Coastal Hazards and Adaptation[1]

I. Introduction

Like other coastal municipalities in New Hampshire, Greenland is confronted by a challenging set of land use and hazard management concerns that include flooding from rising sea levels and storm surge in Great Bay, extreme precipitation events, coastal erosion, and impacts to critical coastal habitats. Greenland has experienced significant impacts during extreme and moderate coastal storm events, extreme rainfall events, and localized flooding from more frequent seasonal highest tides along shorefront land abutting Great Bay, the Winnicut River and other tributaries. These observed impacts may be exacerbated by changes in climate that may cause future increases in the frequency and intensity of storms and rates of sea-level rise. Flooding is compounded by increased stormwater runoff from development and impervious surfaces.

Projected changes in climate and coastal conditions will present challenges to many sectors of municipal governance, asset and infrastructure management, sustainability of recreation and tourism, and protection of natural resources and coastal ecosystems. Adapting to changing conditions will play an important part in the town's strategic planning and actions in the future. Effective preparedness and proactive land use management can help the town reduce its future exposure and improve resilience to increased flood risks, minimizing economic, social, and environmental impacts.

The Coastal Hazards and Adaptation Chapter addresses the following topics:

- Present and future coastal hazards
- Future impacts to coastal assets and resources
- Other climate related impacts
- Future growth demands
- Community adaptation and resilience
- Recommendations for long-term adaptation and resilience strategies and actions

King Tide marker at the end of Tide Mill Road. Photo credit: Laura Byergo

[1] Preparation of this chapter was funded by the NH Coastal Program

II. Vision

A. Vision Statement

Proactive strategies are identified and implemented that address the impacts of coastal hazards, and ensure the community is better prepared to protect the security, health and safety of its citizens, provide for a stable and viable economic future, and create a more sustainable and climate resilient community.

Greenland identifies the following major goals relating to coastal hazards and climate adaptation:

- Critical infrastructure – roads, culverts, railway corridors, utilities - are protected against impacts from flooding and other coastal hazards, and made more resilient to these hazards.
- Salt marshes, wetlands, and shoreland buffers are protected and maintained to provide flood storage, reduce flood and storm damage, and to provide estuarine and riparian habitats to move inland as water levels rise.
- Emergency access and evacuation routes are maintained or enhanced if necessary.
- Private property owners are encouraged to take protective measures to reduce flood risks, including threats to private septic systems and drinking water wells at risk from both rising groundwater levels and saltwater intrusion.
- Residents and businesses are aware of and better prepared to respond and adapt to coastal hazards and extreme precipitation events.

B. Issues of Local and Regional Significance

Based on the 2017 Town of Greenland Climate Risk in the Seacoast (C-RiSe) Vulnerability Assessment, prepared by the Rockingham Planning Commission, and local knowledge of flooding hazards, the following issues of local and regional significance should be addressed in future policy, planning, regulatory and non-regulatory initiatives by the town, state, community and other stakeholders. http://www.rpc-nh.org/application/files/7814/9400/9371/Greenland_CRISE_Assessment_Report_Final.pdf

Adapt municipal and state roads, bridges, culverts, and stormwater systems.

Adapting state and local roads and their associated infrastructure so these systems are functioning and efficient are critical to the growth and stability of the town and the Seacoast region. These systems are vital during storm events when evacuation routes can be impacted by flood waters.

Control flooding and protect natural resources with sound land use and development standards and targeted land conservation projects.

Implementing sound land development standards to protect salt marshes, coastal and inland wetlands, and shoreland buffers is a low-cost way to protect infrastructure. Marshland and wetlands, and the undeveloped land adjacent to them, are on the front lines of coastal adaptation, absorbing flood waters and providing space for freshwater and estuarine habitats to move inland as water levels rise. Consideration should be given to how natural and developed landscapes can complement one another, not at the detriment to either one. All of Greenland's tidal wetlands will be impacted by sea level rise and storm surge, with an estimated 15% at these wetlands most vulnerable negative impacts, including loss of upland vegetation.

Maintain function of septic systems and drinking water wells.

The majority of homes and businesses in Greenland are served by private septic systems and drinking water wells, with 28% of homes served by municipal water supply. Maintaining both these private systems and the public system these systems is critical to the health and safety of the community. Over time, improvements to these systems may be necessary to adapt to rising seas, saltwater intrusion into freshwater systems, and storm-related flooding and power outages. The Town should monitor options for drinking water supply and wastewater treatment for neighborhoods in flood prone areas.

Work with the railway to identify solutions to protect the railway corridor from rising water levels.

The railway running through Greenland is threatened by flooding due to projected sea level rise and storm surge in several locations. In some areas, the railway bed may act as a dam, preventing water from flowing upstream, exacerbating flooding on the Bay side of the railway corridor.

Dedicate funds for infrastructure improvements.

As infrastructure ages and environmental conditions change due to sea-level rise and increased precipitation and stormwater runoff, the cost of maintaining critical infrastructure will grow with time. Identifying new methods for raising funds to do this will be necessary to lessen the burden on taxpayers.

Increase preparedness and raise awareness of flooding and coastal hazards in the community.

Residents need to be engaged and informed about how to protect themselves and their homes in the face of rising seas, coastal storms, and increased precipitation during extreme weather events. Being proactive about planning to respond to these changing conditions is the best course of action but one that needs more attention.

III. Present and Future Coastal Hazards

A. Past and Present Coastal Hazards

Coastal Storms

A wide range of coastal storms have effected Greenland in the past including extreme rainfall, Nor' Easters, hurricanes, tropical storms, and highest tides. Typical impacts from these types of events include flooding from high tides, storm surge, and rainfall, resulting in road closures, disruption of businesses and schools, and increased demand for municipal emergency services.

The severity of flood events depends upon several factors and different types of storm events. A 100-year/1% chance precipitation event is based on the volume of rainfall (in inches) within a 24-hour period. A 100-year/1% chance coastal storm event is based on storm surge elevation which is influenced by tide stage, wind (direction, speed and duration), and seasonal astronomical cycles

Today, extreme precipitation and coastal storm surge (e.g. the 100-year or greater storm event) are the most immediate risk and threat resulting in flooding and property damage, while sea-level rise poses a more long-term risk of increased daily tidal flooding.

