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Maine Coastal Property Owner's Guide to Erosion, Flooding, and Other Hazards, 2nd edition

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INTRODUCTION

Purpose of this Guide

The Maine Geological Survey (MGS) created this guide to:

- Help educate coastal property owners on how to identify and assess specific coastal features and their related hazards; and
- Help to identify potential mitigation and adaptation strategies to minimize those hazards.

Specifically, this guide will help coastal property owners:

- Identify important features of the Maine coastline and familiarize themselves with potential hazards associated with certain types of coastal features;
- Identify specific characteristics of different types of coastal hazards;
- Identify the presence, absence, or level of certain hazard types on their property;
- Identify potential strategies that can be undertaken to mitigate for or adapt to identified hazards; and
- Identify applicable rules and regulations associated with certain hazards.

Please note that this document should be used for *general guidance purposes only to help understand coastal features and their associated hazards*. Although this Guide covers features and hazards found on a great portion of the Maine coast, it is not meant to identify *all existing hazards* along the Maine coastline, nor is it intended to be the sole basis upon which specific land-use decisions should be made by coastal property owners.

For an evaluation of specific coastline features, hazard risks or historical trends, licensed geologists or geotechnical engineers should conduct site-specific studies. Neither the Department of Agriculture, Conservation and Forestry, nor its employees or agents: (1) make any warranty, either expressed or implied for merchantability or fitness for a particular purpose, as to the accuracy or reliability of the information included herein; nor are they (2) liable for any damages, including consequential damages, from using this Guide or the inability to use this Guide.

History of this Guide

The original version of this guide was written in 2011 by Peter Slovinsky, Marine Geologist with MGS and subsequently adapted for the internet by Maine Sea Grant. This update follows the general format of the 2011 Guide and adds relevant new information on existing hazards, along with new resources since the last guide was released.

What is a Coastal Hazard?

Coastal hazards include both natural and man-made events (chronic and episodic) that threaten the health of coastal ecosystems and communities. Although this definition can be quite wide reaching (for example, a hazard could include oil spills, algal blooms, and pollution), for the purposes of this guide, we will be focusing on mostly storm-driven and long-term sea-level driven problems resulting from *erosion and flooding*.

What is Hazard Mitigation and Adaptation?

Hazard mitigation is any sustained action taken to reduce or eliminate the long- term risk generated by hazards to people and the built and natural environment. Mitigation can take several forms, including siting, construction techniques, protective works (erosion control structures, beach fills, dune construction), maintenance, land-use regulation, coastal zone management planning, and enhancement of natural buffers. Hazard mitigation seeks to reduce risk over long durations, rather than preparing for, or responding to, an impending event (Herrington, 2003).

The Intergovernmental Panel on Climate Change (IPCC, 2007) defines adaptation as the *adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*.

These concepts are instrumental to the development of a Hazard Management Plan, outlined below, which assesses and manages coastal hazards and their associated risks.

Develop a Hazard Management Plan

Coastal property owners should consider developing a short- and long-term hazard management plan for their properties. These plans should be undertaken in the context of clearly defined **goals, priorities, and**

expectations for the use of the property based on its proximity to development, natural resources, and coastal hazards. These goals, priorities, and expectations must assume **certain levels of risk** associated with the presence or absence of coastal hazards, which will likely vary among individual property owners. **A general overall goal for hazard management is to reduce or remove the level of risk associated with a certain hazard, while at the same time minimizing associated negative impacts to the natural environment and yet maintaining or achieving a desired use of a property**. Removing all risk from coastal property is likely impossible.

Other goals that can be part of a management plan include but are not limited to ensuring human safety, protecting, enhancing, or restoring property or habitat, or maintaining or developing new uses of property or habitat.

Achieving one or more of these goals may involve delicate balancing of the goals, priorities, expectations, and risks. Be realistic in setting your goals, priorities, and expectations, and be sure to understand the risks associated with these goals. The process of developing and implementing a management plan that addresses a coastal hazard can generally follow the steps of:

- identify appropriate management goals;
- understand and determine the nature of a given hazard;
- evaluate conditions of a property to identify the presence or absence of a certain hazard;
- determine the level of risk associated with identified hazards;
- determine the level of acceptable risk for you as a property owner;
- select appropriate strategies for managing said hazards that achieve the overall goals; and
- implement the chosen strategies to achieve the management goals.

General Coastal Hazard Management Strategies

Although specific strategies will be discussed in much more depth for each geographic or geologic section on hazards, generally, there are three main strategies that can be implemented. These three general management approaches are discussed briefly in this section to provide a context for more specific, subsequent sections. These strategies are independent of the type of coastline and include:

- allowing natural processes to occur;
- mitigating hazards; and
- altering or enhancing the shoreline.

These general management approaches are not mutually exclusive; more than one may apply to or be most effective for a given stretch of coastline or property. However, the decision as to which approach is best for your property will depend upon the property's geological, ecological, and economic considerations, and the goals, expectations, hazards, and risk levels identified in the overall management plan.

Adaptation and mitigation strategies are taken directly from the 2006 Protecting Maine's Beaches for the Future report (Beach Stakeholders' Group, 2006), along with its 2017 update (Integrated Beach Management Program Working Group, 2017). Each specific strategy is discussed further below.

Allow natural processes to occur. This approach of "non-intervention" allows natural processes to change the shoreline. In many cases where permanent structures are not present, this approach is preferred, particularly where critical habitats are involved. In some instances, this approach will best serve the goal of hazard avoidance or reduction.

Mitigate the hazard. The mitigation of coastal hazards refers to a series of techniques that lessen or reduce the effect of a hazard on the built environment. Relocating development away from high hazard areas, purchasing at-risk properties from willing sellers, elevating buildings, road and utilities, elevating and flood proofing building systems such as heating systems, and improving a building's ability to withstand storms through different construction practices are all considered hazard mitigation tools.

Alteration or Enhancement of the shoreline. In situations where other hazard management strategies are not practical, human alteration of the shoreline may be required in order to achieve the goals of hazard management. The levels of alteration needed for a section of shoreline will depend heavily upon the type of shoreline, and the level of exposure to hazard(s), among other factors.

Generally, to the extent practicable for a given property or situation, approaching these strategies in the order listed will minimize impacts on the natural environment; however, that may not always be feasible. Also, in many cases, a combination of the listed strategies may be most applicable to your specific situation. Considering these different strategies and taking into account the goals, priorities, and expectations for a property, coastal property owners should:

- **Understand your property**. Use all available information, including this Guide, to understand the characteristics of your property and the risk associated with certain hazards. You may need to hire professional geologists, certified engineers, landscape architects, or environmental consultants to fully understand the level of risk and the entire planning and permitting process.
- **Be realistic**. In setting your goals and expectations for use of your property, be cognizant of the hazards and risks that you will face. For example,

if you own a small piece of property that is in a flood zone, and it is bound by an eroding wetland on one side, and a dramatically eroding beach on another, building your dream home that you might expect to be in your family for generations may not be as realistic as a small seasonal cottage that can be easily moved or retrofitted in the future.

- **Be neighborly**. Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted to deal with certain hazards more effectively or efficiently.
- **Consider the costs**. When comparing strategies, consider the short- and long-term costs of different strategies. A lesser-priced strategy initially may cost more in the long term.
- **Consider the permit requirements**. Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs - which may relate to specific strategies and overall hazard management goals.
- **Consider timeframes**. Some activities or strategies may have extended permit review processes, certain sensitive habitat types, seasonal restrictions, or extended construction timeframes. All of these might impact how quickly you might be able to implement a specific strategy. Think about the timeframe of expected usage of your property, and what might happen to that property in the future, such as family ownership, impacts from storms, longer-term sea-level rise, and shoreline change.

