GREATER PORTLAND
COUNCIL OF GOVERNMENTS

TOWN OF CHEBEAGUE ISLAND

SEA LEVEL RISE VULNERABILITY ASSESSMENT

April 2016

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This report was prepared by the Greater Portland Council of Governments (GPCOG) under award CZM NA14NOS4190066 to the Maine Coastal Program from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

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Indian Point, one of the island's lower lying areas; Picture courtesy of Rick Harbison

This report considers the impacts of sea level rise and storm surge on town-owned infrastructure including ferry piers, roads, and culverts. Where data is available, the report also addresses the environmental impacts of rising seas and storm surge, such as the potential for increased coastal bluff erosion, landslides, and saltwater intrusion of drinking water resources.

Over the last several decades, sea level rise (SLR) and increased intensity storm surge events have emerged as a significant threats to coastal areas around the world. Locally, potential long-term impacts may include:

- More frequent and severe flooding;
- Flood insurance required for more properties and at higher cost;
- Public facilities and infrastructure more susceptible to flooding;
- Disruptions in the transportation network;
- Reduction in suitable land for development/redevelopment;
- Adverse environmental impacts including the loss of wildlife habitat, wetlands, and saltwater intrusion of freshwater aquifers; and
- Forced relocation of businesses and residences inland.

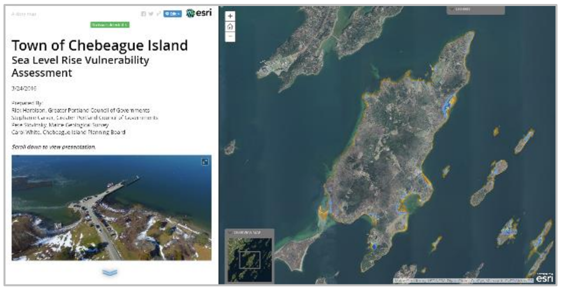
While research around this issue is ongoing, and new data generated by these studies continues to improve predictions, the best scientific evidence available points to a long-term, upward trajectory in both global and local sea levels. Furthermore, most projections expect this trend to accelerate, with significant impacts to our national, regional, and local economies.

While planning for the myriad of challenges associated with a changing climate is financially prudent at every level of government, undoubtedly, much of the repair and maintenance costs to infrastructure will fall incrementally at the local level. For coastal communities, proactive and informed decisions regarding construction and maintenance standards, location of development, and environmental priorities could result in considerable long-term financial savings.

A side view of Stone Wharf at low tide; Picture courtesy of Rick Harbison

The Maine Geological Survey (MGS) has been measuring the potential impacts of sea level rise on Maine's infrastructure for nearly a decade. In Cumberland County efforts began when MGS, with funding from the Maine Coastal Program (MCP), partnered with the Greater Portland Council of Governments (GPCOG) in 2010 to establish a sea level rise pilot project for South Portland. Since this initial project, several other Cumberland County municipalities have followed, including the City of Portland and the Towns of Freeport and Cape Elizabeth. Chebeague is the first island community in Southern Maine to undertake this type of assessment.

Great Chebeague Island is the largest of 17 islands that make up the Town of Chebeague, and the only one with town infrastructure and services. It is served by two ferries and, along with Hope Island, has the only year-round population. With a history as a fishing hub and a rich agricultural past, there is little commercial development on the islands, and an abundance of open space, including many opportunities for the public to access the water. Chebeague has a year-round population of about 350 residents, and a summer population of over 1,200 people, comprised of many families whose ties to the island go back several generations.



An interactive version of this report highlighting specific findings is available here: http://arcg.is/1QC77pf

Although many towns in Cumberland County are beginning to examine ways to address the impacts of climate change and sea level rise, the Town of Chebeague's effort is unique due to its dependence on water-dependent infrastructure for access to the mainland. This assessment is particularly timely for the Town as it embarks on a reevaluation of its land use ordinances and Comprehensive Plan. It is our intention that this report, or an abbreviated version of this report, could be adopted as an amendment to the Town's existing Comprehensive Plan, or included as a chapter in the Town's next Comprehensive Plan update.

Stone Wharf beach; Picture courtesy of Rick Harbison

Causes of Sea Level Rise

The rise in sea level is linked to two main factors – thermal expansion, and the melting of land-based ice – both a direct result of climate change, described below:

- Melting of Land-Based Ice: Higher temperatures have also led to greater-than-average melting of land-based ice, such as ice sheets and glaciers, adding water to the world's oceans.

- Thermal expansion: Rising temperatures are warming ocean waters, which expand as temperature increases. Much of sea level rise is attributable to warmer oceans simply occupying more space. A 2014 study by the Gulf of Maine Research Institute found the Gulf of Maine is warming at a rate faster than 99 percent of the world's oceans.

It is important to note, sea level rise for any particular location can vary significantly from the global average. The reasons for this variability include other factors such as groundwater storage, land subsidence, ocean circulation, and geographic variations in rates of ice melting.

Trends in Sea Level Rise

This section provides a brief overview of the current science and observed trends in sea level rise. *Since this section includes a few technical terms and acronyms, a glossary is included in the Appendix – terms in green text are defined in greater detail in the glossary.*

Global Trends

The pattern of sea level rise can be traced back about 11,000 years, with a slow incremental rate occurring over the past several thousand years. Modern-day measurements, however, indicate the rate of rise is accelerating. Core samples, tide gauges, and satellite measurements tell us over the past century, Global Mean Sea Level (GMSL) has risen by approximately 8 inches (.07 inches/1.8 millimeters per year). In 2007, the Intergovernmental Panel on Climate Change (IPCC) projected that by the end of this century, global sea level will rise another 7.1 to 23.2 inches, depending on several factors including future greenhouse gas emission levels, thermal expansion, and melting glaciers, much faster than any time in the past 5,000 years. According to data from the most recent National Climate Change

Assessment, the annual rate of rise over the past 20 years has been .13 inches– *roughly twice the average rate of the preceding 80 years.*[1]

Local Trends

Local data appears to mirror trends seen in global data. Figure 1, below, shows data collected from the Portland Tide Gauge since 1912[2]. It indicates a rate of increase of 0.07 inches/1.9 millimeters per year, for a rise of approximately 7.5 inches over the last 100 years, only slightly lower than the global average for this same period. Similar results are found up and down the Maine coast, and these figures mimic global ocean changes for the same time period.

As the Portland data illustrates, sea level is never static. For any given year, we may be experiencing a spike, or dip, in mean sea level. For example, a recent study by scientists at the University of Arizona found that during 2009-2010, sea level off Portland rose by five inches.[3] Described as an "unprecedented" two-year spike, the phenomenon is being attributed to abrupt changes in ocean circulation and cyclical weather patterns. *While research about sea level rise is ongoing, and new data generated by these studies continues to improve our predictions, it seems clear we are in the midst of a long-term, upward trajectory in the rate of sea level rise.*

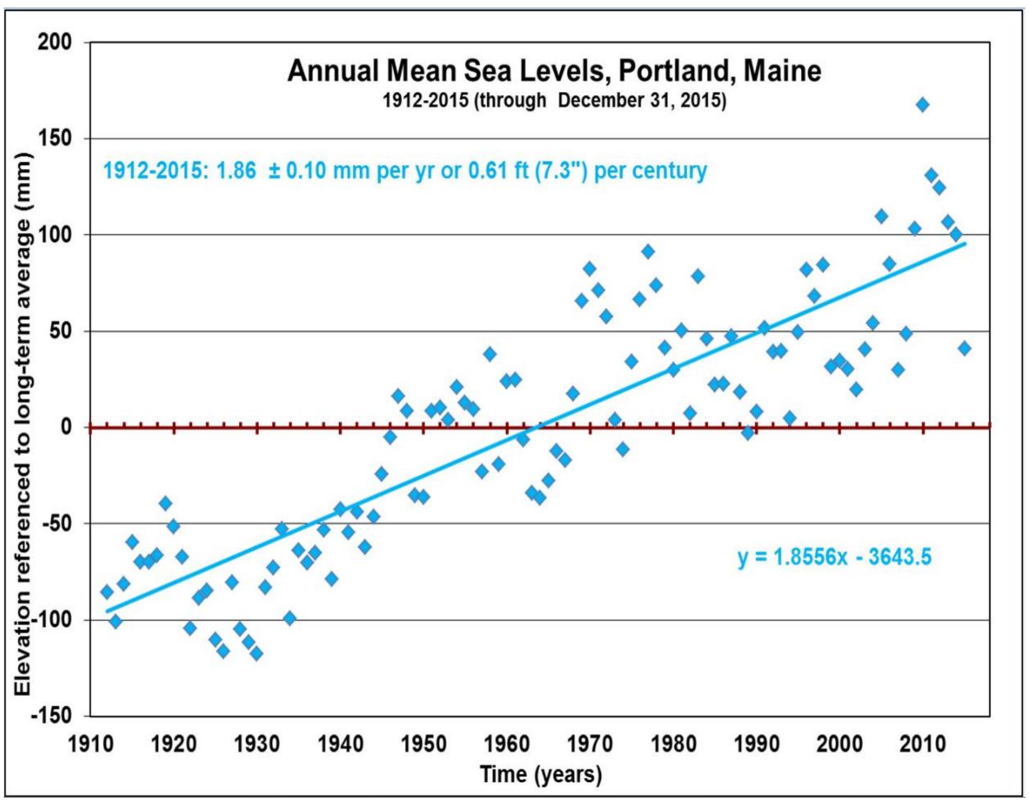


Figure 1: Portland, ME Tide Gauge Data (1912-2013)

[1] Global Sea Level Rise Scenarios for the United States National Climate Assessment, 2012. NOAA Technical Report OAR CPO-1. Climate Program Office.

[2] Graph courtesy of the Maine Geological Survey.

[3] Nature Communications. 2015. ***An Extreme Event of Sea-Level Rise Along the Northeast Coast of North America in 2009-2010.***

Local Scenario Planning

It is anticipated by most in the scientific community that sea levels will continue to rise even if climate change slows, at least for the next few centuries. With many scientific variables, risk perceptions, and political implications unique to each location, it isn't practical to choose a common scenario that will work for every community. The data offered in this assessment is intended to assist the Town of Chebeague with the task of choosing the particular planning scenario that works best for its long-term strategy to adapt to sea level rise and increased storm surge.

The State of Maine also provides guidance for communities choosing an adaptation scenario. In 2006, the report titled, "Protecting Maine's Beaches for the Future (A Report of the Stakeholder's Group to the Joint Standing Committee on Natural Resources 122nd Maine Legislature 2nd Regular Session)," recommends that any analysis of proposed projects or infrastructure should consider a minimum of two feet of sea level rise over a 100-year window. As Figure 2 illustrates, , using nearby Portland's historic sea level rise rate of .07 inches/1.9 millimeters per year, MGS suggests that communities at this point consider planning for the "Intermediate High Scenario" which provides for scenarios of one foot of sea level rise by 2050, and around 3 feet 2090.

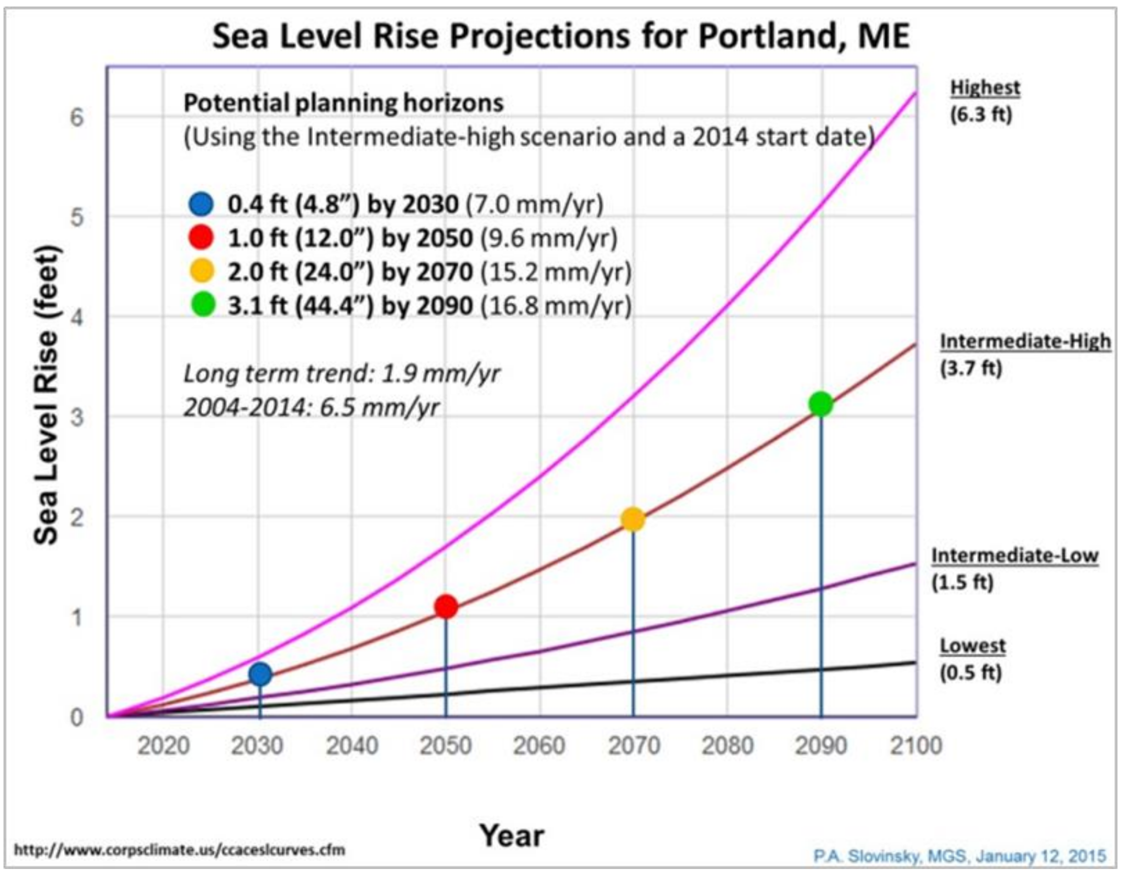


Figure 2: Sea Level Rise Projections for Portland, ME

Stone Wharf during "King Tide," the Highest Annual Tide for 2015; Picture courtesy of Steph Carver.