The New Hampshire seacoast has experienced many significant storm events in the last 50 years including extreme precipitation, Nor' Easters, and storm surge. In recent years the New Hampshire seacoast has narrowly escaped two major storm events – Hurricane Irene (2011) and Super Storm Sandy (2012). The likelihood of such storms reaching our area, with surges of 12 or more feet, has become an increasing concern as heavily developed coastal areas are at high risk of flood impacts (as documented in the Tides to Storms report, 2015).

Figure 2. Recent storm and flood events in Greenland

Event	Type	Rainfall/ Snow	Inland Flooding	Tidal Flooding	High Winds	Surge Height	Tide Stage
February 1972	Nor' Easter			✓	✓		
Blizzard of 1978	Nor' Easter	33" snow					
August 1991	Hurricane Bob		✓	✓	✓		
October 1991 "Perfect Storm"	Nor' Easter			✓	✓	+3.5'	
October 1996	Tropical Storm	14" rain	✓	✓		500-yr	High
Mother's Day May 2006	100-year+	14" rain	✓				
Patriot's Day April 2007	Nor' Easter	6.5" rain	✓		✓		
Super Storm Sandy 2012	Tropical Storm	5" rain	✓	✓	✓		
King Tide 2014	extreme tide	None		✓			High
King Tide 2015	extreme tide	None		✓			High
King Tide 2016	extreme tide	None		✓			High
King Tide 2017	extreme tide	None		✓			High

B. Projected Future Conditions

Studies published in the last five years, including the U.S. Global Change Research Project, 2014 National Climate Assessment, report updated trends and projections for several parameters influenced by changes in climate including sea levels, coastal storms, and precipitation. Information about New Hampshire trends and projections is summarized in sections 1-3 below.

1. Sea-Levels and Coastal Storm Surge[2]

Sea-Level Rise

[2] Paul Kirshen, Cameron Wake, Matt Huber, Kevin Knuuti, Mary Stampone, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends (2015), Prepared by Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

Figure 4 shows the percent contribution of various factors that influence sea levels worldwide. Ocean warming and melting of land-based glaciers are the major drivers of sea-level rise.

Based on local tide gauge data, sea-level along the New Hampshire coastline has risen an average of 0.7 inches per decade since 1900. More recent reports show that the rate of sea-level rise has increased to approximately 1.3 inches per decade since 1983. The 2014 U.S. National Climate Assessment reports projected ranges of plausible sea-level rise scenarios from 0.6 feet to 2.0 feet by 2050, and from 1.6 feet to 6.6 feet by 2100.

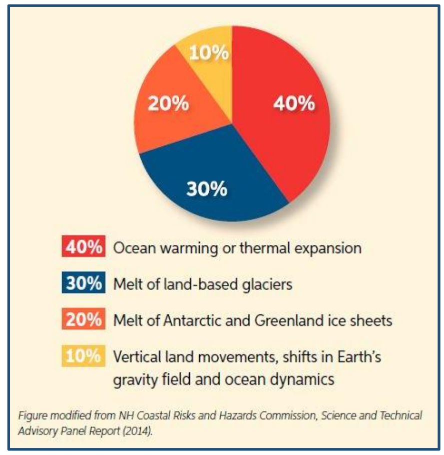

Figure 3. Primary factors contributing to sea-level rise worldwide.

Storm Surge

Among the scientific literature, there is insufficient basis to draw a specific conclusion whether storm surges will increase in the future. However, future storm surges will occur on top of higher sea levels. Considering changes in storm surge and high water levels due to sea-level rise alone, today's extreme surge events such as a 100-year storm will result in increased coastal flooding and expansion of the coastal floodplain over time.

2. Precipitation[3]

Recent studies show the mean annual precipitation in the Northeast has increased by approximately 5 inches or more than 10%, from 1895 and 2011, and has experienced a greater than 50 % increase in annual precipitation from storms classified as extreme events (100-year/1% annual chance or greater event). Climate models are uncertain about future increases in annual precipitation but project increases that could be as high as 20 percent in the period 2071-2099 compared to 1970-1999. Most of the increases may occur in winter and spring with less increase in the fall and perhaps none in the summer.

In 2014, the Northeast Regional Climate Center (NRCC) Extreme Precipitation Atlas was published, improving the accuracy of rainfall data for a range of storm events applied to engineering and science research. The NRCC atlas is the new standard used by the NH Department of Environmental Services, Alteration of Terrain Bureau for the design of stormwater management systems in permitting development projects. Prior to release of the NRCC atlas (2014), engineers and researchers used National Weather Service Technical Paper No. 40 precipitation atlas (TP-40, 1960) based on data from the 1960's. Comparing rainfall data from the TP40 atlas and the NRCC Extreme Precipitation Atlas in Figure 4, rainfall from extreme events (50-year and 100-year storm events) has increased 25 percent and 35 percent respectively in Greenland. For example, Figure 4 shows an increase of 2.3 inches of precipitation for the current 100-year storm event as reported from the new NRCC precipitation atlas.

[3] Paul Kirshen, Cameron Wake, Matt Huber, Kevin Knuuti, Mary Stampone, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends (2015), Prepared by Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

Figure 4. Data for a range of 24-hour rainfall events (TP40, 1961 and NRCC, 2014).

	24-hour Rainfall Event						
Source	**1-year**	**2-year**	**10-year**	**25-year**	**50-year**	**100-year**	**500-year**
TP40*	2.6	3.1	4.4	5.2	5.8	6.5	not reported
NRCC	2.6	3.2	4.8	6.1	7.3	8.8	13.46

* The NH Department of Environmental Services, Alteration of Terrain Bureau has replaced the TP-40 atlas with the NRCC atlas (2014) as the rainfall standard for permitting the design of stormwater management systems.