Introduction to the Maine Coastline

Based on a 2015 assessment using a geographic information system (GIS) and the shoreline along the highest astronomical tide, Maine has 5,408 miles of tidally influenced shoreline (Maine Coastal Program, 2015). About 58% of the coast is rocky, or "consolidated" bluff, while 40% "unconsolidated" bluff. Only about 2% of the entire shoreline is beach. The average tidal range increases from about eight feet in the southwest, to over 18 feet along the Downeast coast. Along with geologic history, this dramatic regional difference in tidal range lends itself to some of the variety of coastline types, ranging from sandy beaches to steep rocky coasts. Generally, the Maine coastline can be classified into four different coastal compartments (Kelley, 1987; Kelley et al. 1988; see Figure 1):

- **Southwest Arcuate Embayments**. Extends from Kittery to Cape Elizabeth and consists of a series of rocky headlands and separated sandy bays of varying sizes with extensive salt marshes and sand beaches.
- **South-Central Indented Shoreline**. Extends from Cape Elizabeth to Saint George, and consists of deep, narrow estuaries separate long bedrock peninsulas. Deposits of muddy glacial sediment fill many of the valleys that were probably carved by rivers over millions of years.
- **North Central Island-Bay Coast**. Extends from Saint George to Machias Bay and is shaped by numerous granitic islands sheltering broad embayments. Like the Indented Shoreline, mud and mixed mud and gravel flats are the most common intertidal settings.
- **Northeast Cliffed Coast**. Extends from Machias

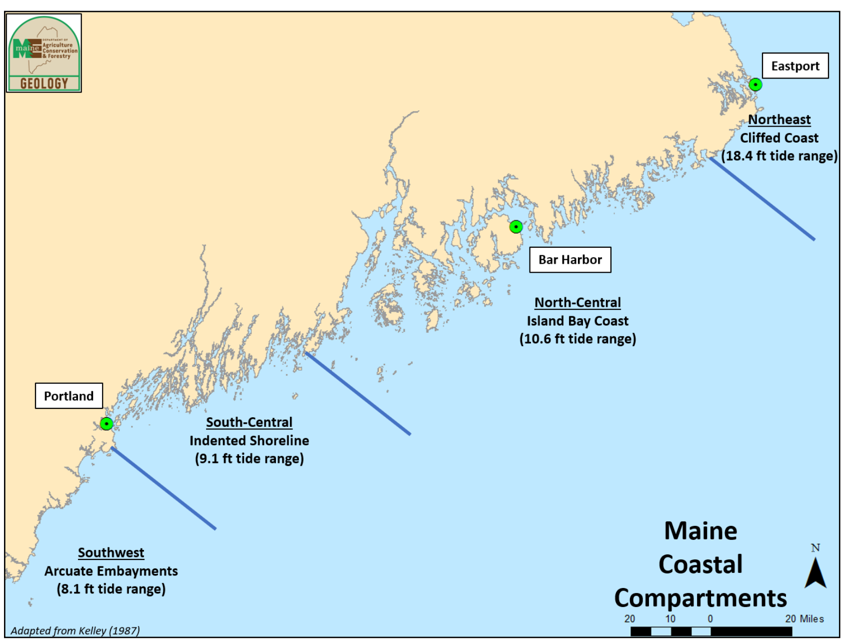

Figure 1. Maine's coastal compartments defined by dominant coastline geomorphology and tidal ranges.

Bay to Eastport. Bedrock faults create a straight coast with abundant bedrock in the intertidal zone. An 18-foot tidal range has led to considerable scouring of the seafloor by tidal currents and formation of extensive tidal flats.

Dominant Hazards along the Maine Coastline

For the purposes of this guide, the two dominant coastal hazards along Maine's coastline include erosion and flooding. These hazards are exacerbated by a compounding factor - sea level rise. The erosion of coastal features (such as dunes, beaches, bluffs, and marshes) increases with sea level rise because the base water level upon which waves from storms act is that much higher. This, in turn, allows for waves during storms to erode coastal features at higher levels. At the same time, sea level rise also increases the frequency, duration, and intensity of coastal flooding. The Scientific Assessment of Climate Change and Its Effects in Maine (Dickson et al., 2020) has a detailed review of sea level rise and storm surge.

Coastal Erosion and Coastal Flooding

Maine's diverse 5,408-mile coastline is made up of a variety of coastal features, including rocky shorelines, armored areas, coastal bluffs, dunes, beaches, flats, and marshes. Some of these features are more susceptible to erosion or impacts from factors such as flooding or sea level rise than others. For example, a rocky shoreline is naturally much less vulnerable to erosion than a sand beach or dune. At the same time, these features naturally respond differently to erosion – for example, a coastal bluff will typically only erode in response to storms and sea level rise, while a dune or beach can have cyclical shoreline change (eroding or accreting).

According to an analysis completed by the Maine Coastal Program for NOAA (Maine Coastal Program, 2015), about 80% of Maine's 5,408-mile coastline has low to very low vulnerability to shoreline change. Table 1 shows some of the different coastal features and their susceptibility to shoreline change.

Like coastal erosion, different coastal features along Maine's coastline have different vulnerabilities to coastal flood events. However, it is the elevation of different features in relation to a coastal flood that is the key factor in determining whether something is at risk, not necessarily the feature itself. That said, the most at-risk features for coastal flooding are the lowest-lying features - sand and mud flats, beaches, and dunes. Bluffs and rocky shores are typically higher in elevation, thus less at-risk to flooding. Armored or engineered shoreline areas of the coast can still be very susceptible to flooding – again, this is based on the elevation of the protective structure relative to the flood elevation.

A further analysis of the susceptibility of dunes and seawalls to coastal flooding (based on the elevation of the feature referenced to the "100-year" storm event) is provided in the Beaches, Dunes, and Coastal Erosion and Flooding Hazards section.

Sea Level Rise

On a global scale, modern sea level rise is caused by two dominant factors which account for around 90% of observed changes: 1) volumetric increase in the oceans from the melting of land-based ice sheets (like Antarctica and Greenland) and glaciers; and 2) thermal expansion caused by warming of the oceans. Additional factors, which generally account for about 10% of global sea level changes, include vertical land movement, terrestrial water storage, ocean circulation, and gravitational changes (IPCC, 2001). Figure 2 summarizes the main causes of modern-day sea level rise.

Over the past century or so, global sea levels have risen at a rate of about 0.56 feet per century (1.8 mm/year) or about 7 to 8 inches (USGCRP, 2018). Over the past 25 years or so, the rate of global sea level rise increased to just over 1 foot per century (3.3 mm/year, University of Colorado, 2020). Maine's longer-term tide gauges (Eastport, Bar Harbor and Portland) have been generally following both short- and long-term trends (Figure 3; Dickson et al., 2020).

Where sea level might go in the future depends on the response of the climate system to warming and the future scenarios of human emissions of greenhouse gasses. The Fourth U.S. National Climate Assessment suggests that sea level rise of 1 to 4 feet by the year 2100 is "very likely," and that emerging science regarding Antarctic ice sheet stability suggests potentially much higher scenarios (USGCRP, 2018). Sweet et al. (2017) developed a series of potential sea level rise

Shoreline Change Vulnerability	**Miles**	**Percent**
Very Low (rocky or armored coast)	1827	34%
Low (flats and stable bluffs)	2549	47%
Moderate (coarse beaches)	355	7%
High (unstable bluffs)	406	8%
Very High (sand beaches, dunes, highly unstable bluffs)	271	5%
Total Shoreline	**5408**	**100%**

Table 1. Table of shoreline types along the Maine coastline and their vulnerability to erosion.

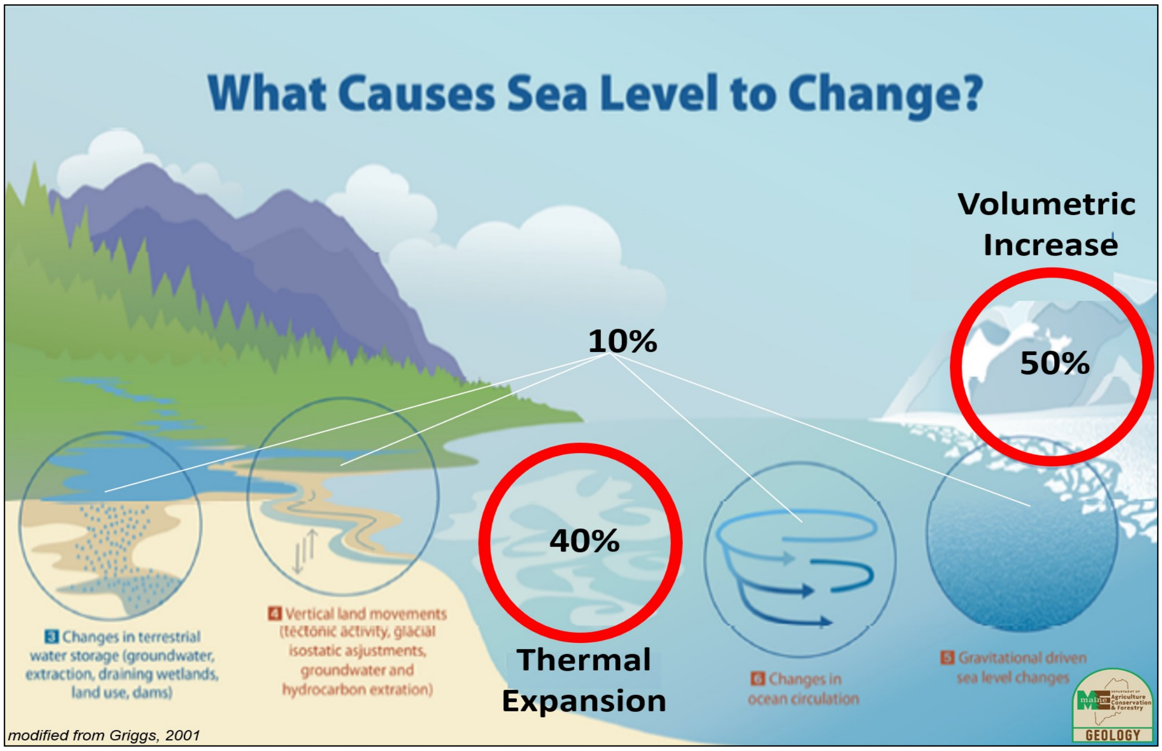

Figure 2. Dominant causes of global sea level rise.

