Hampshire is investigating the effects of climate change, including sea-level rise, precipitation and temperature, on groundwater levels and the impacts to roads in coastal New Hampshire. The groundwater modeling study will have broader applications as it can be expanded to investigate the effects of climate change on drinking water supply, base flow to streams, and the hydrology of wetlands

P7 – Road Maintenance. Evaluate the extent of sea-level rise and storm surge flooding to sections of roadway on Boston Harbor Road, Dover Point Road, Hilton Park Road, as well as various unnamed private roads. Ensure that all existing and future transportation related projects within identified vulnerable areas take projected sea-level rise scenarios into account, in particular, the Route 16 Spaulding Turnpike expansion project.

COMMUNITY OUTREACH AND ENGAGEMENT

O1 - Implement FEMA's High Water Mark Initiative. Communities implement the High Water Mark Initiative by providing 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.

O2 - Coastal Flood Hazard Overlay District. Inform property owners of existing and future risks and hazards based on projected sea-level rise and coastal storm surge flooding by using the Coastal Flood Hazard Overlay District as a tool.

O2 - Living Shorelines and Landscaping. Maintain natural shorelines 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 City lands to demonstrate best practices, and the benefits and effectiveness of living shorelines approaches.

APPENDIX – MAP SET

Map 1: Extent of Projected Tidal Flooding - SLR 1.7’, 4.0’ and 6.3’
Map 2: Extent of Projected Tidal Flooding - SLR + Storm Surge
Map 3: Critical Facilities and Infrastructure - SLR 1.7’, 4.0’ and 6.3’
Map 4: Critical Facilities and Infrastructure - SLR + Storm Surge
Map 5: Roads and Transportation Assets - SLR 1.7’, 4.0’ and 6.3’
Map 6: Roads and Transportation Assets - SLR + Storm Surge
Map 7: Land Resources - SLR 1.7’, 4.0’ and 6.3’
Map 8: Land Resources - SLR + Storm Surge
Map 9: Water Resources - SLR 1.7’, 4.0’ and 6.3’
Map 10: Water Resources - SLR + Storm Surge
Map 11: Climate Ready Culverts - SLR 1.7’, 4.0’ and 6.3’
Map 12: Climate Ready Culverts - SLR + Storm Surge