Consistent with comparison of the precipitation data from the old TP-40 atlas and the new NRCC atlas, Figure 5 shows that the frequency of extreme precipitation events – those greater than 4 inches in a 24-hour period - has increased significantly since 1990 compared with the period from 1950-1990.

Extreme precipitation is also projected to increase with the occurrence of extreme rainfall events during summer and fall influenced by changes in tropical storm activity as the rainfall amounts produced by tropical storms is projected to increase. In general, total annual precipitation is expected to increase as is extreme precipitation.

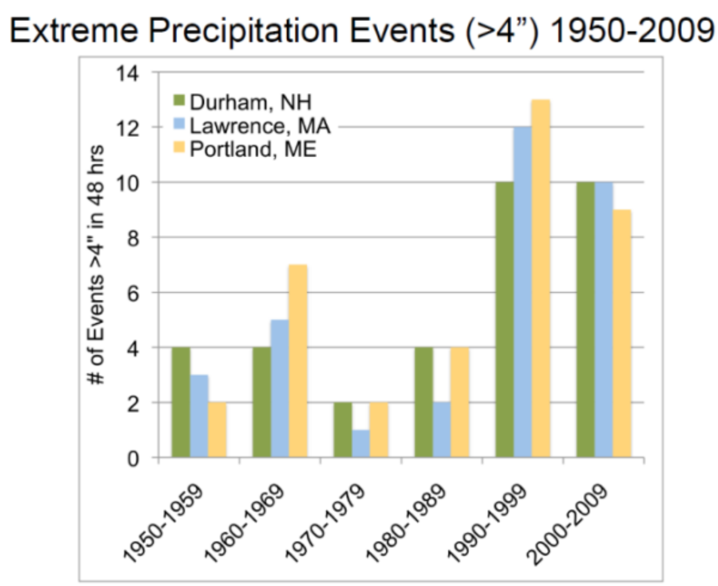

Figure 5. Total number of events with greater than four inches of precipitation in 48 hours per decade since 1950.[4]

3. Temperature[4]

In the last century, annual and seasonal temperatures have warmed by almost 2°F and lake ice-out dates are occurring earlier. Regional climate assessments report expected changes in seasonal temperatures:

- Warmer winters with 20-50 fewer days per year below 32°F. (Based on data
- from climate projection grids for southern NH, the number of days when MINIMUM temperature was below 32°F from 1980-2009 was 142. Source: http://www.climatesolutionsne.org/assessments#map)
- Hotter summers with 3-7 additional days per year above 90° F (compared to about 10 days per year above 90°F during the period 1970-1999).

[4] Wake, C., Burakowski, E., Kelsey, E., Hayhoe, K., Stoner, A., Watson, C., & Douglas, E. (2011). *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future.* Carbon Solutions New England. Retrieved from www.carbonsolutionsne.org/resources/reports/pdf/greatbayreport_online.pdf

IV. Future Impacts to Coastal Areas

A. Vulnerability Assessment

In 2017, the Rockingham Planning Commission completed the Climate Risk in the Seacoast (C-RiSe) Vulnerability Assessment for Greenland which evaluated the risk and sensitivity of roadways, infrastructure and natural resources to sea-level rise and storm related flooding. As shown in Figure 6, the Tides to Storms assessment applied a range of sea-level rise scenarios at 2100, similar those reported in the 2015 U.S. National Climate Assessment. The Tides to Storms assessment produced statistical data and mapping as part of a regional report and a customized assessment report for Greenland. The Greenland data is reported in this section.

Figure 6. Sea-Level Rise Scenarios used in the tides to Storms Vulnerability Assessment (Rockingham Planning Commission, 2015).

Time Period*	"Intermediate Low	"Intermediate High"	"Highest"
year 2050	0.6 ft.	1.3 ft.	2.0 ft.
year 2100	1.7 ft.	4.0 ft.	6.3 ft.

Sea-level rise and storm surge are measured from Mean Higher High Water which is the water elevation based on the average of the highest tides over a 19-year period. In Seacoast New Hampshire Mean Higher High Water is 4.4 feet. Storm surge is the area flooded by the current 100-year/1% chance storm event or greater

Figure 7. Summary of Tides to Storms 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)	0			2 - Outdoor Recreation Sites: Great Bay Discovery Center and Portsmouth Country Club		
Critical Facilities (# of sites)	0			2 - Biospray and dam at Country Club Pond		
Transportation Assets (# of sites)	1 Railroad			1 Railroad		
Residential Structures (# of homes)	0	0	3	4	9	26
Uplands (acres)	51.0	119.8	224.0	162.5	261.3	375.5
Roadways (miles)	0	0	0.23	0.76	1.16	1.40
Freshwater Wetlands (acres)	2.83	9.53	18.83	13.97	23.41	33.76

Tidal Wetlands (acres)	115.59	123.74	124.94	124.35	125.21	125.95
Aquifers (acres)	0	0	0.08	0.01	0.29	1.22
Wellhead Protection Areas (acres)	10.99	16.20	29.18	20.90	34.31	54.15
Conserved and Public Lands (acres)	59.72	112.16	178.10	142.14	198.76	253.11
Wildlife Action Plan (acres)	129.50	199.57	285.62	236.24	313.27	389.42
Conservation Focus Areas (acres)	130.21	190.30	248.95	218.16	265.89	312.22
100-year Floodplain (acres)	136.07	202.22	210.84	207.12	212.52	222.47
Assessed Value of Parcels Impacted	$72,300,700	$74,659,700	$77,676,500	$81,371,600	$83,017,300	$93,990,000

Note: Storm surge refers to the 100-year floodplain as depicted on the FEMA Flood Insurance Rate Maps (2015, preliminary). Upland refers to land above mean higher high water (highest tidal extent). Impacts to the 500-year floodplain were calculated using the full extent of the 500-year floodplain which includes areas within the 100-year floodplain.