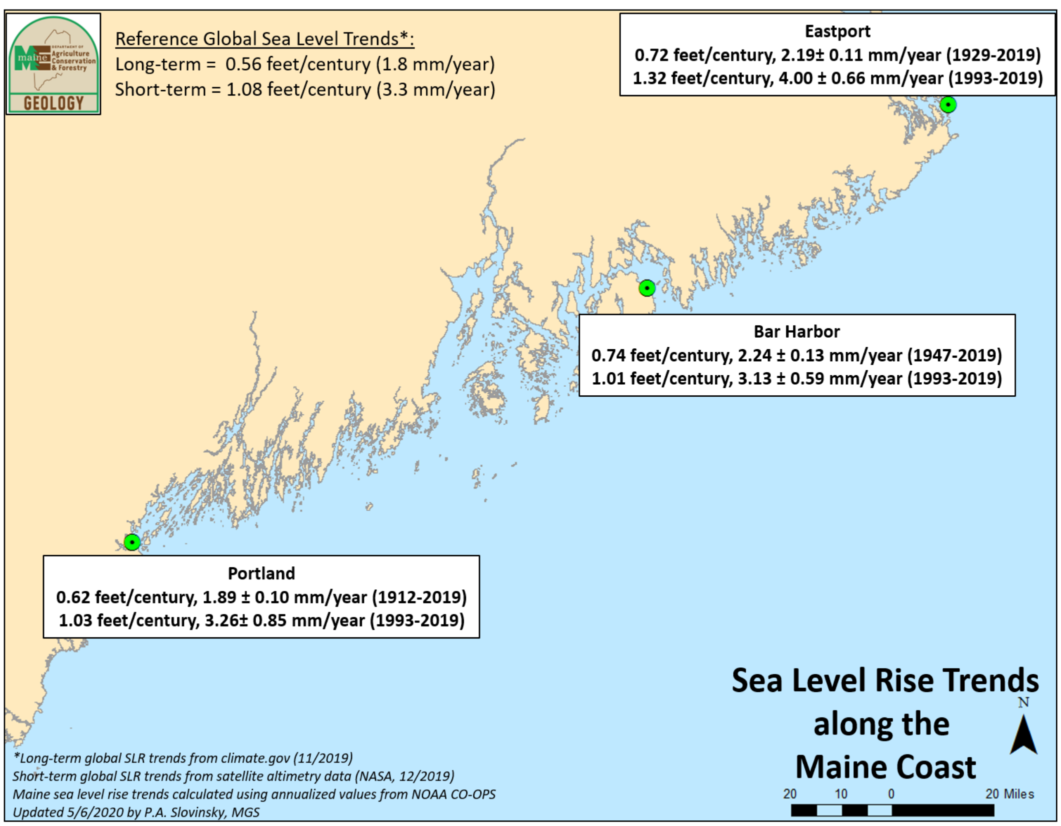

Figure 3. Sea level rise trends along the Maine coastline through 2019. From p. 74 of Scientific Assessment of Climate Change and its Effects in Maine.

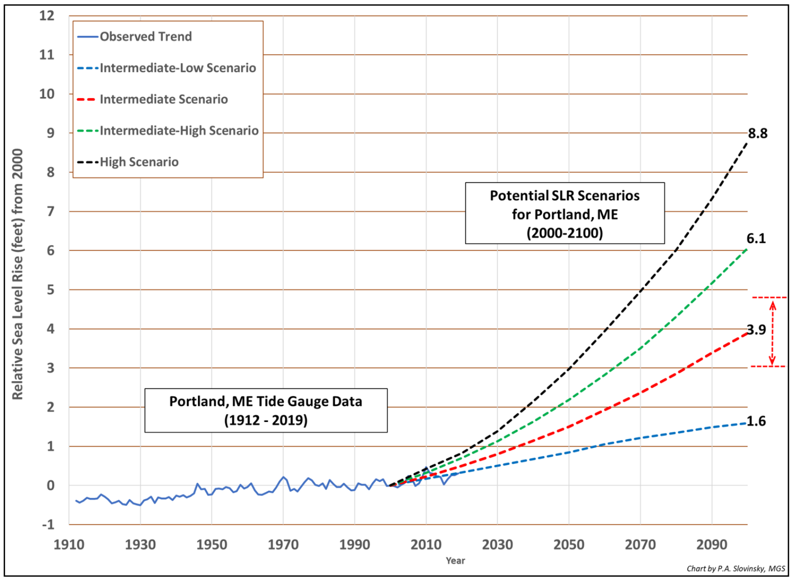

Figure 4. Graph illustrating historical sea level rise in Portland (solid blue line) and scenarios from 2000-2100 with central estimates (50% probability of being met or exceeded) for low-intermediate to high sea level rise scenarios from Sweet et al. (2017). The likely range of 3.0 to 4.6 feet (67% probability of sea level rise falling between these values) for the intermediate scenario is shown as a dashed red arrow and red lines on the right side of the Figure A. Values are presented in tenths of a foot and relate to a year 2000 starting point. Scenario data from the U.S. Army Corps of Engineers Sea Level Change Calculator (2019). From p. 81 of *Scientific Assessment of Climate Change and its Effects in Maine*.

scenarios to the year 2100 (over 2000 levels), accounting for different climate change scenarios. The central estimates (50% probability of being met or exceeded) for intermediate-low to high scenarios are shown in Figure 4. Citing this information, the Maine Climate Council developed recommendations for committing to manage for 1.5 feet of sea level rise by 2050 and 3.9 feet by the year 2100. In addition, it recommends preparing to manage for 3.0 feet of sea level rise by 2050, and potentially 8.8 feet by the year 2100 (Maine Climate Council, 2020).

Influence of sea level rise on "nuisance" flooding

Even relatively small amounts of sea level rise exacerbate both coastal erosion and coastal flooding. "Nuisance" or "sunny day" coastal flooding is especially more pronounced with elevated water levels due to sea level rise. Historically in Portland, nuisance flooding occurred along areas of Back Cove and along Commercial Street when the tide reached near 11.95 feet MLLW, which is also the highest astronomical tide (HAT), or "King Tide" level for Portland according to NOAA's CO-Ops.

Based on hourly historical tide gauge data from 1912 to 2019, MGS determined that the king tide in Portland was reached on average 3.4 hourly readings per year, or about 0.5% of all high tides in a year (Figure 5a; Dickson et al., 2020). Looking only at data over the last 20 years, Portland experienced an average of 11.9 hourly readings per year where the flood stage was exceeded. That is a *250% increase* in flood frequency from the long-term trend and a 138% increase from the flooding frequency recorded in 2000 (5 events). This increase is consistent with findings for the tide gauges along the Northeast Atlantic Coast, which averaged a 140% increase in flood frequency in 2018 vs. 2000 (Sweet et al., 2019).

Should sea levels along the Maine coastline rise just one foot, MGS determined that the flood stage would be equivalent to the current 10.95 feet (since base sea level would be 1 foot higher). For the historical average, flood stage would then have been reached on average 54.3 hourly readings per year, or about 8% of high tides. Over the past 20 years, the flood frequency would be 129.5 hourly reading per year (Figure 5b). These would represent a *10- to 15-fold increase in nuisance flooding*.

In order to provide the public with updated sea level rise data and information on monthly water level trends for five of Maine's tide gauges (from northeast to southwest: Eastport, Cutler, Bar Harbor, Portland, and Wells), MGS created a Maine Sea Level Rise Dashboard. This tool allows users to view water level variability (by month), short-term (last 25 years), long-term sea level rise trends, rankings for the past month's water levels, and graphs similar to Figures 5a and 5b showing historical hours above King Tide and hours above King Tide with 0.8 feet (potentially by 2030 under intermediate SLR scenario) and 1.5 feet (potentially by 2050 under intermediate scenario) of sea level rise. Data on the dashboard are updated monthly.