Table 1**,** below, lists the sea level rise scenarios developed for this assessment. The scenarios were chosen in close consultation with town staff, and represent a range of sea levels, from the current Highest Annual Tide (the highest predicted water level for any given year, which typically happens one-to-two times a year, not including storm surge) to the more extreme -- and less probable -- scenario of a Category 2 hurricane making landfall coinciding with high tide. In the table, each scenario is paired with its respective elevation, as measured against Mean Lower Low Water (MLLW).

Sea Level Rise Scenario	***Elevation*****
Highest Annual Tide (HAT)*	11.8 ft.
HAT +1 ft. SLR	12.8 ft.
HAT +2 ft. SLR	13.8 ft.
Hat +3.3 ft. SLR (1m)	15.1 ft.
CAT 2Hurricane + High Tide	22.1 ft.

Table 1: Sea Level Rise Scenarios
**Data provided by MaineDEP (2015)*
***Elevation measured against MLLW*

It is important to note the simulations of sea level rise scenarios presented in this report are based on a bathtub model. This means the scenarios do not account for changes to topography from erosion or accretion, or potential impacts from waves, riverine flow, or precipitation. Instead, the scenarios assume a static baseline (similar to the water level in a bathtub), and consequently may underestimate the impacts of some storm-related events.

In addition to sea level rise, it has become clear that climate change is resulting in increased storm frequency and intensity. In coastal areas, more amplified storm surge and storm tide events pose a significant threat to both life and property. When large storms hit, higher storm surges have the potential to reach even further inland. Storms like Hurricanes Katrina, Sandy, and Irene are all examples of this. Furthermore, depending on the geographic characteristics of the land, even small increases in sea level under normal weather conditions could have considerable impacts to both infrastructure and the environment. For instance, in many flat, low-lying areas, such as marshes or beaches, even a small vertical rise can result in significant horizontal (or lateral) impact.

It should be noted, there is a difference between the terms "storm tide" and "storm surge." To clarify, storm surge is defined as an abnormal rise of water levels over and above the predicted astronomical tides, typically generated by a low pressure weather system such as a tropical storm or a hurricane. A storm tide is the overall rise due to the combination of storm surge and predicted tidal conditions. Using the illustration below as an example, if the predicted tide was 2 feet, and storm surge was 15 feet, the storm tide would be 17 feet.

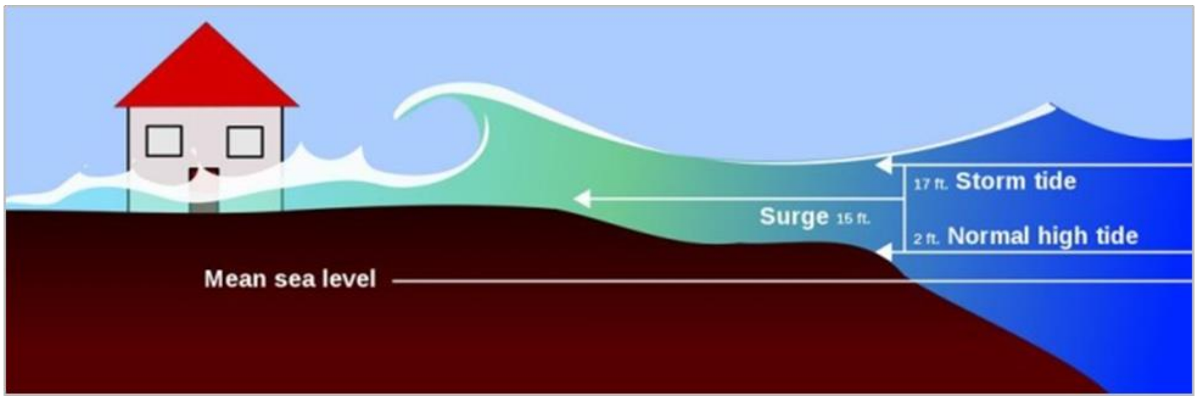


**Image courtesy of NOAA*

Inundation on Stone Wharf; Picture courtesy of www.chebeague.org

Compared to other municipalities in Maine, the Town of Chebeague is fortunate in that relatively few impacts to public infrastructure are expected based on simulations, even in the more extreme scenarios. In fact, to our knowledge Chebeague has *no* public buildings at risk of inundation (i.e., fire station, library, school, town hall, etc.), which is particularly good news for the Town. Furthermore, many of the roads that are at-risk of flooding are dirt/gravel with relatively little traffic, or private roads. However, a few key areas do merit further study and careful review. *(Disclaimer: the sea level rise scenarios included in this report should be used for general planning purposes only, actual conditions may vary considerably).*

Ferry Piers

Chebeague is isolated by having no bridge or car ferry connection to the mainland. However, there are two piers serving ferry transportation to and from Great Chebeague Island – Stone Wharf on the northern end of the island, and Chandler's Cove Wharf on the southern end. Ferry service to these piers makes it possible for workers to live on the island and commute to jobs on the mainland, and is instrumental to maintaining convenience and quality of life on the island.

As such, discussion related to the long-term viability of the island's ferry piers is ongoing, and the Town intends to conduct an engineering assessment at Stone Wharf to complement this planning effort. Alternative sites for building a new ferry landing site have also been introduced, with Sunset Landing garnering the most attention.

Stone Wharf from above; Picture courtesy of Rick Harbison

Stone Wharf

Built in the 19th century, the Stone Wharf is town-owned, and located off Stone Wharf Road on the northwest side of the island. The pier is the island's primary transportation hub, where the non-profit Chebeague Transportation Company (CTC) ferry boat lands. The ferry service is critical to island life and carries an average of 10,000 passengers per month according to the CTC website. In addition to the ferry, commercial fishermen, recreational boaters, tourists, and residents all rely on the pier. *Currently the pier is overtopped at least once a year. This typically occurs when astronomically high tides coincide with storm surge and exceed 13 feet*

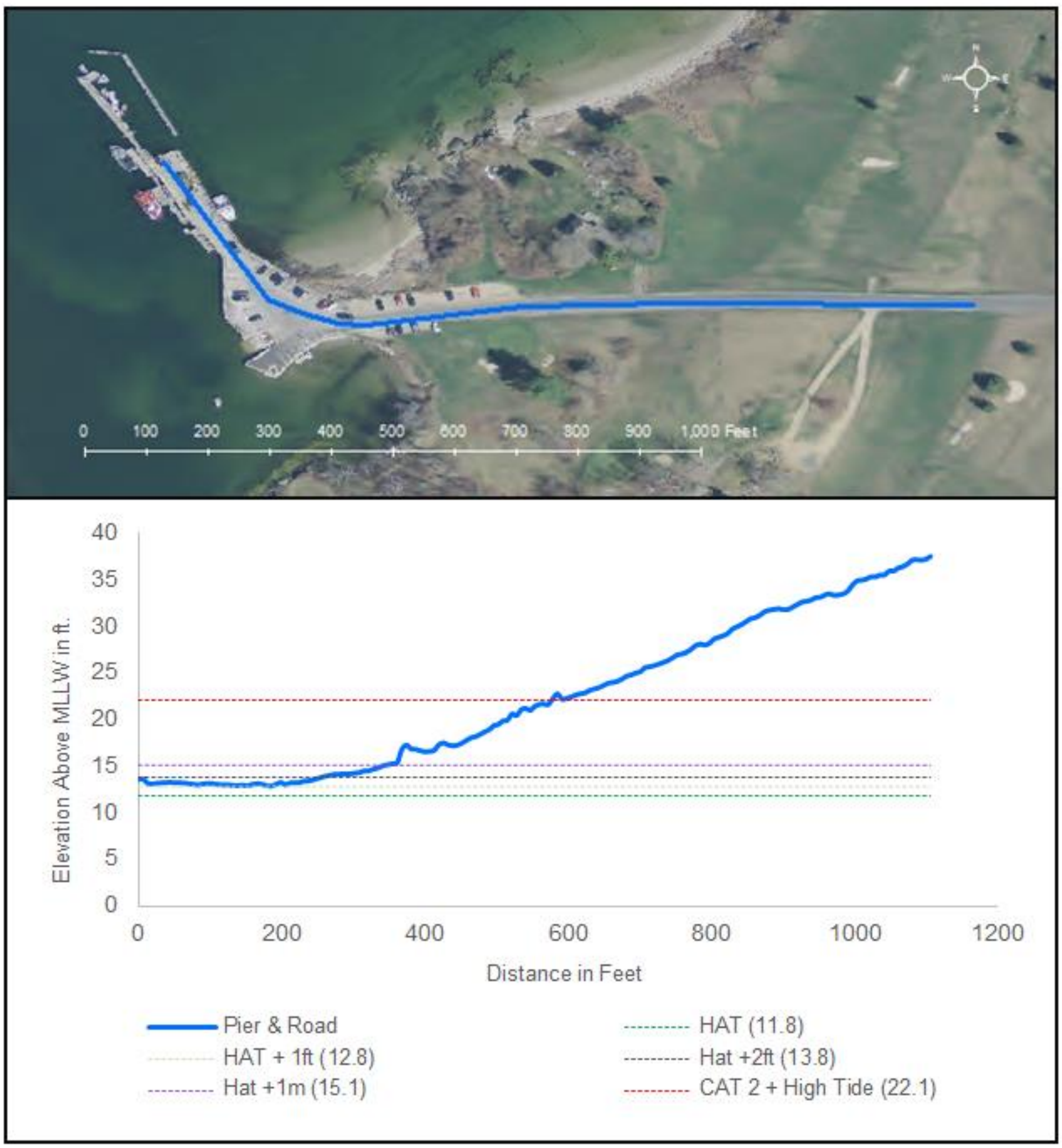
According to the Town’s Comprehensive Plan, the pier is, “inadequate for all the uses it serves.” The Plan recommends:

> *“…A thorough study of the feasibility of developing Sunset Landing for at least some of these uses. The process of doing this study, making the decision about whether to implement a Sunset Landing plan and then carrying it out is likely to take between 10 and 20 years. In the meantime, the current Stone Wharf and the state pier at Chandler’s Cove need to continue to serve the island’s needs.”*

Stone Wharf & Stone Wharf Road Elevation Profile

Figure 3, below, is an elevation profile of the pier and a roughly 1,000 foot stretch of Stone Wharf Road. The profile is based on elevations derived from LiDAR data collected in 2006 and obtained from the Maine Office of GIS. As the table shows, the elevation of the top of the wharf is approximately 13 feet above sea level (as measured against MLLW) for the majority of its length, which puts it between 1-2 feet above the current highest annual tide of 11.8 feet. As the pier transitions to the parking area and Stone Wharf Road it begins to gain in elevation, first gradually then sharply. Based on these scenarios, at a distance of around 600 feet inland from the parking lot the road is out of danger from inundation impacts even in the most extreme scenario of a Category 2 hurricane plus high tide.

Figure 3: Stone Wharf & Stone Wharf Road Elevation Profile



Stone Wharf Inundation Estimates

The analysis below shows estimated inundation depths on the existing pier for various inundation scenarios. For example, at highest annual tide of 11.8 feet (top left) the pier is largely above water, but a Category 2 hurricane coinciding with high tide (bottom center) would likely cover the existing pier in 8-10 feet of water and flooding would extend roughly 200 feet inland. The pier would likely be inundated by higher tides after 2 feet of sea level rise. The Town should consider both high (daily tides) and low frequency (storms) events should it embark on any significant infrastructure upgrades to either the pier or its parking area.