Flooding from sea-level rise and storm surge are projected along Great Bay and the shorelines of the Winnicut River, Pickering Brook, Packer Brook, Haines Brook, Shaw Brook and Foss Brook. Land development in these areas is primarily residential, but rising water level will also impact agricultural land along Great Bay and land associated with the Portsmouth Country Club. Roads, culverts, the railway corridor, and some structures are at risk of flooding. A summary of impacts to road and transportation infrastructure, critical facilities, and natural resources from future sea-level rise and storm related flooding are presented in this section and Figure 8 below.

Roads and Transportation Infrastructure

Local roadways in Greenland are more highly susceptible to flooding than the state roadway network. Local roads identified to be at risk from flooding from sea-level rise and storm surge are Shore Road, Meloon Road, Fairview Terrace, Great Bay Drive West, Bayside Drive, Caswell Drive and Bruce Court. State roadways affected include Route 33/Greenland Road between Golf and Ski Warehouse, located at 1680 Greenland Road, and Rizzo Warehouse/British Aisles, located at 1634 Greenland Road. In addition, the railway line running through Greenland is at risk of flooding or rail bed erosion in several locations.

Critical Facilities

There are no critical facilities susceptible to projected sea-level rise and only two facilities at risk due to sea-level rise and accompanying storm surge flooding – the dam at Country Club Pond and the Biospray parcel.

Natural Resources

Salt marsh and sand beaches provide natural protection against floods and storm surge. The assessment indicates that tidal wetland systems and freshwater wetlands will be heavily impacted by flooding from sea-level rise. Estuarine and marine wetlands are the most impacted natural resources in Greenland, with approximately 126 acres impacted under the highest sea-level rise scenario (6.3 feet plus storm surge). Over 15% of Greenland's tidal wetlands are projected to be impacted.

Figure 8. Example of a Living Shoreline

Example of a living shoreline (Photo Credit: Vance Miller, from Living Shorelines Academy)

Changes in the daily tidal condition and seasonal high tides will affect the stability of these systems and their ability to sustain surface elevations that keep pace with rising water levels. Although a large number of acres are flooded by coastal storm surge these events are infrequent and of short duration so do not result in sustained conditions that might influence the health and function of tidal wetland systems. Impacts that might occur during storm events include erosion, excessive sedimentation and deposition of debris, and loss of salt marsh vegetation.

Figure 9. Natural Water Resources (acres, year 2100)

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	10.99	16.20	29.18	20.90	34.31	54.15
Estuarine and Marine Wetlands	115.59	123.74	124.94	124.35	125.21	125.95
Freshwater Wetlands	2.83	9.53	18.83	13.97	23.41	33.76
Stratified Drift Aquifers	0.00	0.00	0.08	0.01	0.29	1.22
Total water resources	129.41	149.47	173.03	159.23	183.22	215.08

Tidal Salt Marsh

Tidal marshes are susceptible to climate change, especially sea-level rise (SLR). In 2015, NH Fish and Game and Great Bay National Estuarine Research Reserve used a modeling tool – Sea Level Affecting Marshes Model (SLAMM) – to project where salt marsh may persist or migrate inland based on changes in sea level. Protecting land where salt march can potentially migrate as sea levels rise is a good strategy to enhance coastal resiliency.

Results of the SLAMM simulation in Greenland are as follows:

- 230.9 acres of salt marsh in Greenland
- 0.03 acres of salt marsh are "lost" or no longer exist in 2025 under any sea-level rise scenario
- 230.9 acres of salt marsh are "persistent", meaning the salt marsh continues to persist under any one or more of the sea-level rise scenarios
- 71.9 acres of dry land have "potential" to become salt marsh under any one or more of the sea-level rise scenarios

Tidal salt marshes need be able to grow in elevation as water levels rise in Great Bay. Allowing marshes to migrate inward is critical. Tidal restrictions such as dredging, dams, and municipal infrastructure can block a zone of retreat into upland buffers.

What do marshes need to remain healthy while sea levels rise?

- Tidal flooding – remove barriers to hydrology
- Sediment source – remove barriers to sediment supply
- Zone of retreat into upland buffer – remove shoreline barriers and provide areas for marsh migration

Freshwater Wetlands

With the increase in frequency and severity of extreme weather events associated with climate change, New Hampshire is experiencing greater erosion, flooding, habitat loss, and infrastructure damage. In the *2011-2017 New Hampshire Wetlands Program Plan*, the State recognized the importance of tidal and non-tidal wetlands for flood control, water quality protection, wetland habitat, and water recharge for both groundwater and surface waters. Not only do wetlands offer significant environmental values, but confer significant social and economic benefits, such as flood mitigation.

The Town of Greenland's 2010 Natural Resources Inventory recommends several freshwater wetland complexes for protection and/or restoration for the important role these complexes provide in water quality protection, flood mitigation, and wildlife habitat.

Land Conservation

Significant acreage with priority habitats may be affected by projected sea-level rise and increased precipitation events. The Land Conservation Plan for New Hampshire's Coastal Watersheds identified three conservation focus areas along the Great Bay coastline – Bayside Point, Fabyan Point, and Lower Winnicut River. Refer to the new Climate Change section of the Wildlife Action Plan (http://www.wildlife.state.nh.us/wildlife/wap.html) and the Land Conservation Plan for New Hampshire's Coastal Watersheds (for information about these priority habitats.
https://forestsociety.org/sites/default/files/Coastal_Plan%20compressed.pdf)

There are ten conservation properties impacted by rising sea levels and storm surge: Emery, GCNE easement, Great Bay Shoreline South, Great Bay WMA, Hughes #1, Leonard Weeks and Descendents, Portsmouth Country Club, Sandy Point, Smith Tract and a Town of Greenland parcel.

The town may consider aligning its land protection strategies by incorporating criteria in its land conservation selection process that takes into account the value and benefits of protecting critical ecosystems (wetlands, agricultural fields) in areas projected to have high flood risk in the future. These values and benefits include cost avoidance associated with flood storage, infrastructure protection, erosion and sediment control, support of fish and wildlife, nutrient cycling, and carbon storage.