In addition, more information on sea level rise and

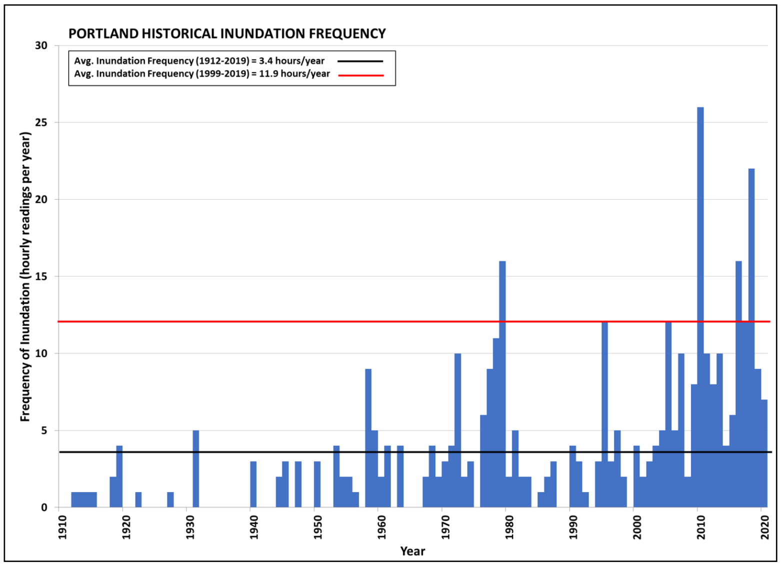

Figure 5a. Frequency of flood stage (12 feet MLLW) being met or exceeded at Portland, Maine from 1912 through 2019. The long-term average is 3.4 events per year (black line). Over the past 2-decades, the average was about 12 events per year (red line). From p. 89 of *Scientific Assessment of Climate Change and its Effects in Maine*.

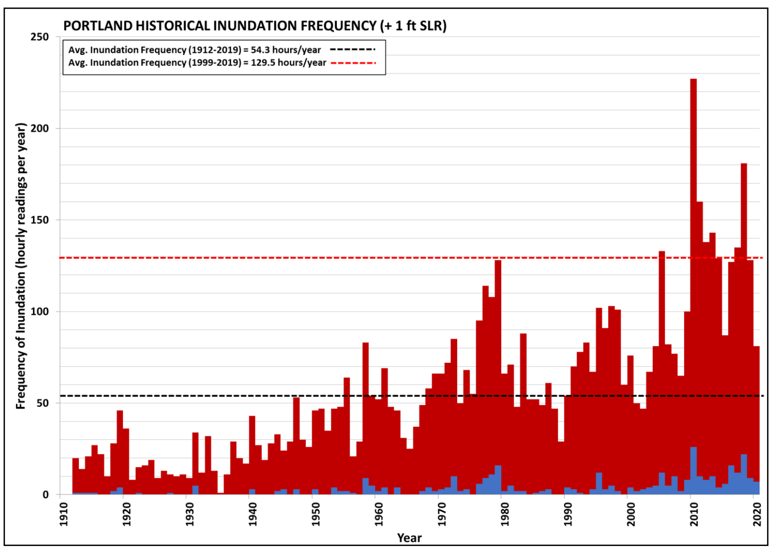

Figure 5b. Potential future nuisance flooding in Portland with 1 foot of sea level rise. Data indicates there would be about a ten- to fifteen-fold increase in nuisance flooding. From p. 90 of *Scientific Assessment of Climate Change and its Effects in Maine*.

storm trends along the Maine coast is available in the report produced for the Maine Climate Council by the Scientific and Technical Subcommittee, titled Scientific Assessment of Climate Change and Its Effects in Maine (Maine Climate Council STS, 2020; 36MB download).

Identifying Hazards along Your Coastal Property

The first steps in identifying what hazards may be associated with your property is to identify what your shoreline type is on or directly near: rocky, unconsolidated coastal bluff, beach or dune, or coastal marsh. This guide will walk you through the process of identifying the different features and their associated hazards.

The most prominent vulnerable coastal features and their associated hazards along the Maine coastline that are presented in this guide as individual chapters include:

- Beaches, Dunes, and Coastal Erosion and Flooding Hazards
- Coastal Bluffs, Erosion and Landslide Hazards
- Coastal Wetlands and Coastal Flooding Hazards

Note that these hazards are the results of different processes that occur along the Maine coastline, including but not limited to sea-level rise, waves, storms, winds and tides. These processes are not discussed specifically as hazards themselves, but impact dominant coastal features and property.

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A. BEACHES, DUNES, AND COASTAL EROSION AND FLOODING HAZARDS

Beaches comprise only about 75 miles of Maine's coastline. Sand beaches account for only about 40 miles. Most large sandy beaches occur along the southern coast between Kittery and Cape Elizabeth, although several stretches of sandy beach also occur in mid-coast Maine near the mouth of the Kennebec River, and along the central and eastern coasts as pocket beaches. Maine's beaches, however, are a resource of statewide significance. Maine's beaches provide multiple values to many different user groups, provide a natural buffer from storm events, and vital critical habitat for a variety of plant, bird, and animal species.

Typical Beach and Dune Features

Maine's beaches are dominantly a combination of barrier beaches or pocket beaches. Barrier beaches typically consist of a beach, front and back dunes, and a back-barrier coastal marsh system (for example, Wells Beach). Pocket beaches tend to be much smaller and are bound by bedrock headlands, and usually do not have extensive back-barrier marshes. An example of such a pocket beach is Willard Beach in South Portland. Unlike some states, Maine does not have any barrier islands, which are barrier beaches and dunes that are backed by wetlands and fully separated from the mainland and by tidal rivers or estuaries on both ends.

Sand dunes and beaches are part of the regulated Coastal Sand Dune System. Under Maine law, "coastal sand dune systems" are defined as sand and gravel deposits within a marine beach system, including, but not limited to, beach berms, frontal dunes, dune ridges, back dunes, and other sand and gravel areas deposited by wave or wind action. Coastal sand dune systems may extend into coastal wetlands (38 Maine Revised Statutes Sec. 480-B(1)).

The term "sand dune system" is used interchangeably with the terms "beach system," "coastal sand dune," "coastal sand dune system," and "dune system." The statutory definition of "coastal sand dune systems" applies equally to all these terms. Sand dune systems include sand deposits within a marine beach system which have been artificially covered by structures, lawns, roads, and fill. Sand dune systems also include all vegetation which is native to and occurring in the system (06-096 CMR 355(1)(W)).

Typical features include a beach berm, frontal dune and back dune, and a back-barrier marsh system (Figure A1). MGS mapped over 2000 acres of sand dunes along the southern (York, Cumberland, Sagadahoc counties) coastline. About one-quarter is mapped as front dune, and the rest being back dune environments. Based on measurements by MGS, the frontal dune is typically between 125 and 150 feet in width, while back dunes can be about twice that or more, depending on the beach system.

Most of Maine's beaches have a dry beach width (DBW), which is the distance from the approximate mean high-water contour to either the edge of vegetation or seawall. This is an excellent proxy for the buffering capacity of the beach but is also a good indicator of the availability of recreational space and habitat for nesting shorebirds. Analysis of dry beach widths for data through fall 2020 by MGS found that the averaged dry beach width along Maine's monitored beaches was 83 feet. Along natural beaches (beaches with natural dunes and no seawalls), the average DBW was 88 feet, while along armored beaches (those backed by a seawall), the average DBW was 51 feet. Maine's Beach Mapping Program (MBMAP) keeps track of the dry beach width, along with shoreline positions of the dune and high water line, and how they change from year-to-year. This data is updated in the fall for each previous year.

Beach and Dune Processes

Beaches and dunes are extremely dynamic landforms, changing almost daily in response to waves, currents, tides, and wind. Beaches and dunes in Maine generally see several different kinds of erosion:

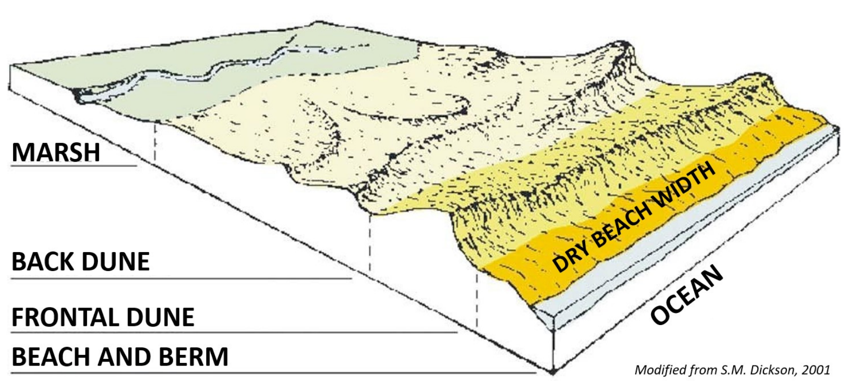


Figure A1. Schematic showing dominant features of a barrier-beach sand dune system.

seasonal changes, short-term (storm-induced) erosion, long-term erosion, and inlet erosion.