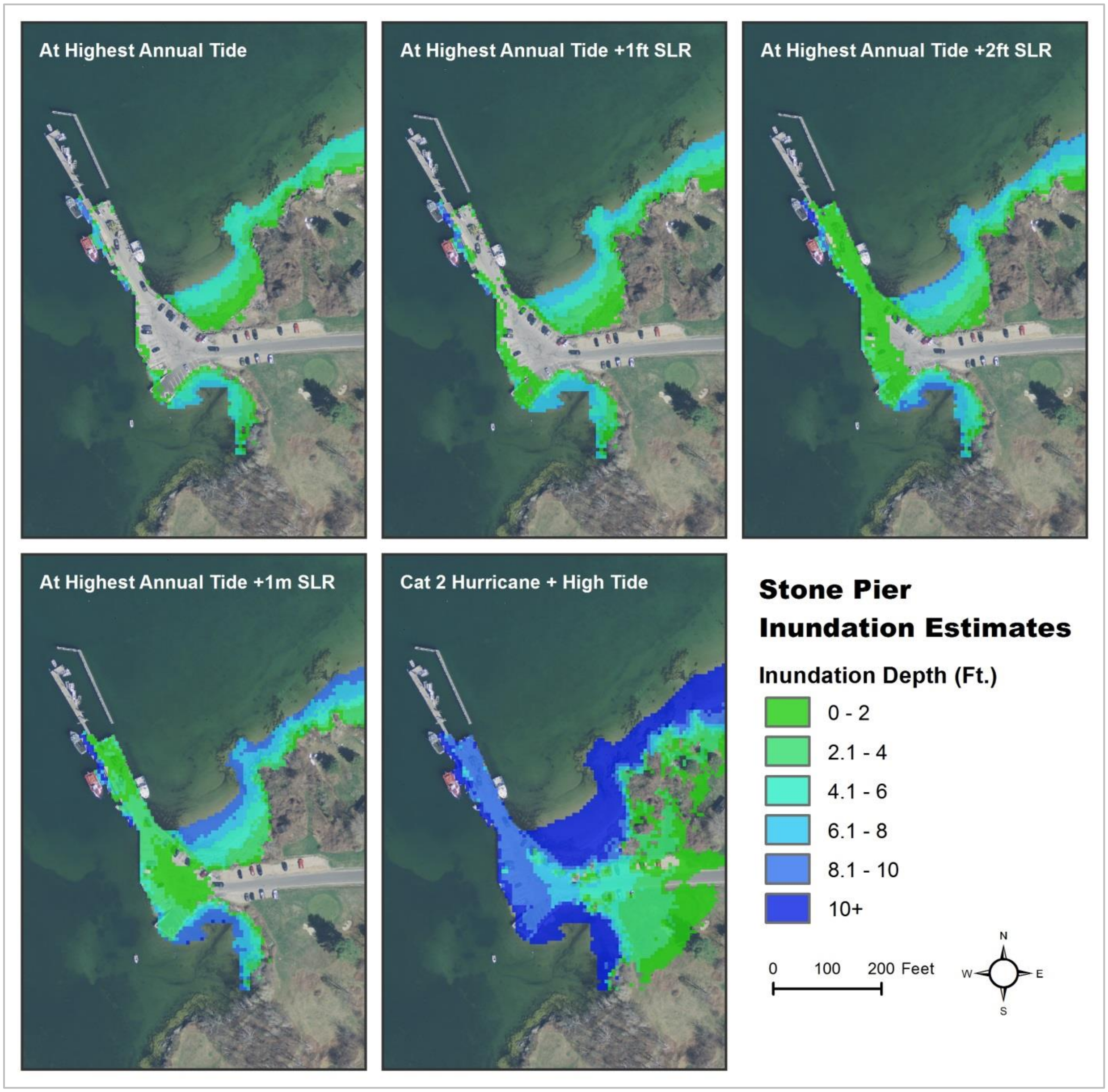


Figure 4: Stone Wharf Inundation Estimates

Stone Wharf Road Inundation Estimates

As Figure 5, below, shows the very end of Stone Wharf Road begins to see inundation at HAT +1m, while the CAT 2 Hurricane + High Tide Scenario covers approximately 200 feet of road in 1-8 feet of water depending on the location – *inundation depths are highest nearest the pier and gradually decrease as the road gains elevation inland.*

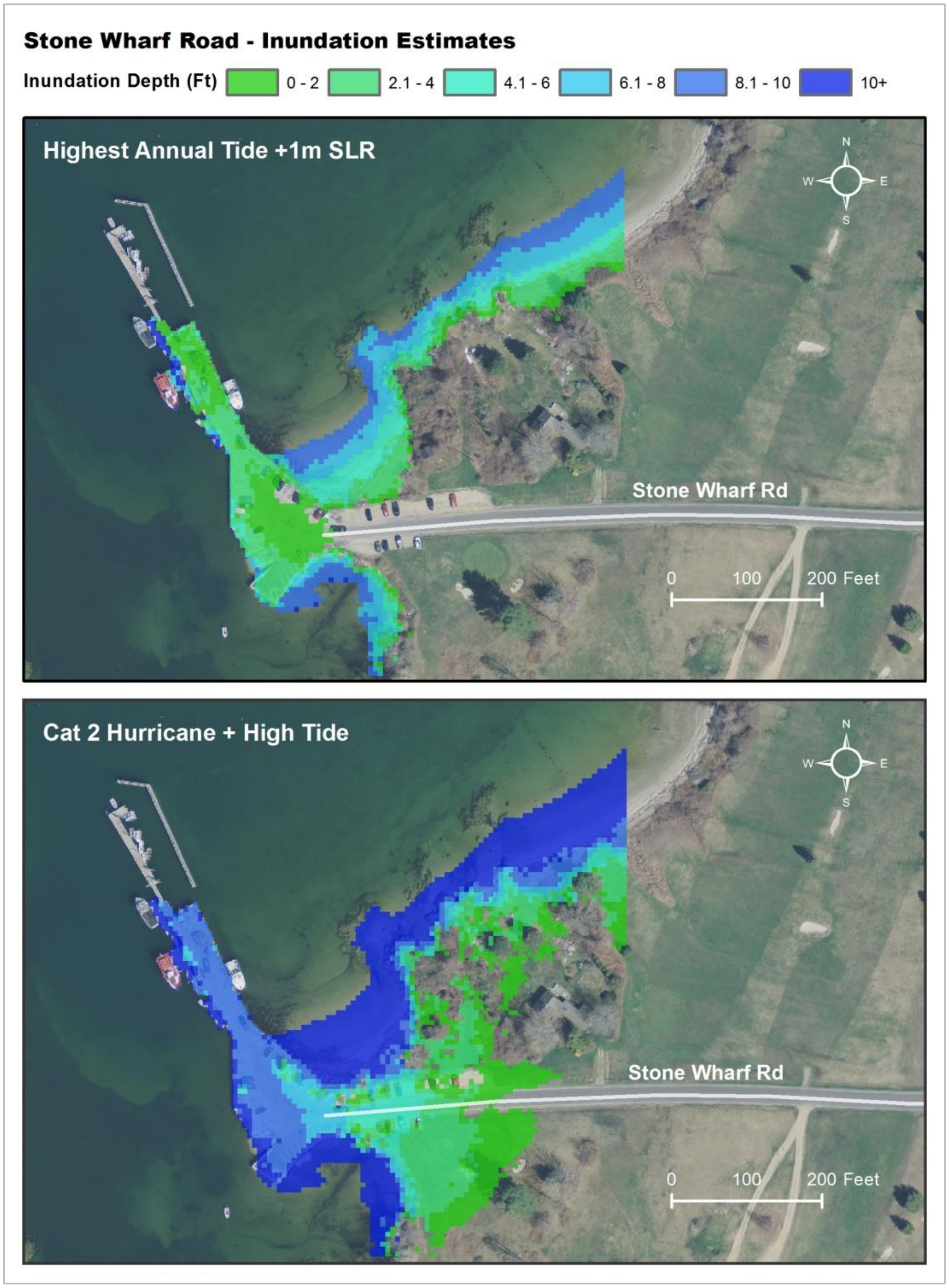


Figure 5: Stone Wharf Road Inundation Estimates

Stone Wharf & Stone Wharf Road Visualizations

Using Canvis, an image visualization tool available by NOAA, the following simulations were prepared to show what water levels *could* look like around Stone Wharf and Road during the two most extreme scenarios that were considered. It should be noted these visualizations are *simulations only*, and are very rough approximations of coastal inundation.

The image below is a simulation of Highest Annual Tide +1m of sea level rise.

Figure 6: HAT +1m Rendering

This visualization simulates a Category 2 Hurricane making landfall in Maine coinciding with high tide.

Figure 7: Category 2 Hurricane + High Tide Rendering

Casco Bay Lines ferry that serves Chebeague Island; Picture courtesy of Steph Carver

Chandler's Cove Wharf

Chandler's Cove Wharf is the other ferry landing site on Great Chebeague Island, located on the southern tip of the island. The pier is owned and maintained by the State of Maine and was replaced in 2000. The pier is specifically designed to serve Casco Bay Lines boats, which dock at a ramp that allows passengers and freight to come ashore at all tides. Based on this analysis, the pier does not appear to be particularly vulnerable to sea level rise or storm surge due in large part to its higher elevation above sea level.

Chandler's Cove Wharf from above; Picture courtesy of Rick Harbison

Chandler's Cove Wharf– Inundation Estimates

However, as Figure 8 below shows, inundation is not *entirely* out of the question. At the HAT +1m of sea level rise scenario water would likely be lapping at the edge of the pier, while the Category 2 Hurricane + High Tide scenario could cover the pier in anywhere from 6-8 feet of water.

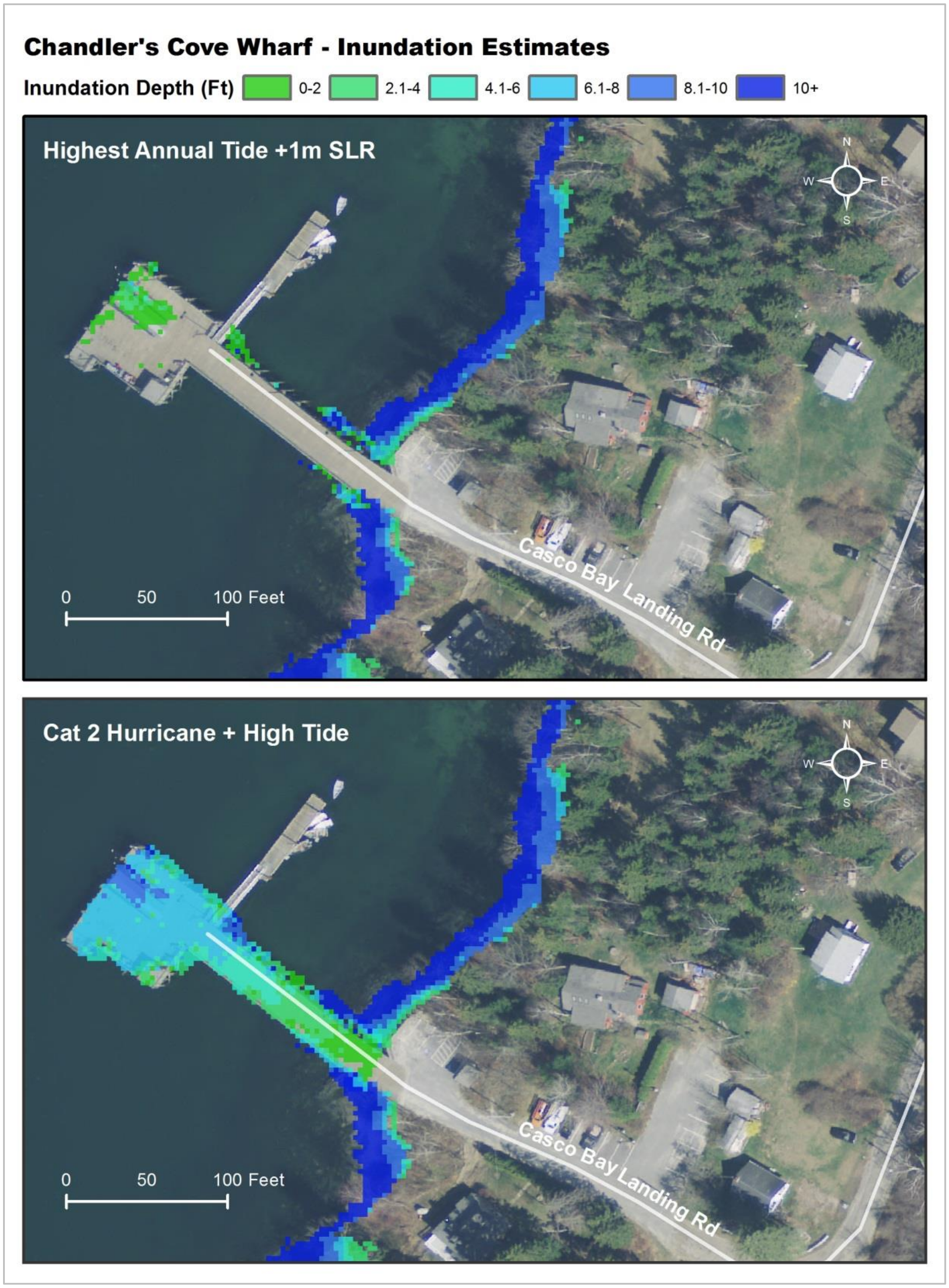


Figure 8: Chandler's Cove Wharf - Inundation Estimates

At-Risk Roads

The Town of Chebeague is fortunate in that very few roads appear to be impacted by the sea level scenarios considered. Of those that are potentially at risk, many are dirt/gravel roads or privately owned. Additionally, in many cases the impacts are not present until a considerable amount of sea level rise or storm surge occurs. Figure 9, below, highlights the key segments of road that are potentially at-risk (red). The map also differentiates between public roads (yellow) and private roads (white).

Figure 9: At-Risk Roads

Table 2, below, provides a more detailed look at various road inundation scenarios. Numbers under each scenario refer to the length of road likely to be inundated under each sea level rise scenario -- this analysis does not consider depth of inundation. The labels in the left hand column correspond to the number labels in the previous map (Figure 9). The colors represent the amount of linear feet of roadway impacted, with yellow the least, orange in the middle, and red the longest. The following pages identify specific town-owned road segments that may be at risk under various scenarios.

Table 2: At-Risk Roads

Label	Street Name	Road Class	HAT	HAT +1 ft.	HAT 2 ft.	HAT + 1 m	CAT 2
1	Brookwood Ln	Private	0	0	0	**18**	**403**
2	Niblic Circ	Private	0	0	0	0	**96**
3	Walker Rd	Private	0	0	0	**130**	**429**
4	Willow St	Private	0	0	0	0	**212**
5	Worthen Dr	Private	0	0	0	0	**4**
6	Bennetts Cove Rd.	Private/Local	0	**1**	**7**	**85**	**260**
7	Indian Point Rd	Private/Local	**142**	**444**	**862**	**977**	**1,262**
8	Casco Bay Landing Rd	Local	**21**	**33**	**29**	**33**	**46**
9	Central Landing Rd	Local	0	0	0	0	**4**
10	East Shore Dr	Local	0	0	0	0	**349**
11	Fenderson Rd	Local	0	0	0	0	**15**
12	Jenks Rd	Local	**18**	**134**	**162**	**192**	**293**
13	Stone Wharf Rd	Local	0	0	0	**20**	**276**
14	Waldo Point Rd	Local	0	0	0	0	**8**
	Total		***181 ft.***	***612 ft.***	***1,060 ft.***	***1,455 ft.***	***3,657 ft.***

Bennett's Cove Road (#6)

Bennett's Cove Road is a relatively narrow dirt road and town right of way used to access Bennett's Cove. While no ferries currently land here, Bennett's Cove is still used as a landing area by private barging companies. The heavy traffic resulting from off-loading barge materials has been hard on Bennett's Cove Road, which was substantially rebuilt by the Town after the extensive barging of materials to repair the island's roads in the wake of the Patriots' Day storm of 2007.