V. Other Climate-Related Impacts

A. Drinking Water and Wastewater Treatment

Rising groundwater levels due to changes in sea level and saltwater intrusion may impact water resources including private drinking water wells and wellhead protection areas. Emerging research from the University of New Hampshire indicates that groundwater levels and salt water intrusion could cause effects further inland than the immediate coast.

Rising groundwater levels and increased precipitation could compromise the function of individual septic systems and both private and municipal stormwater management infrastructure. These system failures may result in increased transfer of pollutants to groundwater, surface waters, wetlands and estuarine systems.

For these reasons, coastal municipalities are encouraged to collaborate on planning for future regional and municipal drinking water and wastewater treatment needs.

B. Economy

The NH Coastal Risks and Hazards Commission report (2016) acknowledges New Hampshire's coastal region as an important economic driver for the state and consistently ranks above the national average for job growth. The report states the following statistics about New Hampshire's coastal economy:

> ***OUR ECONOMY*** *is the systematic and productive exchange and flow of goods, services, and transactions that must be intact, functioning, and resilient to coastal risks and hazards in order to create and sustain a high quality of life in coastal New Hampshire. (CRHC Report, 2016)*

- The Gross Regional Product of the coastal region totaled approximately $11 billion in 2014, with 16 percent derived from the finance and insurance industry and 13 percent coming from the manufacturing industry.
- Between 2002 and 2016 job growth for the coastal region was 12.8 percent, outpacing both the state and national job growth rates of 5.9 and 10.4 percent, respectively.
- As of Q3 2016, the coastal municipalities supported 109,070 jobs.
- In 2014, the coastal region exported $15.5 billion worth of goods and services, imported $14.1 billion worth of goods and services, and produced and consumed $5.9 billion worth of goods and services locally, making the region a net exporter of goods and services.

Impacts from sea-level rise and storm surge flooding can have an effect on the overall municipal tax rate by influencing land values, decisions made about infrastructure investments, need for and delivery of critical services, and maintenance of infrastructure and facilities. The economic vulnerability of a municipality can be evaluated by determining the exposure of its property tax base to coastal hazards. As shown in Figure 11, the Tides to Storms project (RPC, 2015) analyzed the number of tax parcels in Greenland affected by each of the six sea-level rise and storm surge scenarios evaluated. The number of impacted parcels ranges from 135 to 202, with aggregated values of $72,300,700 to $93,990,000.

Figure 10. Parcels and assessed value by sea-level rise and storm surge 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)	135	141	152	160	170	202
Aggregate Value of Parcels ($ value)	$72,300,700	$74,659,700	$77,676,500	$81,371,600	$83,017,300	$93,990,000

A significant portion of the economy in New Hampshire's state, regional and local economies may be vulnerable to changes in climate and coastal conditions such as extreme storms and sea-level rise. New Hampshire's coastal region is an important economic driver for the state and consistently ranks above the national average for job growth. The natural resources that draw residents, visitors and businesses to coastal New Hampshire are a cornerstone of our quality of life. Residents, visitors and businesses depend on clean water for drinking, swimming, and boating; salt marshes and eelgrass beds are critical habitat for commercial and recreational fisheries; and beaches draw hundreds of thousands of visitors that boost the state economy and tax income. In addition to providing recreational opportunities and wildlife habitat, forest and agricultural land and uplands provide materials for heating, building and construction, and farm and food products.

C. Emissions and Energy Use

Climate change mitigation refers to the reduction of greenhouse gas (GHG) emissions through reduction in the burning of fossil fuels, energy efficiency and conservation, use of renewable and alternative energy sources, and carbon dioxide (CO_2) and carbon storage in living plants. Increased emissions also impact air quality which can pose serious health risks to certain populations in regions where air quality is impaired.

Many factors influence transportation emissions including land development patterns, land cover conversion, individual preferences and behavior, convenience, and fuel pricing. Nationwide, the transportation sector contributes roughly 28 percent of the total greenhouse gas emissions each year.

As of 2012, the transportation sector alone accounts for 43 percent of greenhouse gas emissions in New Hampshire, making it the largest single contributor at rates significantly higher than the national average.[5]

D. Human Health

The town recognizes that climate change can impact human health, however municipalities rely primarily on federal and state agencies that regulate environmental conditions and provide public services to address human health impacts from climate change. This Chapter does not suggest recommended actions by the town but does acknowledge the general types of human health impacts that are already occurring and may continue or escalate as climate changes in the future.

Climate change affects human health and well-being in many ways, including impacts from increased extreme weather events, rising temperatures in both cold and warms months, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks. Increasing exposure to environmental pollutants and atmospheric emissions in recent decades has caused concern over its effect on public health, environmental ecosystems and climate worldwide.[6] Human health impacts are intensified with increasing levels of exposure which are likely to worsen with climate variability and change.[7]

Air pollution (ozone, pollen, mold, dust) and heat exposure have a range of mild to severe health effects and can aggravate chronic diseases, including cardiovascular and respiratory diseases, and respiratory conditions such as asthma.

According to the Centers for Disease Control and Prevention, New Hampshire and specifically Rockingham County have one of the highest occurrences of Lyme Disease in the country and among the New England states. Climate change may increase the presence of ticks and Lyme disease with warmers winters which allow ticks to persist year round and increases in the population of its host species (mice, deer). Other diseases carried by insects may increase with increasing insect populations and increased geographic ranges of certain insect species.

VI. Future Growth and Development

Planning for future growth and development should consider the implications of existing and projected future coastal hazard such as areas subject to flooding and erosion. Land use decisions will largely dictate where new development and redevelopment occurs and where it will not. Sustaining the services provided by natural features such as salt marsh, freshwater wetlands and natural shoreline processes will be an important aspect of managing coastal high risk areas into the future.

A. Growth and Development

1. Population

---

[5] NH Department of Environmental Services

[6] *Center for Disease Control and Prevention: Climate and Health*. (n.d.). Retrieved from http://www.cdc.gov/climateandhealth/effects/allergens.htm.

[7] Melillo, J., Richmond, T., & Yohe, G. (2013). *Climate Change Impacts in the United States: Human Health Chapter.* U.S. Global Change Research Project.