Seasonal changes. Typically, beaches and dunes undergo a seasonal transformation from a "summer" beach shape in the summer to early fall months to a "winter" beach shape in the winter and early spring months. The "summer" beach shape typically has a well-developed and wide berm on the beach, and more established, taller, and vegetated frontal dunes. As storminess and wave height (along with a general change in wave and wind direction) increase during the fall and winter months, beach berms and dunes erode in response. This results in a reduction in the buffering dry beach width and a lowering of the beach. Sand is typically pulled offshore from the upper portions of the beach in order to form protective offshore sandbars. The result is typically a flatter, more concave, beach shape during the winter than the summer (Figure A2). The sandbars that build offshore in winter help protect the beach by causing waves to break farther offshore. As conditions subside in the late spring and early summer months, smaller, calmer waves dominate, and sand slowly returns to the beach and berm, and the beach and dunes typically recover. Figure A3 is an example of summer vs. winter beach shapes at Kinney Shores in Saco from 2008. Note the wide sandy berm in the

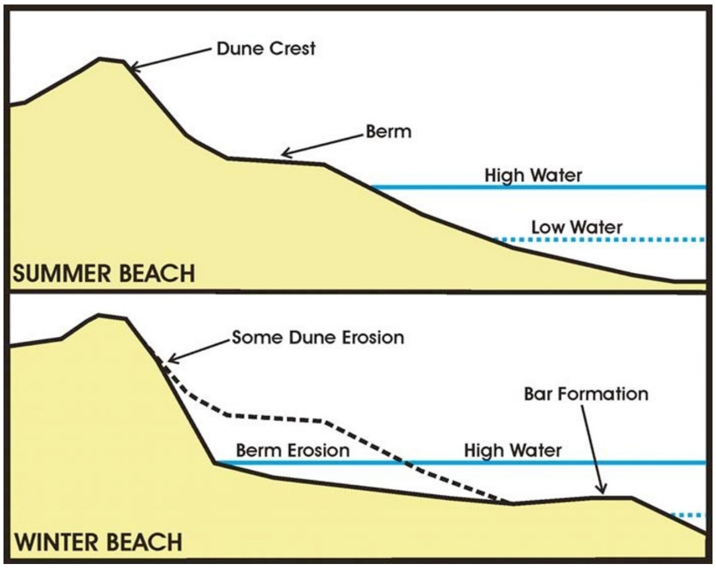


Figure A2. Schematic showing seasonal changes that many beaches undergo between summer (top) and winter (bottom).

Figure A3. Comparison of summer (top) and winter (bottom) beach profile shapes from Kinney Shores, Saco. Images from Maine Beach Profiling Program volunteers, 2008.

summer image and the flatter, concave beach in the winter image. This is a seasonal cycle that generally maintains a beach profile of equilibrium as long as sediment is not permanently lost offshore. The key here is that the berm is what generally undergoes the most seasonal change seen on the beach.

Short-term (storm-induced) erosion. Generally, this kind of erosion can be in response to a single large storm event or series of storm events that cause significant erosion. Typically, these occur in the fall, winter, or early spring months when the "seasonal" beach profile is already lean in shape. Changes seen at the beach are similar to the seasonal changes, such as lowering of the beach, extensive loss of the berm, or exposure of marsh peat or tree stumps near mid-tide on the profile. Change can also include extensive dune erosion and sometimes leave a scarp (a vertical drop in the front of the dune). Short-term erosion can result in extensive overwash in which sand washes onto or landward of the dunes during storm events. Cumulative storm erosion can lead to the complete loss of the frontal dune so that erosion extends into forested areas (Figure A4). Figure A5a shows scarping, while Figure A5b shows overwash. Figure A5c exposure of marsh peat in the surf zone, while Figure A5d shows frontal dune erosion into forested uplands.

Post-storm recovery follows a similar process of seasonal beach rebuilding, with offshore sandbars providing protection and a sand source. After a storm and in response to smaller waves, there is a slow, landward movement of sand that leads to the gradual rebuilding of the berm. This process can start right after a storm. Beach recovery can take weeks and be interrupted by additional storms. Extreme erosion from one or more storms may take a year or more to rebuild. Dune recovery is a slower process which involves re-establishing dune vegetation, wind transport of sand, and other processes. It can take several seasons to several years for a dune to recover elevation and vegetation naturally after a large storm.

Long-term erosion. By definition, long-term erosion is permanent erosion occurring over longer periods of time, typically decades. Long-term erosion can be caused by numerous factors, including a deficiency in longshore sediment transport caused by engineering structures (i.e., a jetty) or a decrease in available sediment due to impoundment behind river dams. It can be caused by tidal river dynamics that cause the migration of sand into ebb- or flood-tidal deltas that function as sediment sinks or traps. It can also be caused by rising sea level and a deficient sediment budget, in which the rate that sand is delivered to a beach cannot keep up vertically with sea-level rise or the rate of offshore loss due to storms carrying sand into ever deepening water.

Generally, almost all Maine beaches are transgressing or moving landward in response to coastal storms and gradual sea-level rise. This landward migration of the beach and dune system is like the motion of a tank tread - the beach migrates over eroded dunes and dunes move into uplands in response to storms and sea-level rise (Figure A6).

Inlet Erosion. Tidal inlets tend to be quite dynamic features. Channels meandering and change shape in response to storms, flooding, and altered sand supply. In fact, some of the fastest changing beach shorelines are typically found adjacent to tidal inlets (Rogers and Nash, 2003). Inlets can meander predictably or unexpectedly in one direction or another in response to storms. Some may migrate in a single direction continuously. Some inlets migrate in a single direction for a certain amount of time until they reach a point where they abruptly jump back to their original starting place in a process called avulsion.

A great example of this phenomenon is the Morse River at Popham Beach State Park in Phippsburg. The channel of the Morse migrated dramatically to the northeast over the past few decades eroding large

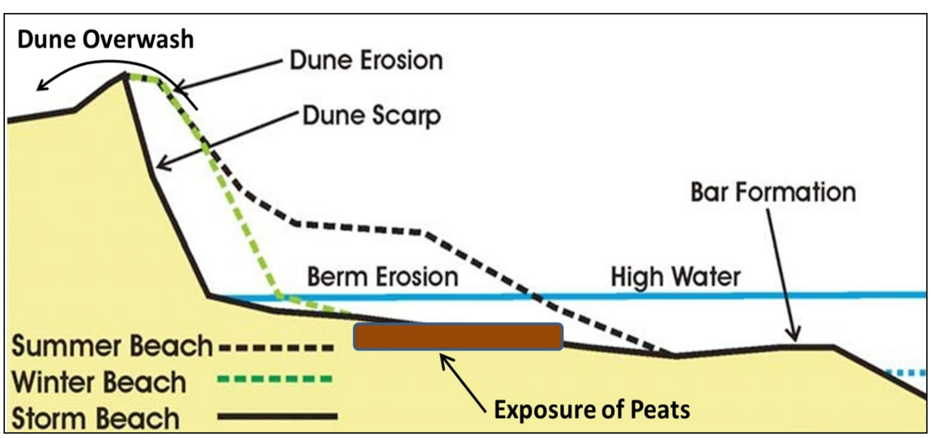


Figure A4. Schematic showing typical storm induced erosion features of the beach and dune.

Figure A5a. Dune scarp after a storm event at Pine Point, Scarborough, ME. Image by P.A. Slovinsky, March 2018, MGS.

Figure A5b. Overwash after a storm event at Ferry Beach State Park, Saco, ME. Image by P.A. Slovinsky, March 2018, MGS.

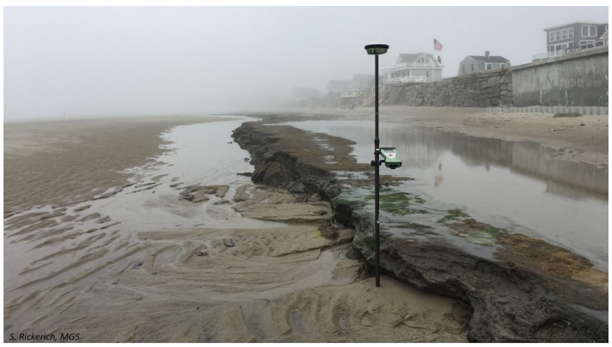


Figure A5c. Exposure of historic marsh surface (peat) along the beach at Fortunes Rocks Beach, Biddeford, ME. Image by S. Rickerich, July 2018, MGS.

Figure A5d. Complete erosion of the front dune into a pitch-pine upland near Ferry Beach State Park, Saco, ME. Image by P.A. Slovinsky, March 2019, MGS.