The impact of the barges on the beach (the power of the propellers holding the barge to the shore churns a large hole into the substrate), combined with rising sea levels will likely continue to cause increased erosion in this area. As Figure 10 below shows, inundation of Bennett's Cove Road is most pronounced in the more extreme scenarios (HAT +1m / Cat 2 Hurricane + High Tide).

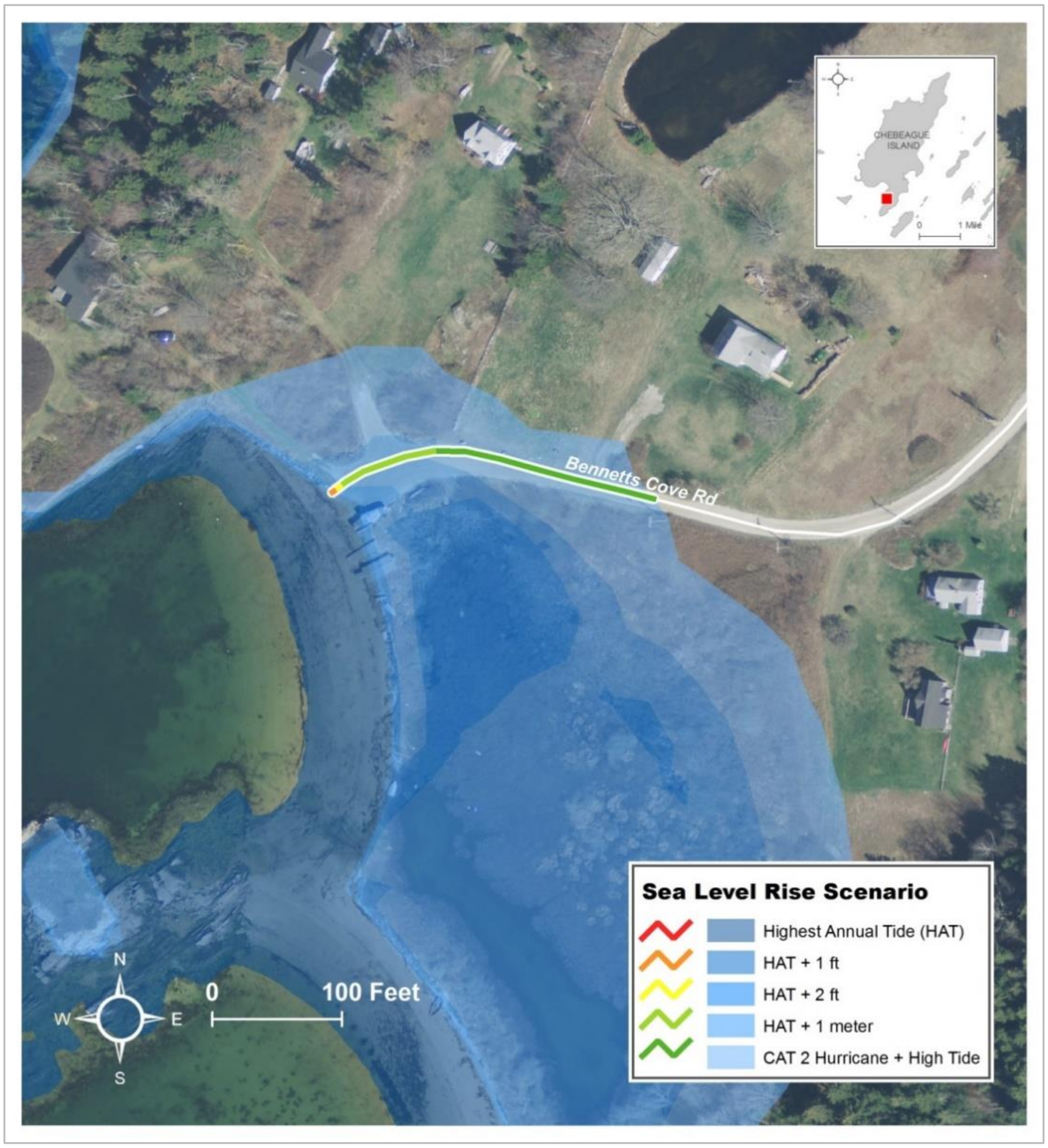


Figure 10: Bennetts Cove Road | Potential Impacts

Indian Point Road (#7)

Indian Point, also known as "The Hook," is located on the west side of Chebeague Island adjacent to the tidal sandbar to Little Chebeague Island. In 1999 the owners and stockholders of the Indian Island Company granted a conservation easement to the Chebeague & Cumberland Land Trust on twenty-five acres of land, which includes 3,700 feet of shoreline. The area is also classified by the Town as a Resource Protection Zone. Indian Point Road is a narrow dirt road that serves as the primary access to this unique area. There is a small structure located at the end of the road. While the road inclines steeply as it travels inland, the low-lying portions along "The Hook" are quite exposed. As Figure 11 below shows, the point experiences inundation at current high tides and additional sea level rise will continue to alter this landform in years to come.

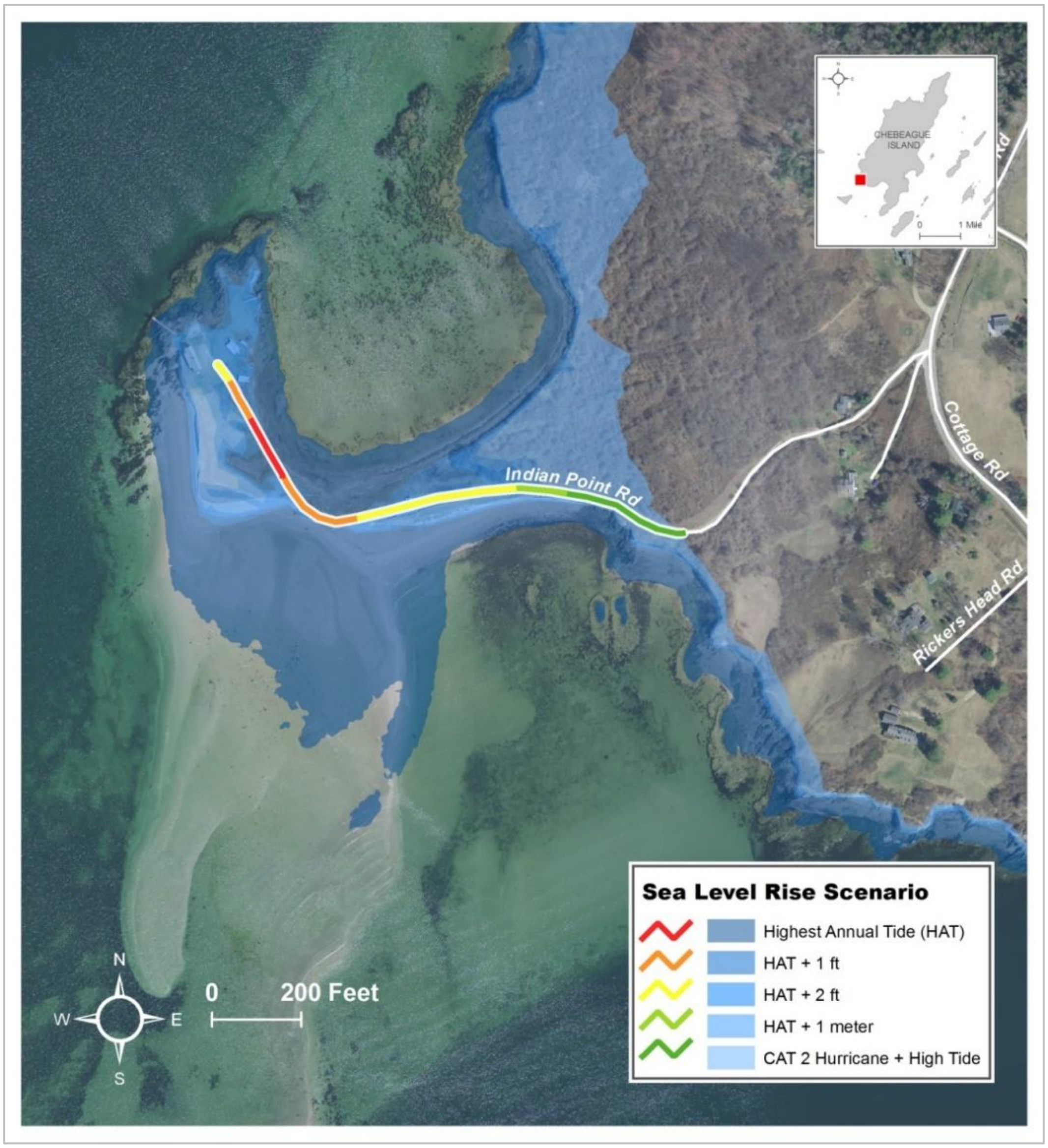


Figure 11: Indian Point Road | Potential Impacts

East Shore Drive; Picture courtesy of Rick Harbison

East Shore Drive (#10)

East Shore Drive is a town-owned dirt road that accesses the very northern tip of Chebeague Island. Although it does show inundation at the most extreme scenario (Cat 2 Hurricane + High Tide), the rocky bluffs and ledges along the coastline will likely buttress the road from most impacts. While the road is relatively protected, as the picture above illustrates, drainage can sometimes be an issue.

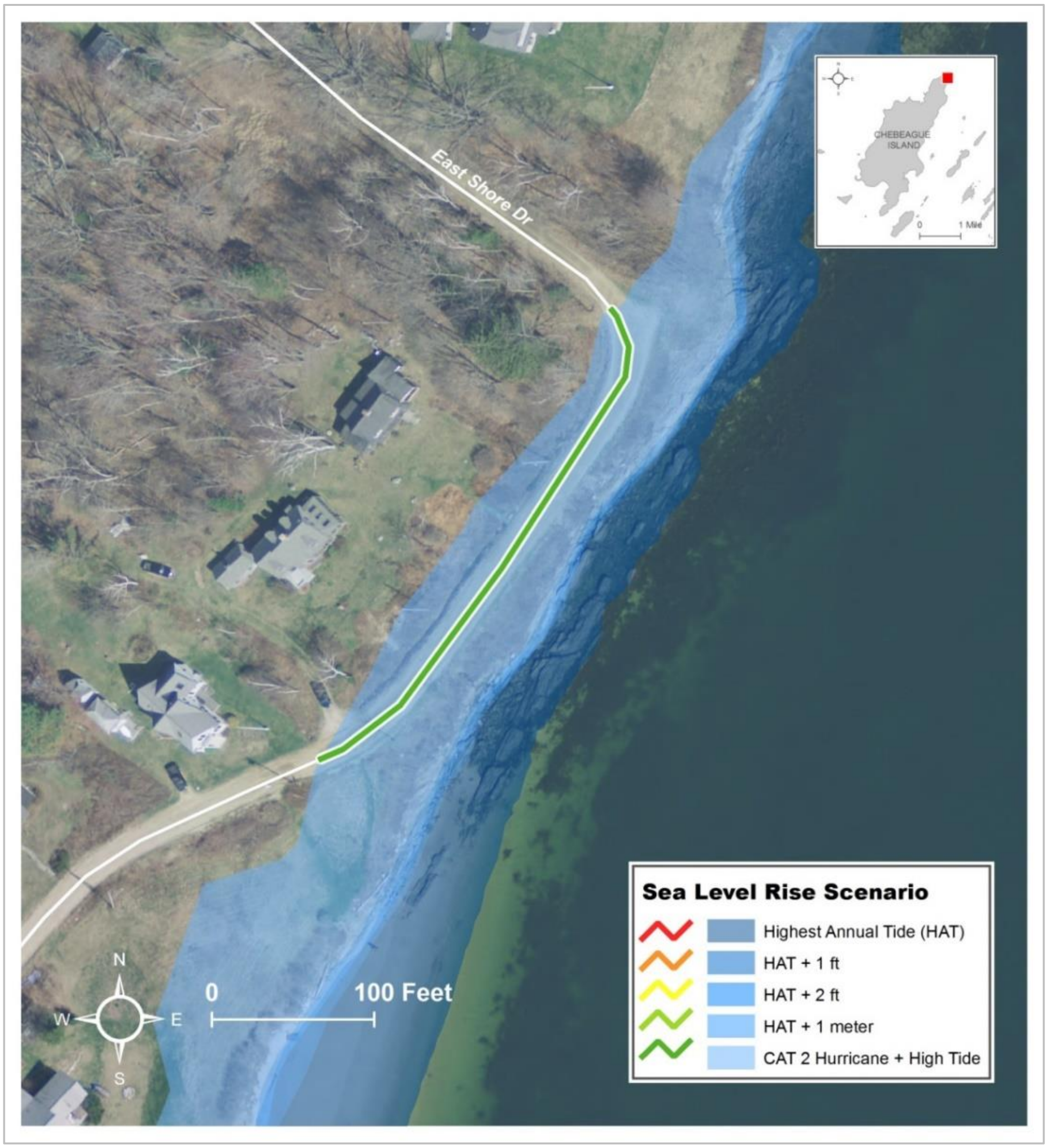


Figure 12: East Shore Drive | Potential Impacts

Jenks Road (#12)

Jenks Road is a town-owned dirt road that serves as the primary access to Jenks Landing Beach. The beach itself is designated as a Federal Coastal Barrier Resource Area (CBRA). The CBRA designation is a federal designation that encourages the conservation of flood prone, environmentally significant coastal barriers by restricting federal expenditures that can encourage development, such as federal flood insurance. Under these restrictions, CBRA areas can still be developed, but only if private developers bear the full cost of development, using no federal subsidies. A roughly 200-foot portion of the road closest to the beach is potentially susceptible to rising seas. However, as Figure 13 below shows, the road is unimproved and does not serve a major transportation function other than accessing the beach.