As reported by the U.S. Census, the population of Greenland is reported as 2,707 in 1990, 3,227 in 2000, and 3,549 in 2010. The current population is estimated to be 3,724. The town has grown by 37.5 percent from 1990 to 2015.

2. Land Use Changes and Regulations

Impervious Surfaces

From 1990 to 2010, impervious surfaces (paved roads, parking lots, roofs) in Greenland have increased from 6.7 percent (450 acres) to 15.7 percent (1,055 acres) of the total land area in Greenland (6,722 acres). Referring back to Figure 5, the amount of precipitation associated with 50-year to 100-year or greater storms events has increased in the last 40 years resulting in more frequent flooding and failure of older infrastructure not designed to manage this increased runoff volume. Over the last several years, the Greenland Planning Board has been increasingly concerned about flooding related to increased impervious cover. The Board has discussed ways to reduce the risks and impacts of flooding as the town continues to grow and develop.

Studies show that impervious surface cover exceeding 10 percent of a watershed area can negatively affect water quality and the health and diversity of aquatic species. Locally, pollutants discharged in stormwater runoff routinely result in closure of shell-fishing areas in Great Bay.

Non-Point Source Pollution

Coastal erosion and sediment transport during storm events can introduce pollutants to salt marshes and freshwater wetlands near the coast. The changes in precipitation documented in the Northeast Regional Climate Center - Extreme Precipitation Atlas increases the volume of stormwater runoff generated from impervious surfaces during moderate to severe storm events. Stormwater runoff often contains harmful pollutants that are discharged into waterways, wetlands and salt marshes.

Shoreline Stabilization

Maintaining the stability of the shoreline along Great Bay, Winnicut River and other tributaries requires keeping sea grass healthy and propagating to secure the mudflats and sediment in place. Human encroachments cause the structure of these mudflats to weaken and the sediment to be transported by runoff.

3. Land and Zoning Districts Impacted by Sea-level Rise and Storm Related Flooding[8]

Upland impacted by flooding from 1.7 feet of sea-level rise is low while impacts increase with 4.0 feet and 6.3 of sea-level rise. The most heavily impacted areas are residential neighborhoods along Shore Drive, Meloon Road, Bayside Road, Fairview Terrace, Great Bay Drive West, Bruce Court and Caswell Drive, shoreland associated with the Great Bay Discovery Center and shoreland and upland associated with Portsmouth Country Club.

[8] Tides to Storms Coastal Vulnerability Assessment, 2015 prepared by Rockingham Planning Commission

Figure 11. Acres of upland impacted by sea-level rise and storm surge.

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Acres of upland impacted	51.0	119.8	224.0	162.5	261.3	375.5
% Upland impacted	0.08%	1.88%	3.52%	2.55%	4.11%	5.90%

Total Upland in Greenland = 6,357 acres. Upland refers to land above mean higher high water (highest tidal extent) and excludes wetlands.

Greenland's coastal area is predominantly developed as single-family dwellings, served by private septic systems and drinking water wells. Conservation and open space lands in these areas can act as important flood storage areas and buffer development from damaging flood waters, wind and erosion, and by allowing salt marsh and freshwater wetlands systems to store flood waters and migrate inland as conditions change. Preserving these natural landscapes and ecosystems will be an important strategy for mitigating and protecting developed areas from future impacts.

B. Planning for Public Safety

1. Hazard Mitigation Plan

FEMA requires that municipalities maintain an updated and approved Hazard Mitigation Plan in order to qualify for federal disaster relief, grant funding, and participation in the National Flood Insurance Program. The Plan documents the town's exposure to past, current and future natural hazards, and recommends specific actions to reduce risk from these hazards. Greenland's 2015 Hazard Mitigation Plan includes the following recommendations that address coastal hazards:

- **Review Existing Infrastructure**: Evaluate existing infrastructure (Roads, Bridges, Storm water Management Devices, Etc.) for repair replacement needs. Emphasis on infrastructure critical during hazard situation (e.g. evacuation route, culverts).
- **Repair/ Replace Infrastructure**: Implement schedule for repair or replacement of infrastructure in need. Incorporate into CIP or as warrant articles.

The town may incorporate information from the Tides to Storms Coastal Vulnerability Assessment as part of its next scheduled Hazard Mitigation Plan update including maps, statistics of future impacts, and recommended adaptation strategies to reduce risk and vulnerability of municipal assets and resources.

2. Emergency Operations Plan

The Emergency Operations Plan is maintained by Greenland's Emergency Management Director. The Plan provides a comprehensive set of protocols that are activated in the event of an emergency, natural disaster or other situation that poses a threat to public safety and the town.

Incorporating new information about changes in weather, extreme events and long-term climate change can enhance emergency planning. The town could reduce its risk and exposure by incorporating coastal hazards and risks assessments in municipal emergency management and hazard mitigation plans, and improving connections and efficiencies between these plans. Collaborating with private sector representatives to evaluate and identify necessary improvements to emergency communications systems preparedness can ensure 911 and other critical communications services remain operational during emergencies and disasters. Local officials recognize the need to update a regional comprehensive emergency evacuation plan for coastal flood and storm events that includes early notification to highest risk areas and properties.

VII. Community Adaptation and Resilience

A. Ways of Adapting and Being Resilient

Incorporating the latest flood trends and future projections into municipal planning and projects will minimize vulnerability and prove beneficial even if future hazards turn out to be less extreme than anticipated.

Adapting to changing conditions means designing buildings, roadways, utilities and other infrastructure that account for flooding or modifying uses of land that are compatible under a wide range of conditions. The process of adapting creates buildings and systems that are more ***resilient*** and better able to perform under changing conditions with fewer impacts.

Adaptation – 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]

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. [http://epa.gov/climatechange/glossary.html]

1. Land Development and Natural Resource Protection

To the extent necessary based on expected impacts, the town should integrate comprehensive land use and environmental planning with floodplain management approaches that prevent and minimize impacts from coastal hazards. Establishing minimum regulations that consider vulnerability assessment information can support appropriate amendments to land development standards, building codes, floodplain management, erosion hazard zones, and stormwater management. Implementing strategies and tools (such as land use regulations, incentives, and building codes) can maintain or restore pervious surfaces, provide pollution reduction, protect vegetated buffers, and protect water quality.