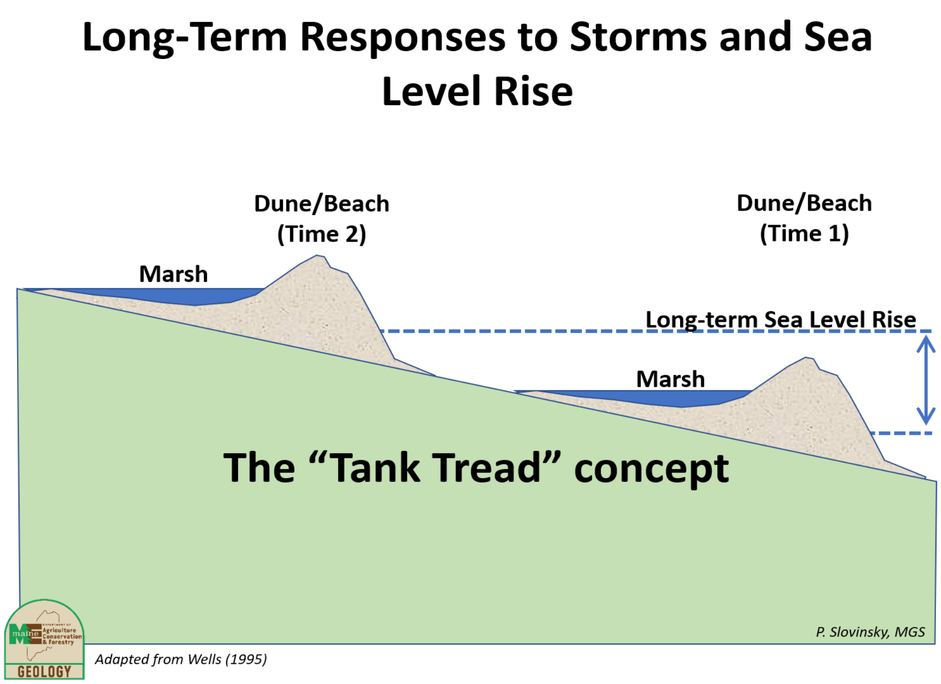


Figure A6. Schematic showing long-term landward migration of the beach and dune due to storm events and overwash, and sea level rise. This is referred to as the "tank tread" concept as the beach rolls over itself in a landward direction in response to long-term changes.

stretches of Popham Beach. Meandering moved the channel several hundred feet inland. Frontal dunes and a pitch pine back dune forest eroded over a few years. The channel into the State Park and near its main bath house. The river underwent a dramatic course change in 2010 and opened a new channel through dunes to the west, adjacent to bedrock headlands, and over half a mile away. The Maine Geological Survey completed a series of publications documenting migration of the Morse River and subsequent erosion at Popham Beach State Park:

- Tombolo Breach at Popham Beach State Park
- Seawall and Popham Beach Dynamics
- Storm and Channel Dynamics at Popham Beach State Park
- Migration of the Morse River into Back Dunes at Popham Beach State Park
- Setting the Stage for a Course Change at Popham Beach

In some inlets, jetties (or stabilization on one side by seawalls) don't allow natural alongshore migration to occur, but nearby beach erosion remains an issue, likely due to sediment movement associated with ebb- or flood -tidal delta formation. For example, Western Beach in Scarborough adjacent to the Scarborough River has undergone extensive erosion due to tidal river dynamics. In order to try to maintain the beach for recreational use and habitat, the U.S. Army Corps of Engineers nourished the beach in 2005 and subsequently in 2015 (along with a dune restoration project). However, the beach continues to erode at relatively high rates. Once again, the Maine Geological Survey published a series of reports documenting inlet changes and subsequent responses:

- Beach Nourishment at Western Beach, Scarborough, Maine: Benefits for the Beaches and the Birds
- Shoreline Erosion at Western and Ferry Beaches, Scarborough, Maine
- Status of Beach and Dune Restoration at Western Beach, Scarborough

Erosion of Maine's Beaches and Dunes

Coastal erosion and associated flooding from storm events not only impact public and private property directly, but also compromises the ability of beaches to:

- buffer adjacent development from storms and flooding;
- provide vital natural habitat; and
- accommodate recreation and attract tourism.

Erosion problems in Maine are generally caused by a persistent rise in sea level, storms, changes in sand availability, and the construction of jetties and seawalls. MGS determined that about 43% of Maine's southern sandy beaches (in York and Cumberland Counties) are armored with hard engineering structures. These structures limit the natural ability of beaches and dunes to move in response to storm events and to properly maintain themselves by exchanging sediment. In addition, a large majority of coastal engineering structures and sand dunes are lower than the predicted base flood elevation shown on FEMA Flood Insurance Rate Maps (see Coastal Structure and Dune Crest Inventory and Overtopping Potential Viewer).

The 2017 Integrated Beach Management Program Working Group Report (IBMPWG, 2017) determined that of the approximate 21 miles of sandy beaches in York, Cumberland and Sagadahoc Counties that are monitored:

- About 17% of the 21 miles of beaches have high erosion rates (over 2 feet per year);
- About 24% have moderate erosion rates (between 1 and 2 feet per year);
- About 41% have low erosion rates (less than 1 foot per year); and
- About 17% are stable or gaining sand.

Resources to Help Identify Dunes and Beach Hazards

Numerous resources are available to help understand beach and dune erosion and coastal flood exposure. These include:

Maine Geological Survey Coastal Hazards Viewers

- Maine Beach Mapping Program Viewer
- MGSCollect/Southern Maine Beach Profiling Program
- Maine Coastal Structure and Dune Crest Inventory and Overtopping Potential Viewer
- Maine FEMA Flood Insurance Rate Maps Viewer
- Maine Highest Astronomical Tide Line (HAT) Viewer
- Maine Sea Level Rise and Storm Surge Viewer
- Maine Sea, Lake and Overland Surges from Hurricanes (SLOSH) Viewer
- Living Shoreline Decision Support Tool for Casco Bay

Other Useful Resources:

- State of Maine's Beaches reports
- Maine Coastal Sand Dune Geology Maps
- Maine Coastal Marine Geologic Environments (CMGE) Maps
- Coastal Barrier Resource System (CBRS) Maps
- Coastal Flooding Nomogram for Portland, Maine
- Maine Flood Resilience Checklist

MGS Coastal Hazards Viewers

Maine Beach Mapping Program. As part of the Maine Beach Mapping Program (Slovinsky and Nutt,

2020) each year, MGS scientists map the seaward edge of dune vegetation, the edges of seawalls, and the approximate mean high water line. Along most beaches, dune vegetation has been mapped since 2007, while the newer features have only been mapped over the past few years. By comparing the positions of these different shoreline types from year-to-year, MGS can calculate several different features that are displayed in the MBMAP viewer:

- Shoreline Positions and Types (vegetation line, seawall, or high-water line);
- Dune Change Rates (calculated by comparing the dune "shoreline" from year-to-year);
- Beach Change Rates (calculated by comparing the mean high-water line "shoreline" from year-to-year);
- Dry Beach Width (the width of the beach between the mean high-water line and a seawall or edge of dune for the current survey year); and
- Dry Beach Width Change (the change in dry beach width from the previous year to the current year).

Dune change rates (in feet per year) give an indication of how the dune has been changing over time; dune positions can be influenced by storms or human-based efforts, such as dune restoration or dune planting. Beach change rates (in feet per year) indicate how the beach has changed over time. The dry beach width (calculated for each year) is an indicator of the buffering capacity of the beach and indicates how much beach space is available for recreation and for habitat. The MBMAP webpage also includes a Frequently Asked Questions section.

As of 2020, there were beaches in 16 communities monitored by MBMAP:

- Crescent and Seapoint Beaches, Kittery;
- Long Sands and Short Sands Beaches, York;
- Ogunquit Beach, Ogunquit;
- Wells, Drakes Island, and Laudholm Beaches, Wells;
- Crescent Surf, Parsons, Great Hill, Mothers, Goochs and Colony Beaches, Kennebunk;
- Goose Rocks Beach, Kennebunkport;
- Fortunes Rocks and Hills Beaches, Biddeford;
- Camp Ellis, Ferry, Kinney Shores, Bayview Beaches, Saco;
- Old Orchard Beaches, Old Orchard Beach;
- Pine Point, Ferry, Western, Scarborough, and Higgins Beaches, Scarborough;
- Crescent Beach State Park and Kettle Cove Beach, Cape Elizabeth;
- Willard Beach, South Portland;
- Indian Point, Chandler Cove, Sandy Point, and Roses Point, Chebeague Island;
- Small Point and Popham Beaches, Phippsburg;
- Reid State Park, Georgetown; and
- Pemaquid Beach, Bristol.

Southern Maine Beach Profiling Program. The MGS Collect/Southern Maine Beach Profiling Program (SMBPP) collects beach profile data with trained volunteers. Beach profiles are shore perpendicular topographic transects of the beach extending from a seawall or dune to the low water that are collected using a simplified survey method developed by Emery (1961). Volunteers have been collecting data at set locations since 1999. As of 2020, beaches in 10 different communities that were being monitored, including:

- Long Sands Beach, York (2 profiles);
- Ogunquit Beach, Ogunquit (2 profiles);
- Wells Beach (3 profiles), Drakes Island Beach (2 profiles), Laudholm Beach (3 profiles), Wells;
- Goochs Beach, Kennebunk (4 profiles);
- Goose Rocks Beach, Kennebunkport (4 profiles);
- Fortunes Rocks Beach, Biddeford (2 profiles);
- Ferry Beach (4 profiles), Kinney Shores (2 profiles), Saco;
- West Grand Beach, Old Orchard Beach (4 profiles);
- Higgins Beach, Scarborough (3 profiles); and
- Willard Beach, South Portland (4 profiles).