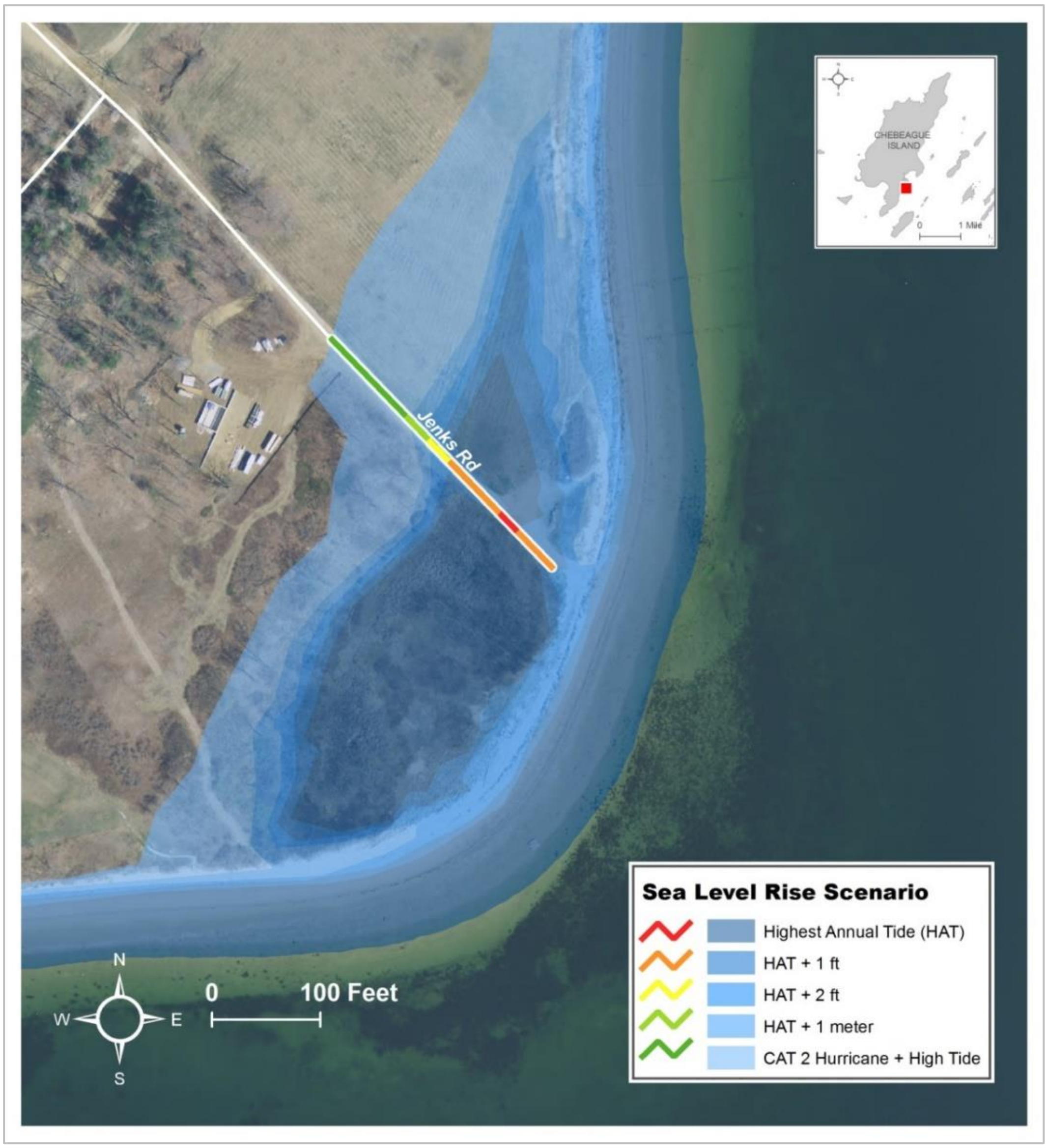


Figure 13: Jenks Road | Potential Impacts

Culverts

The map below shows the locations of mapped culverts on Chebeague Island. While the condition, capacity, and degree to which these culverts represent habitat barriers or concerns for quality of stormwater runoff is unknown, *there do not appear to be any culverts at immediate risk from sea level rise or storm surge based on the scenarios examined.* Further analysis would be needed to determine whether existing culverts are adequately sized for precipitation events and stormwater.

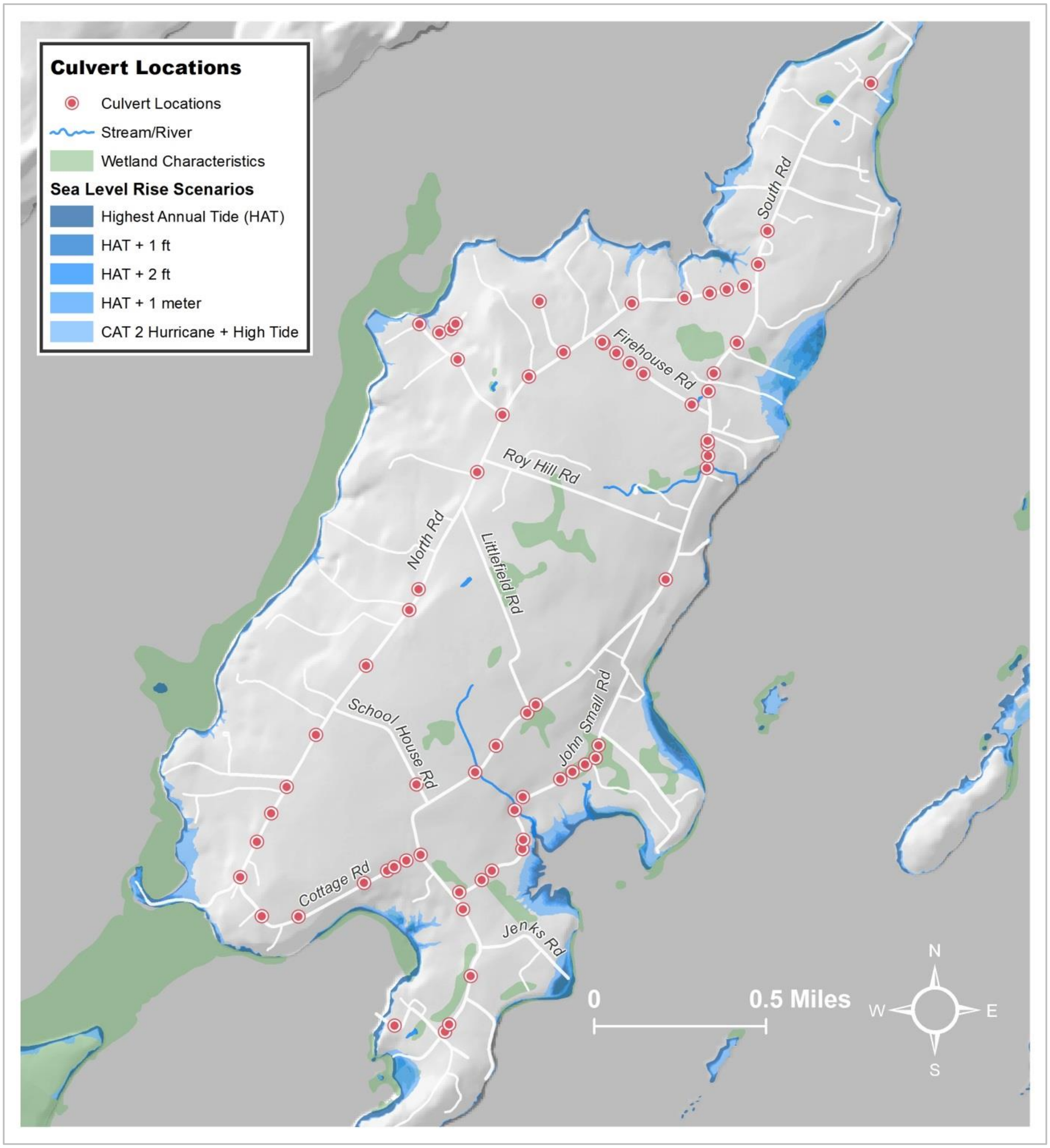


Figure 14: Culvert Locations

Coastal Wetlands

In 2013, the Casco Bay Estuary Partnership (CBEP) reviewed ten of the fourteen municipalities that line Casco Bay to identify potential areas of marsh migration and possible impacts to existing developed areas due to tidal inundation from sea level rise.[4]

The report looks at, "places where roads, railroads, trails, dams, and other structures cross tidal wetlands." In most cases, the report notes, "these structures alter the way water is passed from one side of the wetland to the other. When tidal exchange is restricted, even if it is restricted only during astronomical spring tides, long-term impacts to wetlands can develop that reduce ecosystem resiliency to respond to impacts such as sea level rise.

Chebeague Island was not included in the 2013 reports, and a thorough marsh migration assessment is beyond the scope of this initiative. However, if there is interest in studying the issue further, reviewing these reports, and contacting the Casco Bay Estuary Partnership, would be a good starting point.

Bluff Stability

The coastal bluff stability dataset, provided by the Maine Geological Survey (MGS), is based on visual inspection of the coastline from the water. A bluff is defined as a steep shoreline slope formed in sediment (loose material such as clay, sand, and gravel) that has three feet or more of vertical elevation just above the high tide line. (Cliffs or slopes in bedrock surfaces are not bluffs and not subject to significant erosion). The slope, shape, exposure, and amount of vegetation covering a coastal bluff and the adjacent shoreline directly impact a bluff's stability. The following list defines three different categories of coastal bluffs:

- Highly unstable: Bluff is very steep (> 20 degrees) and largely devoid of vegetation. Dead and dying trees are commonly found on the slope and at the toe of the bluff.
- Unstable: Bluff has a more gentle slope (10-20 degrees) and contains only a few, scattered patches of bare ground without vegetation, but trees on the slope are usually bent as a result of creep.
- Stable: Bluff is characterized by a very gently slope (< 10 degrees), and the presence of mature vegetation (or a lawn) completely covering the bluff face.

[4] Casco Bay Estuary Partnership. 2013. *Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts.*

Figure 15, below, shows the interpretation of the location of stable, unstable, and highly unstable bluffs for the Town of Chebeague Island. According to Shoreland Zoning regulations, for a parcel of land with coastal bluffs that have been rated “unstable” or “highly unstable” by the MGS (and published on the most recent coastal bluff map), setback measurements for principal structures shall be taken from the top of that bluff, not the normal high-water line or upland edge of the coastal wetland.

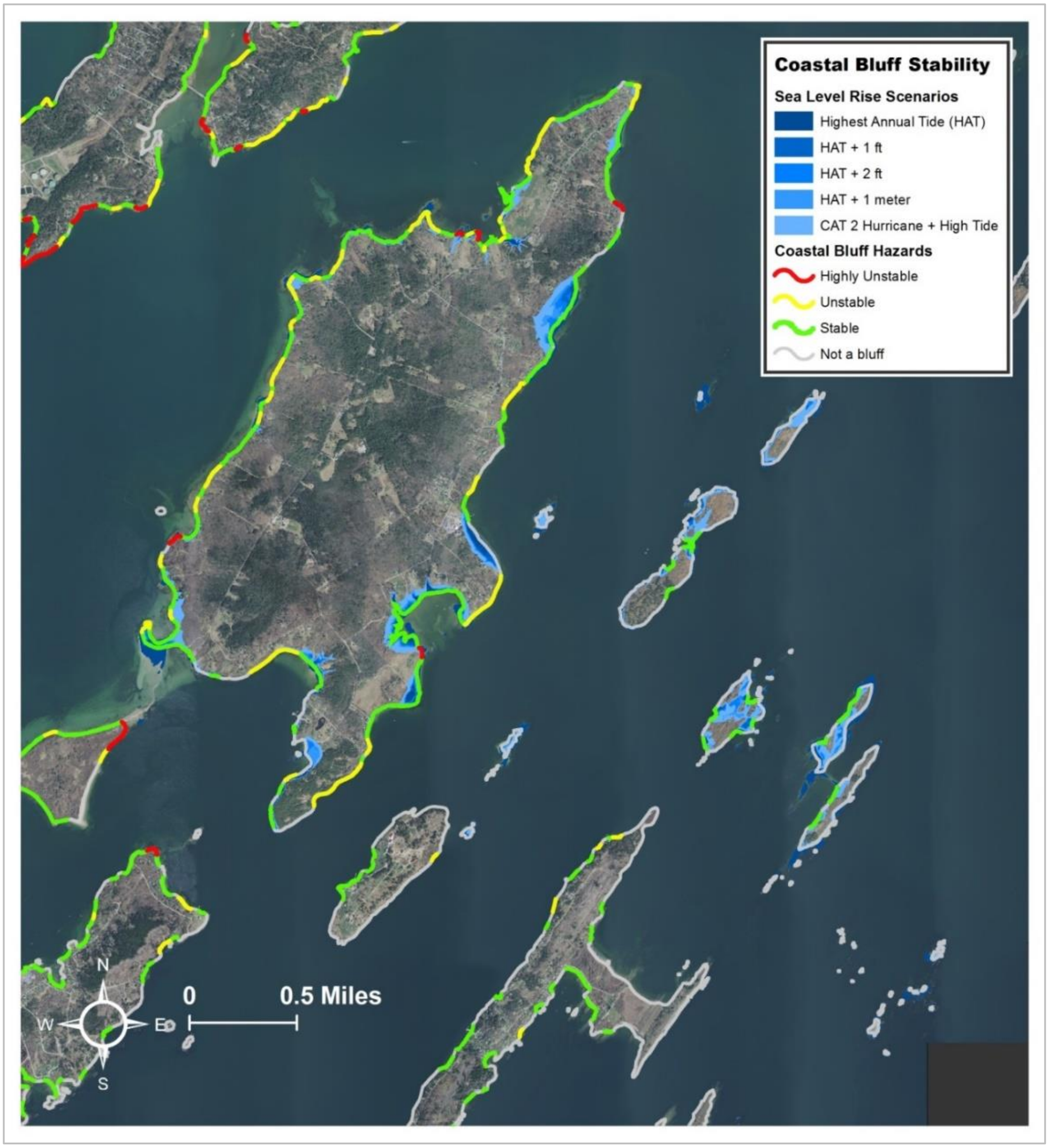


Figure 15: Coastal Bluff Stability

Coastal Landslide Hazards

The coastal landslide hazard dataset, provided by the MGS, shows locations of known landslides and areas of potential landslide hazard or bluffs along the Maine coast. As sea levels gradually rise, waves will continue to erode beaches and flats at the base of coastal bluffs. Over time, erosion removes material from the base of a coastal bluff and steepens its face. Sediments at the base of the bluff stabilize it, so when they are removed the bluff will no longer be in equilibrium. Only the strength of the material within the bluff holds it in place. Continued erosion or lubrication of the bluff materials by exposed waves or rising ground water may overcome this internal resistance and result in a landslide. Figure 16 shows the locations of potential landslide hazard areas on Chebeague Island.