Over time and as warranted, additional approaches may include adoption of flood hazard overlay districts that include higher development standards that minimize impacts from natural hazards and climate change. In the long-term, prohibiting development in areas subject to chronic flooding and erosion can ultimately reduce risk and exposure along the coast. In the future, finding ways to acquire at-risk private properties and adapting them for new uses, such as recreational areas, will ensure continued enjoyment of coastal living.

Land use and development regulations can be focused to reduce vulnerability while protecting ecosystem services. One of the most effective strategies is to conserve land that allows coastal habitats and populations to adapt to changing conditions while protecting natural functions that protect people, structures, and facilities. Watershed-based plans can include comprehensive water resource management principles focused on changes in hydrology resulting from climate change. Maintaining or restoring critical natural systems such as salt marsh and sand dunes will ensure greater protection from storm surge and long-term impacts of sea-level rise. Best management practices for shoreline development can include alternatives to shoreline hardening, bank stabilization techniques, and vegetation restoration.

2. Infrastructure and Building Guidelines

Increased precipitation and sea-level rise will produce more inland runoff and localized flooding in addition to coastal flooding. Experts recommend that for floodplain and coastal locations, where there is little tolerance for risk (e.g. costly to repair or serves a critical function), that the following guidelines be used in the siting and construction of infrastructure and facilities.[9]

- The range of sea-level rise scenarios from the Intermediate High to the Highest (Figure 4) be applied as follows:
  - **Determine** the time period over which the system is designed to serve (either in the range 2014 to 2050, or 2051 to 2100).
  - **Commit** to manage to the Intermediate High condition, but be **prepared** to manage and adapt to the Highest condition if necessary.
  - Be **aware** that the projected sea-level rise ranges may change and adjust if necessary.

- Development projects continue to use the present frequency distributions for storm surge heights and be added to projected ranges for sea-level rise. The flood extent of the current 100-year storm surge will increase as sea level rises, and the 100-year floodplain will be flooded more frequently by smaller surges as sea level rises.

- At a minimum, infrastructure is designed using precipitation data from the current Northeast Regional Climate Center (Cornell) atlas and infrastructure be designed to manage a 15 % increase in extreme precipitation events after 2050. Infrastructure design should incorporate new precipitation data as it is published or updated.

3. Town Actions to Address Coastal Hazards

Climate Risk in the Seacoast (C-RiSe) Vulnerability Assessment

In 2017, town staff and boards participated in the development of a town-specific Vulnerability Assessment with the Rockingham Planning Commission. Through a series of meetings, maps and statistical information about impacts to roadways, critical infrastructure and natural resources was evaluated. Staff and board members provided their perspectives on critical issues facing the town and drafted recommendations to address current and future flood hazards which were included in a final report and map set for the town. Information from these maps and report are being incorporated into this chapter.

---

[9] Paul Kirshen, Cameron Wake, Matt Huber, Kevin Knuuti, Mary Stampone, *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends (2015)*, Prepared by Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

Not a lot of data or local information exists about what residents and businesses have done or are doing to accommodate and adapt to coastal hazards and climate change. However, many residents have installed generators to supply electricity in the event of power outages.

VIII. Recommendations for Long-Term Adaptation and Resilience Strategies and Actions

The goal of becoming a resilient community is to sustain the local economy, implement sound land use and development, protect natural resources and their functions, and ensure public safety. To address the potential future impacts of climate change, the town can benefit by collaborating with state agencies, other municipalities, and technical service providers. The following recommendations can serve as guide to short-term and long-term actions that can be implemented incrementally over time as conditions warrant.

Municipal Policy and Planning

The Board of Selectman and Town Administrator would lead implementation of the following recommended strategies and actions with assistance from municipal Departments, and boards and commissions as necessary.

M1 Strengthen municipal capacity to utilize the best available science related to potential future impacts of climate change and its risks in order to improve decision-making and action planning.

M2 Identify funding to support preparation of an application to the FEMA Community Rating System Program, a voluntary program whereby the municipality takes specific actions to reduce flood risk and receives discounted flood insurance premiums for NFIP policy holders.

M2 Utilize the best available climate science and flood risk information for the siting and design of new, reconstructed, and rehabilitated municipal structures and facilities.

M3 Collaborate with private sector representatives to evaluate and identify necessary improvements to emergency communications systems preparedness to ensure 911 and other critical communications services remain operational during emergencies and disasters.

M4 Incorporate coastal hazards and risks assessments in municipal emergency management and hazard mitigation plans, and improve connections and efficiencies between these plans.

M5 Begin discussions with elected officials, planning board and zoning board of adjustment about long term land use development standards, building code, and zoning options in areas at high risk for flooding and erosion.

M6 Consider vulnerabilities of local tax base, state economic development plan, retention or replacement of economic resources, at risk populations and population migration.

M7 Adapt economic development planning approaches to respond to changing environmental conditions, leverage shifting opportunities, and promote resilience and sustainability planning as economic development strategies.

M8 Explore options for provision of drinking water and wastewater treatment in neighborhoods at risk of saltwater intrusion into wells and leach fields.

Land Use and Natural Resource Strategies

The Planning Board, Conservation Commission, Town Planner and Code Enforcement Officer would lead implementation of the following recommended strategies and actions with assistance from other municipal departments and organizations, such as the Winnicut River Watershed Coalition, as necessary.

L1 Adopt land development regulations aimed at minimizing impervious surfaces and stormwater flooding, and reducing or preventing non-point source pollution.

L2 Revise building codes and septic system and drinking well design standards to enable adaptive and innovative construction techniques and designs to protect these structures from flooding and rising groundwater levels (e.g. elevating above base flood elevation, wet and dry flood-proofing).