Coastal Sand Dune Crest and Coastal Engineering Structure Viewer. For open coast communities along the York and Cumberland County shorelines, MGS created a Coastal Structure and Dune Crest Inventory and Overtopping Potential which allows for stakeholders to view several different important coastal features, including the linear extent of protective coastal sand dune crests and coastal engineering structures. For this viewer, coastal engineering structures include riprap, bulkheads (or a combination of the two), breakwaters, and jetties. This same viewer also shows coastal engineering structures for communities in Casco Bay, from South Portland to Phippsburg. Note that sand dune crests have not been mapped in the Casco Bay region.

The viewer allows users to inspect the linear extent of sand dune crests and coastal engineering structures. It also allows closer inspection of the elevations of sand dune and coastal engineering structures in relation to FEMA Base Flood Elevations (BFEs) from preliminary Digital Flood Insurance Rate Maps (DFIRMS), which are discussed below.

Maine Floodplain Management Program's FEMA Flood Insurance Rate Maps Viewer. Low-lying coastal areas along the open coast are susceptible to coastal flooding and are defined by the Federal Emergency Management Agency (FEMA) as Special Flood Hazard Areas, or SFHA. SFHA are areas that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. The elevation of the 1% annual chance flood is also referred to as the base flood elevation (BFE) or 100-year flood elevation. These flood zones are mapped by FEMA in a series of maps called the Flood Insurance Rate Maps (FIRMs). FIRMs are used to identify flood insurance risk and insurance premiums in areas associated with different flooding events. Maps include areas of the SFHA in addition to areas of minimal flood hazard, which are areas outside of the SFHA and higher than the elevation of the 500-year (0.2% chance of being equaled or exceeded each year) flood elevations. Most flood zones have a determined base flood elevation, or BFE, which is the elevation to which flooding is expected during a 1% flood event.

The most commonly defined flood zones include the "VE" or "Velocity zone" (with a defined base flood elevation) and "AE" or "A-zone" with a defined base flood elevation. Velocity zones, or V-zones, are dynamic hazard zones where the BFE has been determined and includes waves of 3 feet or larger, while A-zones are considered more "static" flood zones. A-zones can include "Coastal A" zones, which are typically landward of a V-zone along the open coast and can have waves of between 1.5 and 3 feet. Figure A7 depicts a profile view of the different flood zones in reference to a transect along the coastline.

Most FEMA FIRMs are now available as digital FIRMs, or DFIRMs and can be viewed at the Maine Floodplain Management Program's Online Viewer or from the FEMA Map Service Center. The Maine Floodplain Management Office's Maine Floodplain Management Handbook can also be a great resource for property owners.

Maine Highest Astronomical Tide (HAT) Viewer. MGS created a mapping tool representing the limits of the Highest Astronomical Tide, or HAT, which enables users to view the approximate limits of the highest astronomical tide, which is a regulatory boundary for Maine's Shoreland Zone (for the Maine Department of Environmental Protection) and for the U.S. Army Corps of Engineers jurisdiction. The HAT can also be used to visualize where inundation might occur during "King Tide" events. The limits of HAT have been estimated by adjusting tidal predictions at NOAA tide stations with a tool called VDATUM and interpolating tidal elevations along sections of the coastline with no tide predictions. This allows for an estimation of the value and limits of the HAT. Note that this tool doesn't account for tidal restrictions (besides those allowed for by tide predictions) and should only be used for general planning purposes. Site-specific HAT measuring and mapping may still be needed for certain sites along the Maine coast, especially those with tidal restrictions or up at the heads of rivers/estuaries. A Frequently Asked Questions section is included with the data.

Maine Sea Level Rise and Storm Surge Viewer. Using the HAT as the starting point, MGS created a mapping tool representing potential sea level rise and/or storm surge scenarios along the Maine coast. The sea level rise scenarios were developed by using available long-term sea level rise data from Portland, Bar Harbor, and Eastport tide gauges and the U.S. Army Corps of Engineers Sea-Level Change Curve Calculator (v. 2017.55; USACE, 2019) and sea level rise scenarios established by NOAA et al. (2017) prepared for the U.S. National Climate Assessment. Scenarios were averaged for all three tide gauges and include low, intermediate

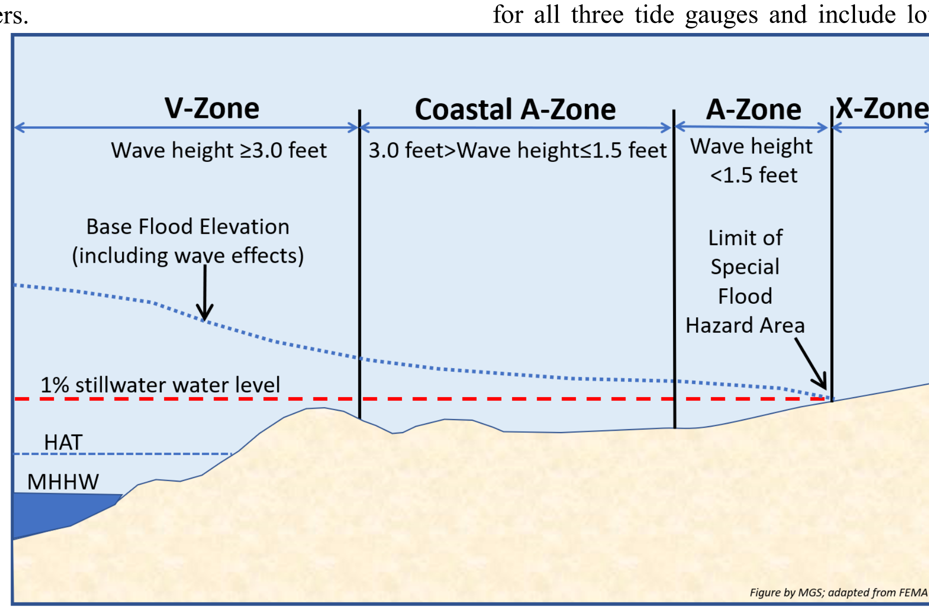


Figure A7. Profile view of the storm stillwater level, Special Flood Hazard Areas (dark blue, VE, Coastal A, and AE zones) and the 500-year floodplain (X-zone) in reference to beach and dune topography. Adapted by MGS from FEMA.

low, intermediate, intermediate high, high, and extreme sea level rise at the 50% confidence interval. These scenarios can be viewed as future sea level rise on top of the HAT, or storm surge on top of the current HAT, or a combination of a future sea level rise and storm surge. A Frequently Asked Questions section is included with the data.

Maine Sea, Lake and Overland Surges from Hurricanes (SLOSH) Maps. MGS worked with FEMA, NOAA, and the U.S. Army Corps of Engineers to develop hurricane inundation maps for the Maine coastline. These maps were created using maximum of "maximum envelopes of water", or MOMs, from the National Hurricane Center's SLOSH model, and overlain onto a digital elevation model of the Maine coastline. The maps represent potential inundation from landfalling hurricanes from Category 1 to 4 strength and were used by the Maine Emergency Management Agency in preparing hurricane evacuation plans for Maine's coastal counties.

Living Shoreline Decision Support Tool for Casco Bay. MGS developed a decision support tool to help guide planning-level decisions relating to the siting of living shorelines in Casco Bay. This tool accounts for a variety of factors, such as fetch, bathymetry, landward and seaward shoreline types, relief, slope, and aspect and provides an overall ranking of the general suitability (using stop light red, yellow, green color-coding) of a shoreline for green infrastructure approaches. Note that this tool is a planning-level guidance tool only, and site-specific decisions should be made in conjunction with trained professionals.

Other Useful Resources

State of Maine's Beaches Reports. Every two years, MGS compiles a "State of Maine's Beaches" report, which is released in conjunction with the Beaches Conference, a biennial event which brings together coastal stakeholders from the Maine and New England region. Reports generally describe the trends observed from analyzing data from SMBPP (and more recently, MBMAP). In general, reports are more qualitative than quantitative, though some reports focus more on statistical analyses than others. The 2019 report focuses solely on MBMAP data, while a supplemental report focuses on new methods for analyzing beach profile results. The following reports are available:

- State of Maine's Beaches in 2007 (Slovinsky and Dickson, 2007)
- State of Maine's Beaches in 2009 (Slovinsky and Dickson, 2009)
- State of Maine's Beaches in 2011 (Slovinsky and Dickson, 2011)
- State of Maine's Beaches in 2013 (Slovinsky, Dickson, and Dye, 2013)
- State of Maine's Beaches in 2015 and a Summary (Slovinsky, Dickson, and Adams, 2015)
- State of Maine's Beaches in 2017 and a Summary (Slovinsky, Dickson, and Cavagnaro, 2017)
- State of Maine's Beaches in 2019 (Slovinsky, Dickson, and Corney, 2019) and
- 2019 Beaches Conference: Maine Beach Profiling Program Posters (Corney, Slovinsky, and Dickson, 2019)

Coastal Sand Dune Geology Maps. The MGS created Coastal Sand Dune Geology Maps that identify the frontal dune and back dune areas along the majority of Maine's larger beach systems in southern and mid-coast Maine. These maps are also available through MGS' Coastal Sand Dune Geology Map Web App and through the local Maine DEP office, and at your town office. These maps are regulatory in nature and are referenced in Maine DEP's Chapter 355 of the Natural Resources Protection Act. The photographic maps are meant to identify dominant dune features of the coastal sand dune system, including frontal (D1) and back (D2) dunes, along with Erosion Hazard Areas (EHA), portions of the coastal sand dune system that may become part of a coastal wetland over the next 100-years from the combined impacts of long-term erosion, short-term erosion, and potential sea level rise. Please note that additional dunes along the rest of Maine's coastline have been mapped but, as of 2000, data have not been released.