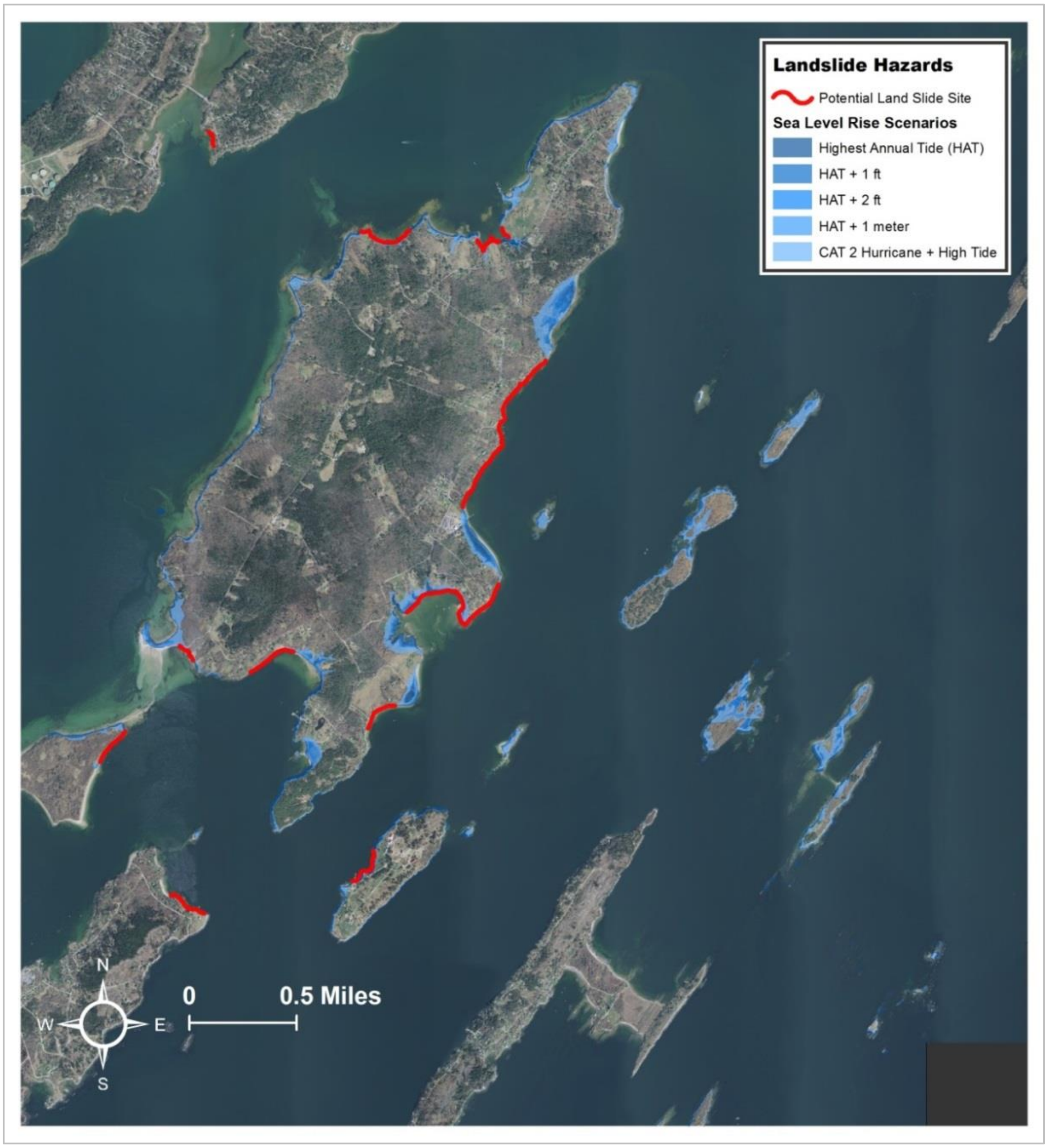


Figure 16: Coastal Landslide Hazards

Coastal Sand Dunes

The MGS also provided a dataset showing the locations of newly mapped coastal sand dunes, delineated by dune type (i.e., front dune, back dune). Sand dunes are a landform composed of loose sediment created from the deposition of sand (and sometimes gravel) by waves and wind. Coastal sand dunes form landward of beaches and often have a linear ridge, called a frontal dune that parallels the beach. Landward of the frontal dune are back dunes, or secondary dunes, that have a variety of shapes and relief. Back dunes tend to be lower in height than frontal dunes. Figure 17, below, shows the locations of coastal sand dunes on Chebeague Island. Dune features are regulated by the State through several programs administered by the Maine Department of Environmental Protection.

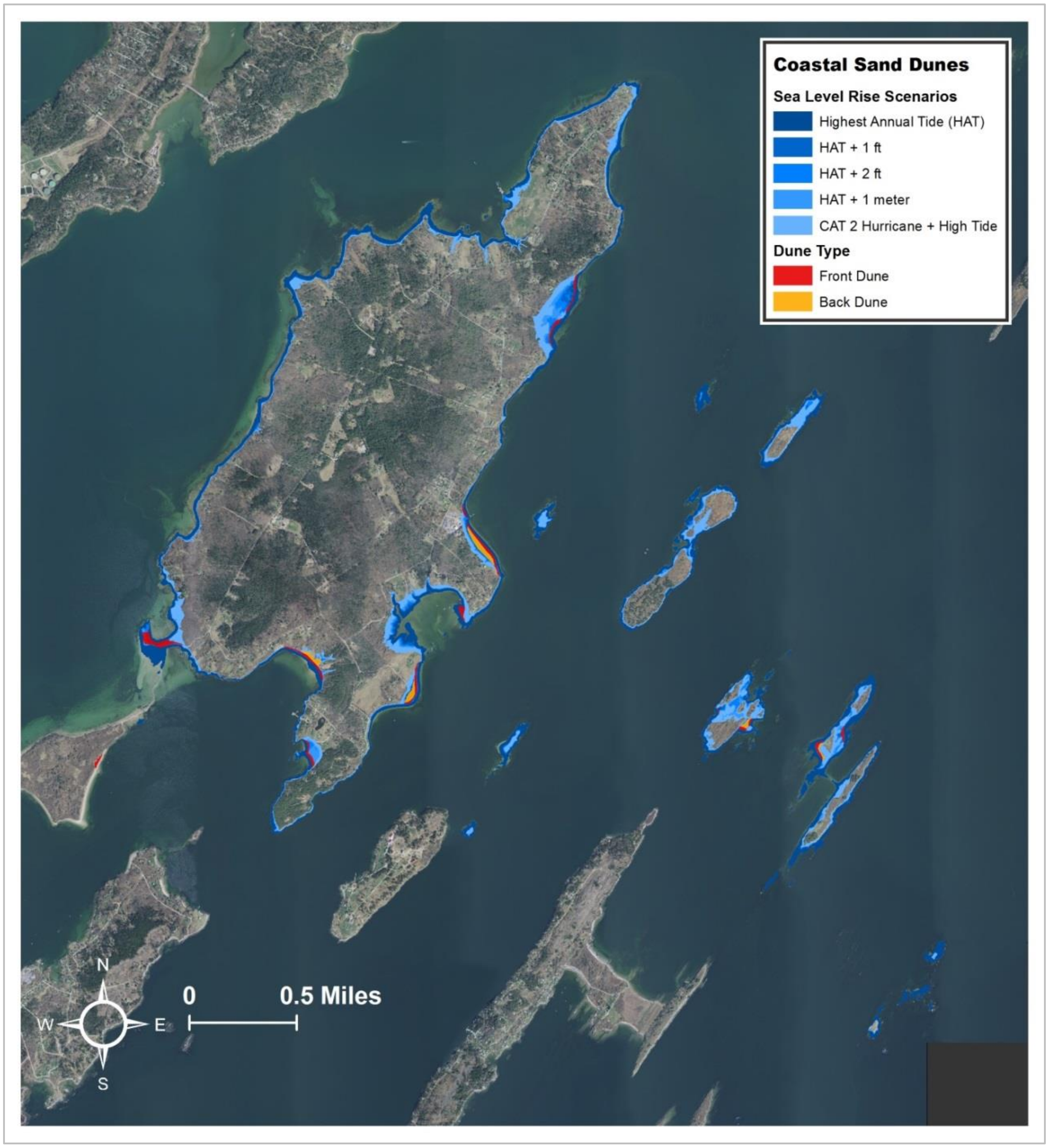


Figure 17: Coastal Sand Dunes

Salt Water Intrusion

Rising sea levels will likely exacerbate the issue of salt water intrusion, a considerable threat to groundwater all along the east coast. Saltwater intrusion is the displacement of fresh groundwater by saltwater in coastal water supplies, and occurs when groundwater levels in aquifers are depleted faster than they can recharge. There are about 400 wells on the island, which all draw from a single source aquifer -- all of the island's drinking water comes from precipitation that seeps into the ground and floats in a lens over the bay's salt water. Figure 18 shows the location of many -- but not all -- of the island's private, and private shared wells. *(Data courtesy of Maine Office of GIS and the MGS).*

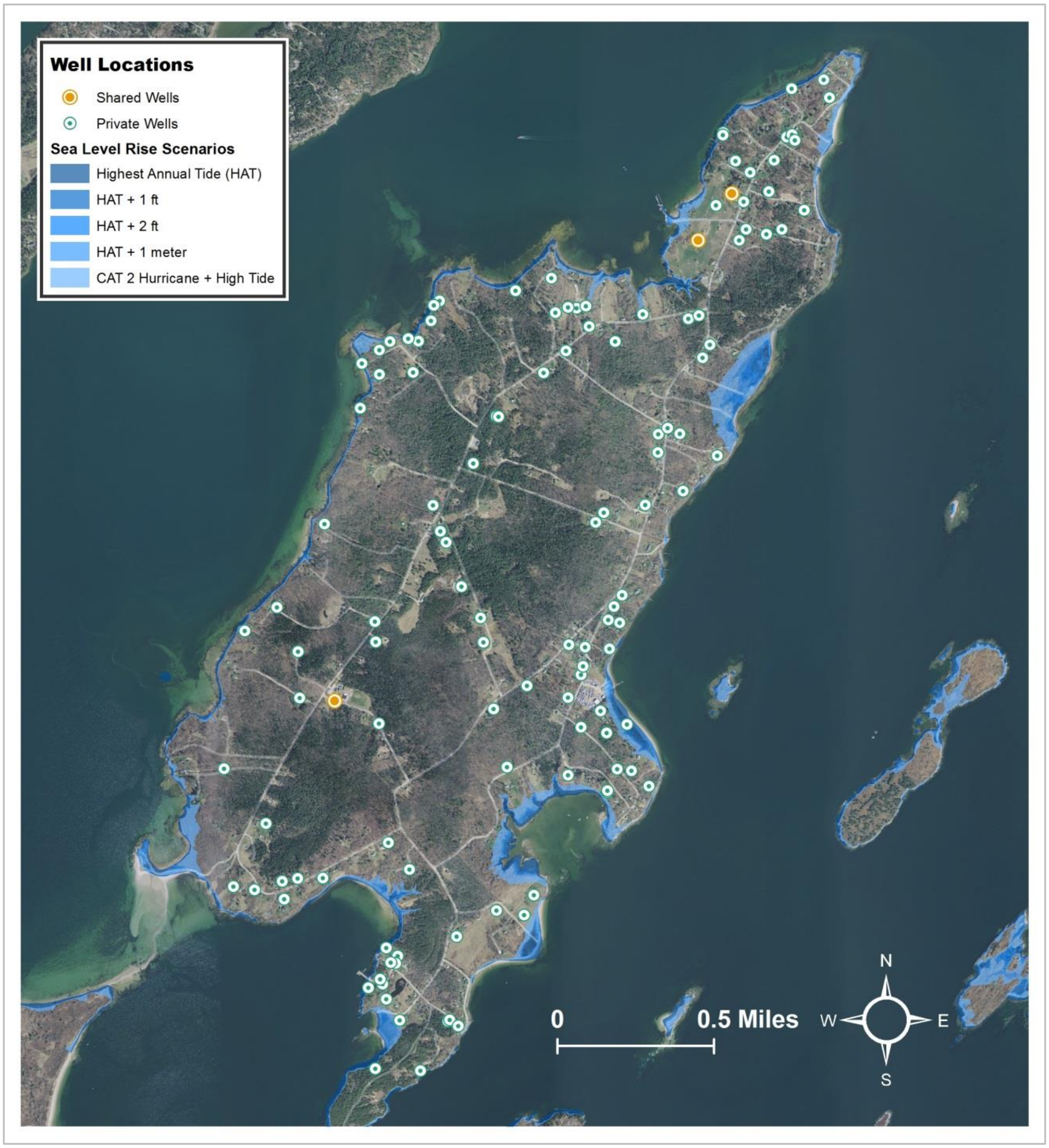


Figure 18: Well Locations

Ensuring the Town's drinking water is not polluted and continues to be recharged is essential. One strategy to help prevent saltwater intrusion may be to require that any new wells be located back from the shore -- 250 feet, for example. Once a well has saltwater intrusion, it can be difficult to restore water quality. Figure 19, below, shows the results of a survey of wells on Chebeague Island conducted in 2005. Based on the results of this study potential saltwater intrusion problems were identified in a few areas on the island, in particular Roses Point, Deer Point, Division Point, and near Central Landing.