L3 Over time and as warranted, consider adoption of flood hazard overlay districts that include higher development standards that minimize impacts from natural hazards and climate change.

L4 Require development project approvals to include drainage maintenance plans for stormwater infrastructure and streams or open drainage ways on site.

L5 Maintain or restore critical natural systems such as salt marsh and agricultural fields to ensure greater protection from storm surge and long-term impacts of sea-level rise. Employ best management practices for shoreline development such as bank stabilization techniques and vegetation restoration as alternatives to shoreline hardening.

L6 Utilize existing state and federal grant programs for natural resource restoration.

L7 Develop natural resource restoration plans that explicitly consider future coastal risk and hazards, and the ecological services that they provide.

L8 Encourage appropriate buffers and setbacks that promote ecosystem services (e.g. flood storage, storm surge protection, habitat, recreation).

L9 Be aware of opportunities to upgrade structures and facilities, such as freshwater and tidal crossings, that can 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.

L10 Engage in best practices for invasive species planning and removal and incorporate climate considerations in invasive species removal plans.

L11 Identify areas where erosion and shoreline instability exist, and prioritize areas for nature-based approaches (e.g. mudflat and salt marsh restoration).

L12 Protect future marsh migration areas identified by marsh migration modeling.

L11 Improve designs for dams, culverts and bridges to maintain existing function and reconnect fragmented surface waters (wetlands, lakes, ponds, rivers and streams) and protect high quality habitat for aquatic organisms.

L13 Incorporate in plans and implement strategies to prepare and adapt coastal recreational resources based on best available climate science.

L14 Assess existing and future recreational areas for their potential to provide storage for flood waters and stormwater runoff.

L15 Preserve freshwater wetlands, forestlands, agricultural fields, and recreational areas that serve to minimize climate change impacts, including floodwater mitigation, water storage in times of drought, and migration of wildlife habitat.

L 16 Support the work of the Winnicut River Watershed Coalition, including the Coalition's Better Backyard Campaign, designed to protect the integrity of the Winnicut River and its tributaries, as well as Great Bay.
http://www.winnicutcoalition.org

L17 Consider a municipal tree planting program, such as the Tree City USA program, to mitigate effects of climate change and contribute to carbon sequestration.

L18 Consult the 2010 Town of Greenland Natural Resources and the 2006 Greenland Conservation and Land Stewardship Plan, for recommendations regarding natural resource protection opportunities and priorities for stewardship of town owned land.

Local, Regional and State Coordination

The Board of Selectman and Town Administrator would lead implementation of the following recommended strategies and actions with assistance from municipal Departments, and boards and commissions as necessary.

R1 Coordinate with municipalities and private water companies to evaluate water resources drinking water needs, and wastewater treatment for the seacoast region.

R2 Coordinate with the NH Department of Transportation on anticipated improvements to state and local roadways most vulnerable to flooding and leverage funding necessary for such improvements.

R3 Coordinate evacuation route planning with Portsmouth, Newington, Rye, North Hampton and Stratham. Incorporate early communication and notification into regional evacuation route planning.

Community Preparedness and Awareness

The Town Administrator and municipal Departments would lead implementation of the following recommended strategies and actions with assistance from Planning Board, Conservation Commission, and civic organizations as necessary.

C1 Form a citizen lead committee to address flood impacts and act as an advocacy group for the community on flood related issues of concern.

C2 Provide informational materials about flood risk reduction at public and community events.

C3 Schedule events at the library or other public venues featuring topics relating to coastal hazards and preparedness, and climate adaptation.

C4 Provide information through outreach to residents and businesses about alternative approaches, reducing risk and lowering insurance premiums through adaptation.

C5 Provide information through outreach to residents and businesses about the benefits of living shorelines.

C6 Implement the FEMA High Water Mark Initiative to illustrate past flood elevations and future water levels associated with the 100-year storm surge and projected sea-level rise. https://www.fema.gov/high-water-mark-initiative

C7 Provide outreach and information to residents about how to clean up after a storm event (e.g. drainage ways, driveway culverts etc.)

C8 Continue participating in and supporting the Winnicut River Watershed Coalition.

C9 Continue participation in the NH Coastal Adaptation Workgroup to facilitate, coordinate, provide technical information, and convene public outreach events about climate adaptation.

C10 Partner with federal and state agencies as well as regional and local organizations to expand resources for education, outreach, and coordination.

C11 Encourage the incorporation of climate science and information about the risks and hazards associated with changing climatic conditions in public school curriculum.

C12 Improve information available to property owners and prospective buyers about coastal hazards and vulnerabilities.

C13 Improve consumer protection disclosure of properties vulnerable to coastal flooding.

C14 Distribute flood protection safety information to property owners in high-risk areas.

C15 Encourage homeowners to obtain flood insurance through the National Flood Insurance Program, and in moderate- to low-risk areas, to purchase a Preferred Risk Policy.

C16 Encourage landowners to preserve the beneficial functions of natural features like wetlands, salt marsh, and shorelines.

There are a variety of ways Greenland can prepare and adapt to coastal hazards. The New Hampshire Coastal Risks and Hazards Commission (CRHC) Report, titled Preparing New Hampshire for Projected Storm Surge, Sea Level Rise, and Extreme Precipitation (2016) outlines six guiding principles for action http://www.nhcrhc.org/wp-content/uploads/2016-CRHC-final-report.pdf:

1. Act Early. Start planning now. Being proactive will save money in the long run when compared to a more traditional reactionary approach to flood management.

2. Collaborate and Coordinate. Take manageable steps to prepare over the long run.

3. Respond Incrementally. As the science improves, adjust your approach to match expected conditions.

4. Incorporate Risk Tolerance in Design. Work together across sectors and with neighboring municipalities to maximize impact.

5. Revisit and Revise. Design projects based on willingness to accept risk associated with unacceptable performance. Risk tolerance will likely vary based on the importance and cost of maintaining or replacing a structure.

6. Make No Regrets Decisions. Take actions that offer multiple benefits to your municipality, and will therefore provide added value regardless of the flood scenario that occurs.