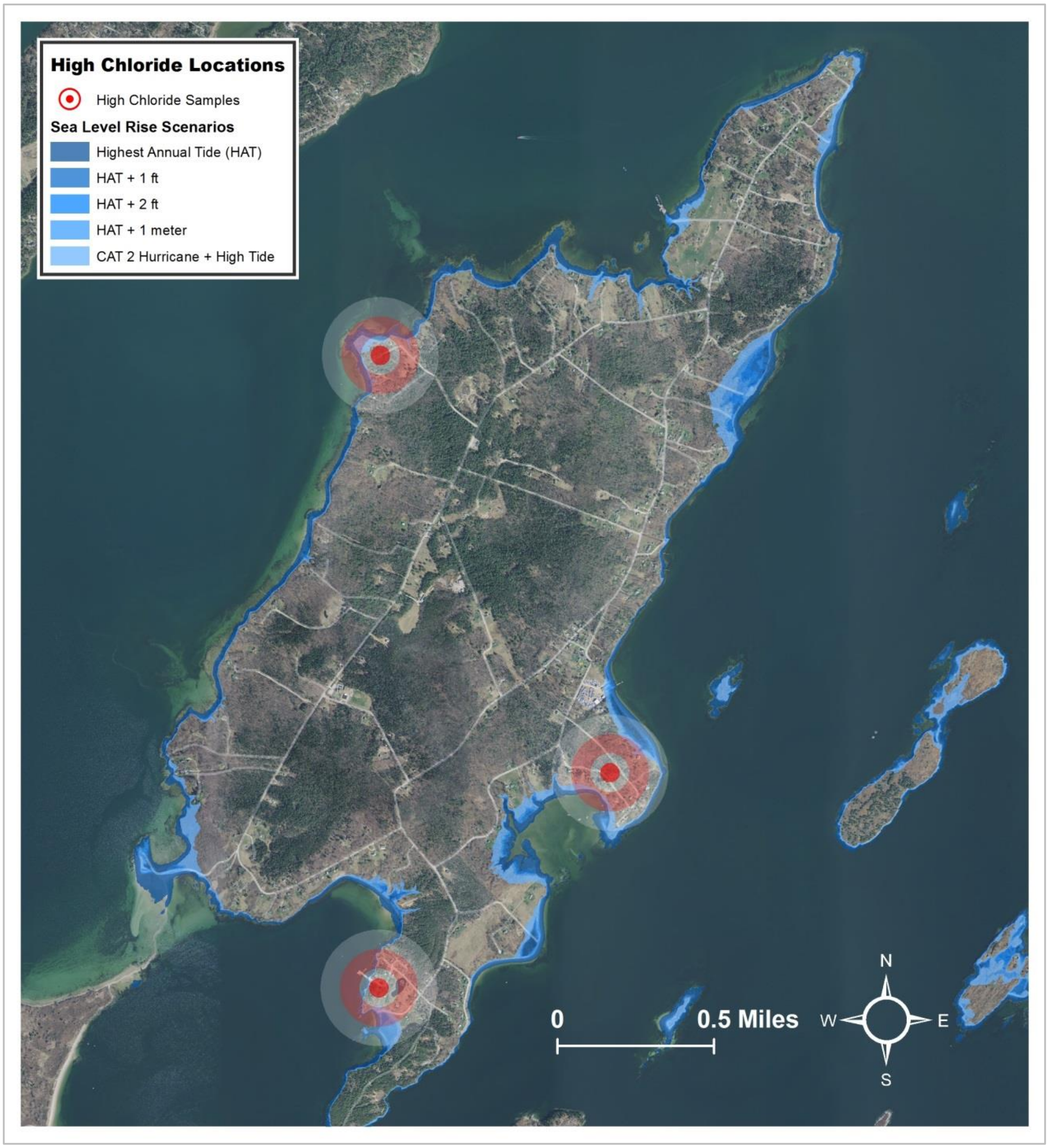


Figure 19: High Chloride Locations

For long-term adaptation strategies to be effective they must also be incorporated into the local regulatory and policy framework. For example, local zoning can be used as a tool to reduce the susceptibility of future development to flooding through regulations that address such standards as finished floor elevations, setbacks, and lot sizes. Although Chebeague's land use policies are consistent with most coastal Maine towns, specific language can be amended or added to ordinances to increase the potential success of long-term adaptation strategies.

The following sections offer a brief summary of existing state and local policies relevant to sea level rise, and include some specific examples of regulatory language the Town may wish to consider through the adaptation planning process.

Maine Natural Resources Protection Act and Coastal Sand Dune Rules

Protecting valuable natural resources from the impacts of sea level rise and climate change is critical to protecting our environment and our state's economy. Historically, with its adoption of significant policies dating back several decades, the State of Maine is considered more progressive than most states in establishing adaptation policies to protect these resources.

The *Maine Coastal Policies Statute (Title 38 M.R.S.A sec. 1801),* passed in 1985, was the first documented reference to sea level rise in Maine. This statute focuses on protecting coastal resources and implements planning and development policies consistent with its guidelines. It addresses such topics as port and harbor development, marine resources, shoreline access, and hazard development.

The *Natural Resources Protection Act, or NRPA (38 Me. Rev. Stat. Ann. § 480-A.)*, which was adopted in 1988 by the Maine Legislature, protects natural resources such as coastal sand dune systems, coastal and freshwater wetlands, wildlife habitat, fragile mountain areas, great ponds and rivers, and streams or brooks. It establishes a permit system, regulated by MaineDEP, for all activities in any protected natural resource, and any activity adjacent to a water resource if the activity would result in runoff to that area. Particularly relevant to this assessment is Chapter 355 of the NRPA, known as the Coastal Sand Dune Rules. In simple terms, sand dunes are sand and gravel deposits located within a beach system. They are fragile, dynamic and environmentally rich areas that act as natural barriers, and often protect the shoreline during storms.

The ***Coastal*** *Sand Dune Rules Act (Chapter 355)* is particularly significant to coastal towns like Chebeague, because it defines the specific rules regarding development in coastal sand dune areas. The language in Chapter 355 assumes *two-feet of sea level rise over the next 100 years*, and regulates sand dunes according to this prediction (beach nourishment and dune restoration projects are excluded from this requirement). Additionally, the rules state that buildings greater than 35 feet in height, or covering a ground area greater than 2,500 square feet, may not be constructed in a coastal sand dune system unless the applicant demonstrates convincing evidence the site will remain stable (reliance on a seawall is not sufficient evidence) after allowing for *two-feet of sea level rise over 100 years*.

Other important elements of these rules include:

- A prohibition on new or expanded seawalls;
- A prohibition on rebuilding (unless it can meet new construction standards) if a structure is damaged by more than 50% of the appraised market value; and
- A requirement that if the shoreline recedes such that coastal wetlands extend to any part of the structure (including support posts) for six months or more, then the structure shall be removed and the site restored to natural conditions.

The rules identify sand dunes as either “frontal” or “back” dunes, depending on their location relative to the water, and this designation often impacts the degree to which they are regulated. Chebeague’s sand dunes have been mapped by the state, and are included in the assessment. It is unclear to what extent these dunes are currently regulated at the local level, and without local identification, a state review may never occur.

Shoreland Zoning

Local land use regulations control the extent of development which can directly impact efforts to adapt to sea level rise. In Maine, coastal areas are regulated locally through ordinance language mandated by state law called the Maine Shoreland Zoning Act. Local Shoreland Zoning provisions regulate areas within 250 feet of the upper edge of the shoreline coastal and freshwater wetlands, great ponds, rivers and 75 feet from streams.

Most coastal municipalities use the highest annual tide (HAT) to measure the boundary of the shoreland zone. The HAT is the highest *predicted* water level for any given year. The highest astronomical tide (HAsT), by contrast, is the elevation of the highest predicted astronomical tide over the current 19-year National Tidal Datum Epoch (NTDE). The current NTDE is from 1983 to 2001. Cape Elizabeth, has chosen to use the HAsT plus three feet to better address its municipal coastal concerns. Using the HaST offers more consistency for CEO’s who are tasked with enforcing these regulations in most communities.

As is often the case with Shoreland Zoning provisions, Chebeague’s provisions are scattered throughout the zoning ordinance, rather than existing as a stand-alone document. This format can make amending and performing required updates to the language more challenging as some amendments could impact other areas of zoning if the language is not thoughtfully crafted. Given the extent of the state’s most recent round of changes to the law, updating the local provisions may be particularly challenging in this format.

Chebeague’s provisions were originally adopted prior to its secession from the Town of Cumberland, and because this language is based on a state model, Chebeague’s is consistent with most other coastal towns. The town’s coastline is zoned for limited residential, commercial development, or resource protection, with a few areas zoned for existing maritime uses. Several of the Town’s islands are entirely zoned resource protection.

The Town’s Zoning Map depicts these districts and notes the lines are not an exact delineation, but rather a general guide. Chebeague’s districts could be redrawn using LiDAR elevation data to provide a more precise picture of where the resources and setbacks are located. Additionally, establishing the normal high water line using highest astronomical tide (HAsT), (as discussed previously in this report) would provide a guideline that would not require annual updates. Specific amendments the Town may wish to consider to its Shoreland Zoning Provisions language (within the Land Use Ordinance) include:

- ☐ Section 102 Purpose (pg.1): Add language stating the purpose is *also* to adapt to impacts associated with sea level rise and climate change.
- ☐ Section 103 Authority (pg. 1): Consider amending the text to reference the Highest Astronomical Tide (HAsT) adjacent to tidal waters. The Town may wish to add additional feet to this measurement along the coast, or in certain areas identified as more vulnerable as a result of this sea level rise and storm inundation assessment *(see Cape Elizabeth model).*
- ☐ Section 100 Definitions: Add the following language to the ordinance if HAsT measurement is adopted:
    - *Highest Astronomical Tide (HAsT):* Add the following definition: "<u>The elevation of the highest predicted astronomical tide at a specific tide station over a 19-year period called the National Tidal Datum Epoch (NTDE). The current NTDE is from 1983 to 2001.</u>"
    - *Normal High Water Line:* Add to existing definition: *"*<u>Adjacent to tidal waters, the normal high water line shall be the topographic line located at the Highest Astronomical Tide</u>*."*
    - *Shoreland Zone:* Clarify that the upland edge of the coastal wetland is defined as the contour line at the elevation of the highest astronomical tide level.
    - *Shoreline:* Specify "upland edge" is defined as the contour line at the elevation of the highest astronomical tide level.
- ☐ Section 204.2 Shoreland Area Overlay Districts: Consider the addition of coastal sand dunes, as mapped by Maine Geological Survey and defined by Chapter 355 of NRPA, to Resource Protection District. Currently most of the area along the coast is in the Limited Residential District.
- ☐ Section 427.1 (pg.121): Increase floor elevation requirements (or "freeboard") beyond the existing one foot above the effective 100 year base flood elevation (BFE) which is the minimum state standard. Some towns in coastal Maine have chosen to increase to their floodplain management ordinances to include freeboards of two (Cape Elizabeth) or three feet (Saco) above the BFE. Ultimately, the Town should consider the assessment results to reach this determination. See the following section on Floodplain Regulations.

Floodplain Regulations

The National Flood Insurance Act of 1968 established the National Flood Insurance Program. This program made flood insurance available to any city or town that agreed to adopt an ordinance regulating development in flood-prone areas. Maine's Floodplain Regulations are managed by the Maine Floodplain Management Program in the Department of Agriculture, Conservation, and Forestry (DACF) and are based on data provided by the Federal Emergency Management Agency (FEMA), as presented in Flood Insurance Rate Maps (FIRMs). FIRMs designate Maine's coastal floodplains typically as "V" flood zones (V refers to velocity due to dynamic storm surge and waves over 3 feet), "AO" flood zones (dynamic zones with waves less than 3 feet), and "A" flood zones (stillwater flood zones).

The State of Maine has a model ordinance for towns to use as a framework for their own, and although a community may decide to make its floodplain ordinance more stringent, the law requires it must at least meet the requirements of the state and federal floodplain laws. Currently, the law requires structures within flood zones to be elevated a minimum of one foot above the effective Base Flood Elevation (BFE) associated with the special hazard flood zones (V, AO, or A). In Maine, several coastal towns have voted to increase this requirement, also called "freeboard," to two or three feet.

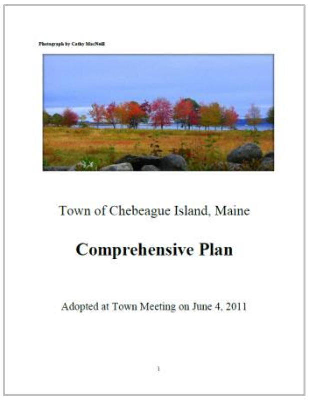
Portland, Cumberland, and Cape Elizabeth require buildings in most defined flood zones to be elevated two feet above BFE. Chebeague's requirements in both A and V zones are currently set at a minimum of one foot above BFE. Increasing freeboard is the most effective adaptation strategy a community can implement under the Floodplain Ordinance. The Town should consider strengthening floodplain standards beyond the minimum FEMA Flood Insurance Program requirements for new or replacement construction in areas that currently flood. As discussed in the Floodplain section, increasing freeboard requirements in flood prone zones is an option many towns have implemented. For this report we recommend using BFE plus three feet, although the Town may choose another option as a result of this process. This and other modifications to ordinances can offer potential premium savings to policy holders through participation in the FEMA National Flood Insurance Community Rating System (CRS) program. More information on the CRS program is available at NFIP and the Community Rating System.

Suggested amendments to Floodplain Ordinance language:

- ☐ Section 1: Add text to Purpose section referencing the Town's intention to establish standards to protect against flooding beyond those minimum requirements of the National Flood Insurance Program, to adapt to observed and predicted sea level rise, progressively higher tides and more severe and frequent coastal storm events.
- ☐ All references to Section 6.P should be changed to Section 6.O to match formatting of ordinance. This appears to be a typo in the ordinance.
- ☐ Section 6.O: New construction or substantial renovation in a floodplain should be required to be elevated such that the lowest floor is elevated to two or three feet above (decide an exact number) the BFE.
- ☐ Section 6.O: Add language prohibiting the use of fill for structural support in coastal floodplains adjacent to tidal waters.

Comprehensive Plan

A comprehensive plan acts as a policy foundation to carry out a community's vision for future development and preservation. Although it is not a regulatory document, it serves to lay the groundwork for the Town's land use regulations, and can be used to legally support those policies. The document can also serve to educate citizens and officials about the need to incorporate adaptation planning into local policies.


Town of Chebeague Island, Maine

Comprehensive Plan

Adopted at Town Meeting on June 4, 2011

Chebeague's Comprehensive Plan was adopted at Town Meeting on June 4th, 2011. The Plan does not directly address the potential impacts of climate changes or sea level rise on the islands public or private transportation infrastructure. However, clean groundwater, pollution of Casco Bay, and protection of fish and shellfish habitat are specifically cited as priorities for the future. Additionally, the Plan's vision chapter identifies a desire to encourage, "environmentally-friendly transportation and energy sources," and dictates that a new set of land use ordinances be developed by residents, since the ordinances previously adopted from Cumberland are still in effect today.

The State recommends that comprehensive plans be revisited at least every 10 years, making the Chebeague's next update necessary in 2021. However, the Plan can be revised or amended at any time, and it is recommended the Plan at least be reviewed for a possible update every five years. Many residents feel the land use ordinances inherited from Cumberland following the Town's secession should be discarded in favor of policies more suited to the Town's unique rural island character. In fact, the current Comprehensive Plan recommends a rewrite of the land use ordinances.

Given the age of the Plan, and the lack of reference to sea level rise and climate change issues, an update or amendment to the Town's Comprehensive Plan may be prudent prior to the development of new ordinances. For any update, or rewrite, the Town should consider either the adoption of a specific chapter addressing sea level rise and storm surge, or the incorporation of updated language in the relevant chapters. For example, the transportation chapter and water and natural resources chapters should reference any relevant sea level rise issues as well. Suggested amendments to the Comprehensive Plan include:

- ☐ Consider initiating an update to the Comprehensive Plan prior to adopting any amendments to land use ordinances recommended in this assessment.
- ☐ Consider amending or updating the existing plan to include this assessment, or an abbreviated version of this assessment, as an additional chapter.

Land Use Ordinance and Low Impact Development (LID) Techniques

This report is a starting point for discussion of potential responses to sea level rise. As Chebeague looks at amending or redrafting its land use ordinances, it should consider encouraging the use of low impact development (LID) standards. LID techniques are defined by the use of structural or non-structural practices to reduce stormwater runoff, pollutant loads, discharge volumes, and/or peak flow discharge rates of stormwater runoff, by preserving or mimicking the natural hydrology of a development site.

Specifically targeting stormwater requirements can reduce or prevent flooding and control erosion, and protect water quality. The State's *LID Guidance Manual for Maine Communities (2007)* is an excellent guide for communities interested in learning more about LID techniques.

Suggested amendments to the Land Use Ordinance language:

- ☐ The Town may wish to include more requirements as part of the Aquifer Protection section of the Land Use ordinance. Although the Shoreland Zone puts a 20% limit on impervious surface, this limit does not appear to apply to areas outside of the Shoreland Zone which may impact the aquifer. Such a limit could be added to all areas documented as Aquifer Protection on the map included in the Land Use Ordinance Appendix.
- ☐ 206.8 Submission Requirements: Encourage or incentivize the use of LID techniques that attempt to treat more stormwater onsite using natural features is an alternative approach to traditional stormwater infrastructure, possibly ensuring water quality. The Town may also wish to include a stormwater maintenance plan requirement, also to be cited on the approved set of plans.
- ☐ Definitions: Depending on the amendments the Town chooses to adopt, the follow additional definitions may be necessary:
    - *Low Impact Development (LID):* The use of structural or non-structural practices that are designed to reduce storm water runoff pollutant loads, discharge volumes, and/or peak flow discharge rates of stormwater runoff by preserving or mimicking the natural hydrology of a development site. The land through the use of structural or non-structural practices.
    - *Stormwater:* The part of precipitation, including runoff from rain or melting ice and snow, that flows across the surface as sheet flow, shallow concentrated flow, or in drainageways.
- ☐ Dimensional Requirements:
    - Consider an increase to setback requirements for certain sensitive areas beyond what is required by the Shoreland Zoning Act.

General Recommendations for Additional Town Adaptation Strategies

- ☐ *Accommodating Inundation:* When feasible, the Town should consider encouraging public or private purchases of areas identified as vulnerable to sea level rise. Protecting undeveloped land identified as vulnerable to flooding, or taking back previously developed areas subject to frequent inundation can allow marshes to migrate, and protect environmentally significant resources as sea level rises.
- ☐ *Risk Assessment Inventory:* According to this assessment, most town roads do not appear to be at risk. However, it should be mentioned that the Town is currently developing a draft road plan in coordination with Maine DOT. This plan provides an inventory of roads and associated infrastructure, and outlines a maintenance and reconstruction plan. The information included in this assessment should be a consideration in the future maintenance and construction of new and existing roads and related infrastructure.
- ☐ *Low Impact Development:* The Town should encourage, incentivize or require developers to consider Low Impact Development (LID) techniques. LID techniques offer natural ways to make shorelines more resistant to erosion, such as installing native plantings and creating berms, rather than hard infrastructure that may just shift the location of erosion.
- ☐ *Parking Requirements:* Although these are not entirely relevant to the typical scale and type of development Chebeague receives, the Town may wish to refine parking standards to encourage the use of permeable pavement, and limit the number of parking spaces for office, retail, municipal uses, or encourage shared parking for neighboring uses. Other parking policies may include reducing the number of cars on the island through a more formalized ridesharing or seasonal bus service. This concept is ideal for an island community.
- ☐ *Drinking Water Resources:* All new and replacement water supply systems should be designed to minimize or eliminate infiltration of flood waters into these systems. The Town may wish to improve regulations of domestic water wells located within a newly designated Sea Level Rise Overlay District, or an aquifer protection area depending on the potential impacts associated with sea level rise. Regulations may include extending the elevation required for well casings, installing a sanitary seal or cover on the casing, or other similar methods of protection.
- ☐ *Subsurface Sewage Disposal Systems:* Subsurface sewage disposal systems should be identified and mapped if located within the Sea Level Rise Overlay District. Depending on their age, maintenance history, and location, these systems may be particularly at risk to the impacts of sea level rise. The Town may wish to adopt requirements to protect these systems from impacts associated with sea level rise and storm surge. Such requirements can include sealing of all pipe penetrations through walls and foundations, sealing of the septic tank access cover, utilizing a watertight cover for the septic tank inspection pipe, and protecting the sewage connection pipe and tank from flood damage. The Town might also consider an increase to the minimum vertical distance required between the bottom of a leach field and the high ground water table.

Glossary of Terms

Base Flood Elevation: The elevation to which floodwater is anticipated to rise during the "base flood" (i.e., the "100-year storm" or a flood having a one percent change of being equaled or exceeded in any given year). Base Flood Elevations are shown on Flood Insurance Rate Maps (FIRMS) and on various flood profiles. The BFE is the regulatory requirement for the elevation or flood proofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.

Bathtub Model: The sea level rise scenarios used in this report are based on the bathtub model, which solely takes into account rising water levels. It does not factor in changes to topography, nor the impacts of waves, or wind.

Coastal Wetlands: All tidal and sub-tidal areas, including all areas below any identifiable debris line left by tidal action; all areas with vegetation present that is tolerant of saltwater and occurs primarily in a salt water or estuarine habitat; and any swamps, marsh, bog, beach, flat, or other contiguous lowland which is subject to tidal action during the maximum spring tide level as identified in tide tables published by the National Ocean Service (38 MRSA 480-B).

Global Mean Sea Level (GMSL): The globally averaged height of the oceans measured by a network of satellites to sub-millimeter precision. It is sometimes referred to as the "eustatic sea level." The eustatic sea level is not a physical sea level (since the sea levels relative to local land surfaces vary depending on land motion and other factors), but it represents the level if all of the water in the oceans were contained in a single basin.

Highest Annual Tide (HAT): The highest predicted water level for any given year. The highest annual tide corresponds to the full moon, and is reached within several inches numerous tides a year. This boundary coincides with the limits of regulatory coastal wetlands. The value changes slightly each year.

Highest Astronomical Tide (HAST): The elevation of the highest astronomical tide predicted at a specific tide station over a 19-year period called the National Tidal Datum Epoch. The current NTDE is from 1983 to 2001.

Land Subsidence: The sinking or lowering of the land surface due to land adjustment post-glaciation, natural compaction of materials, or groundwater or natural resource withdrawal. Land subsidence can increase flooding, alter wetland and coastal ecosystems, and damage infrastructure and historical sites.

LiDAR: LiDAR is an acronym that stands for "Light Detection and Ranging." LIDAR is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. LiDAR is typically collected from planes that produce a rapid collection of points (more than 70,000 per second) over a large geographic area. These points are used to measure elevations or distances on land and result in a more refined geography. The technology can be used to make high-resolution maps with great accuracy and precision.

Mean Lower Low Water (MLLW): The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Sea Level: The average level of the sea surface over a long period, normally 19 years, or the average level which would exist in the absence of tides.

National Tidal Datum Epoch (NTDE): The specific 19-year period adopted by the National Ocean Service as the official time segment over which the tide observations are taken and used to obtain mean values (i.e., mean lower low water, etc.). The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years.

Normal High Water Line: The seaward-most boundary of the shoreland zone in non-tidal areas (see Shoreland Zone, below). Development is limited within 250 feet of the boundary, and none is allowed within 75 feet.

Shoreland Zone: The Mandatory Shoreland Zoning Act (MSZA) requires municipalities to adopt, administer, and enforce local ordinances that regulate land use activities in the "shoreland zone." The shoreland zone is comprised of all land areas within 250 feet, horizontal distance of the normal high-water line of any great pond or river; upland edge of a coastal wetland, including all areas affected by tidal action, and upland edge of defined freshwater wetlands; and all land areas within 75 feet, horizontal distance, of the normal high-water line of certain streams.

Storm Surge: Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge is typically caused by winds and low pressure associated with an atmospheric front.

Storm Tide: Storm tide refers to the overall rise in water level due to the combination of storm surge and astronomical tide. (For instance, if the predicted tide was 11 feet, and storm surge was 3 feet, the storm tide would be 14 feet).

Additional Resources

Specific references to data, quotations, news articles, etc. are cited in footnotes throughout the report. Below is a list of additional resources that might be useful for the Town's future planning efforts.

- Cumberland County, Maine, "Hazard Mitigation" (webpage).
- Greater Portland Council of Governments, "Casco Bay Environmental Planning Assessment 2013" (report).
- Maine Climate Change Institute, "Maine's Climate Future – 2015 Update" (report).
- Maine Coastal Program, "Coastal Erosion and Sea Level Rise" (webpage).
- Maine Stream Connectivity Work Group, "Maine Stream Habitat Viewer" (web map).
- NOAA, "Digital Coast" (webpage).
- NOAA, "National Sea Grant Resilience Toolkit" (webpage).
- NOAA, "U.S. Climate Resilience Toolkit" (webpage).
- Town of Bowdoinham, "Comprehensive Plan - Sea Level Rise and Climate Change Adaptation Goals and Strategies" (report).
- Town of York, "Adaptation to Sea Level Rise Chapter – Comprehensive Plan Inventory and Analysis, 2013" (report).
- Urban Land Institute, "Waterfronts of Portland and South Portland Maine" (report).

Additionally, the following resources are particularly relevant to any policy discussion or decision-making regarding sea level rise and natural resources:

- *"Anticipatory Planning for Sea Level Rise along the Coast of Maine"* is a report created by the former State Planning Office and the United States Environmental Protection Agency in 1995. The report is considered to be one of the most comprehensive reports examining the issue of sea level rise in Maine. In the prior administration this report was often cited as an example of the "disconnect" between state policy and local implementation because most of its recommendations were never implemented on the local level.
- *"Protecting Maine Beaches for the Future"* completed in 2006 which was the result of a two-year stakeholder process. As a result of this report, Maine adopted 2 feet of sea level rise over the next 100 years, which was considered a "middle-of-the road" prediction for global sea level rise, into its Natural Resources Protection Act (NRPA) Coastal Sand Dune Rules (Chapter 355).
- In 2010, the Maine Department of Environmental Protection released *"People and Nature Adapting to a Changing Climate: Charting Maine's Course,"* a collaboration of 100 stakeholders throughout the state from diverse interests. The report was commissioned by the Joint Standing Committee on Natural Resources of the 124th Maine Legislature, and provided an extensive list of recommendations regarding preparing Maine for the potential impacts of climate change. Some of the most applicable recommendations for the current work focused specifically on developing sea level rise vulnerability data, and bringing it to the local level for development of local adaptation strategies.