Coastal Marine Geologic Environment (CMGE) Maps. The MGS Coastal Marine Geologic Environment (CMGE) maps show regional geologic characteristics of the Maine coast. They illustrate which areas are rocky, muddy, sandy, etc. along the shoreline between the high - and low-tide lines. These maps include sand and gravel beaches and dunes in areas of the state where MGS has not published detailed sand dune maps. These maps illustrate the location of salt marshes and other tidal wetlands for evaluation of coastal habitats, impact of dredging, and siting of coastal facilities.

Coastal Barrier Resources System (CBRS) Maps. Some coastal beach and dune systems are classified as part of the Coastal Barrier Resources System (CBRS), comprised of generally undeveloped barrier beaches that were stablished as part of the Coastal Barrier Resources Act. In these locations, public funding for infrastructure or erosion protection is not permitted, and flood insurance is not available through FEMA. Most of Maine's largest developed beaches are not part of the CBRS. Maps showing the geographic extent of the Coastal Barrier Resources System are available via the U.S. Fish and Wildlife Service's CBRS Mapper. Maine Revised Statutes Title 38 Chapter 21 has listed the coastal barriers within the Maine Coastal

Barrier System, which differs slightly from the USFWS designation.

Coastal Flooding Nomogram for Portland, ME. The National Weather Service and the Northeast Atlantic Regional Coastal Ocean Observing System (NERACOOS) have developed a simple model that predicts when coastal flooding may occur given water levels and wave heights. This predictive model, called a nomogram, has been developed for the Portland area, and predicts when simple splashover begins, followed by mild, moderate, or severe beach erosion and coastal flooding.

Maine Flood Resilience Checklist. The Maine Coastal Program created the Maine Flood Resilience Checklist as a non-regulatory self-assessment tool designed to assist Maine communities evaluate how well positioned they are to prepare for, respond to, and recover from flooding events and sea level rise. It offers an integrated and practical framework for examining local flood risk, evaluating vulnerability of the natural, built, and social environments, and identifying opportunities to enhance flood resilience. Additionally, it allows communities to identify specific intervention points where local decision-makers can develop policy, strategies, and actions to address areas of vulnerability. The Checklist can help communities integrate sea level rise considerations into comprehensive plans, strengthen local floodplain ordinances, and incorporate resilience activities into capital improvement plans. It is recommended that the Checklist be completed at the municipal level in conjunction with support staff.

Regulations Governing Dunes, Beaches, Coastal Erosion and Coastal Flooding. There are many local and state regulations that apply to activities on or adjacent to beaches and dunes. To help guide property owners, the Maine DEP has released A Homeowner's Guide to Environmental Laws Affecting Shorefront Property in Maine's Organized Towns (Maine DEP, 2000).

Natural Resources Protection Act (NRPA). Maine's Natural Resources Protection Act (NRPA) provides for the protection of specific natural resources in Maine. The most applicable Rules from the NRPA for this section include the following Chapters:

Permit by Rule (Chapter 305). Some activities within the coastal sand dune system can be undertaken with a Chapter 305, Permit By Rule (PBR). A PBR activity is considered one that will not significantly affect the environment if carried out in accordance with Chapter 305 standards, and generally has less of an impact on the environment than an activity requiring an individual permit. A PBR satisfies the Natural Resources Protection Act (NRPA) permit requirement and Water Quality Certification requirement. Specific attention should be paid to Section 16. Activities in Coastal Sand Dunes.

Maine Wetland Protection Rules (Chapter 310). Portions of Maine NRPA regulate activities that occur in coastal wetlands, which may exist in the coastal sand dune system, or vice versa. Coastal wetlands are defined as:

all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the highest tide level for the year in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes. (Title 38, §480-B, 2).

Activities that extend into defined coastal wetlands – based on the highest tide level for each year - will likely require a permit from Maine DEP. To support these regulations, MGS provides Maine DEP with a listing of the highest annual tide (HAT) elevations for many portions of the Maine coastline, based on NOAA tide gauge data.

Coastal Sand Dune Rules (Chapter 355). The Maine Natural Resources Protection Act (NRPA) includes Chapter 355, Coastal Sand Dune Rules, which governs activities within the mapped Coastal Sand Dune System. The Coastal Sand Dune Rules, administered by Maine DEP, have specific guidelines for activities that require permits, or for *de minimus* activities, those not requiring permits. Maine DEP has also released a very helpful bulletin on Common Questions and General Guidelines for Repair or Rebuilding in the Coastal Sand Dune System.

Maine's Shoreland Zoning. By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 feet of the normal high-water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance. In coastal areas, the shoreland zone is defined by the highest annual tide. Shoreland Zoning creates different types of districts within which you might be located that regulate certain activities within those districts, based on the presence of specific resources and uses. It is also used to establish certain setbacks from resources. Maine DEP maintains a Mandatory Shoreland Zoning page which has a lot of pertinent information.

Municipal Floodplain Management Ordinance. Maine's coastal communities have a minimum state requirement that first floor elevations of habitable structures be at least one foot above the effective FEMA Base Flood Elevation (BFE). Your community might have adopted higher standards.

Consult your local Town Code Enforcement or

Planning Department to determine the specific regulations within your Municipal Shoreland Zone and Municipal Floodplain Management Ordinance.

Federal Clean Waters Act and Rivers and Harbors Act. Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act govern activities within coastal wetlands (and therefore waters associated with beaches) and tidal creeks and adjacent rivers. Permits are administered by both the U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (USEPA). Many regulated activities in Maine are governed by a Maine General Permit. Federal permitting review typically includes review comments provided by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Environmental Protection Agency.

Eroding Beaches and Dunes: What can I do?

Whether you are considering buying, building, or modifying a coastal property, there are several overall strategies for addressing erosion along open beaches.

1. Identify the hazard(s) and classify the level of risk
2. Determine if the hazard(s) identified can be mitigated.
3. Determine if the risks associated with known hazards are acceptable.
4. Determine setbacks or elevation standards.
5. Get appropriate permits.
6. Appropriately adapt to or mitigate the hazard.
   a. Do nothing.
   b. Avoid the hazardous area.
   c. Design and build properly.
   d. Elevate or relocate existing infrastructure.
   e. Severe damage and reconstruction
      i. Emergency actions to protect property.
      ii. Seawall reconstruction or enhancement.
   f. Consider best management practices for dunes and green infrastructure approaches
      i. Post-storm driftwood, litter, and overwash management.
      ii. Seaweed management.
      iii. Simple and enhanced dune fencing.
      iv. Cobble-trapping fencing.
      v. Dune path and walkover management
      vi. Dune restoration or creation
      vii. Beach scraping
      viii. Beach nourishment

These actions, along with pros and cons, the effort and comparative costs involved, are summarized in Table A1.

Beaches, Dunes, and Coastal Erosion and Flooding Hazards Response Actions				
Action	**Pros**	**Cons**	**Effort**	**Cost**
Do Nothing	No to low cost; easy to implement	Must accept a level of risk; uncer-	Low	$
Avoid Hazardous Area	Reduces hazard to new structures; part of design phase	Applicable to new construction only; site constraints	Low	$
Design and build properly	Reduces hazards to new structures; part of design phase	Applicable to new construction only; site constraints	Low-Mod	$-$$
Elevate or relocate	Reduces hazards to structures	Site constraints; hard and expensive to elevate or relocate large structures	Mod-High	$$-$$
Manage overwash and litter	Easy to implement	None	Low	$
Manage seaweed	Easy to implement; aids dune growth	None	Low	$
Use dune fencing	Easy to implement, aids dune growth	Must be maintained seasonally	Low	$
Use cobble-trapping fencing	Reduces impacts to structures	Limited to cobble-dominated systems; need to be maintained	Low-Mod	$-$$
Build or change dune access	Reduces impacts to dunes and structures	Site constraints; must work with neighbors; permitting	Low-Mod	$-$$
Restore or create sand dunes	Reduces impacts to structures using green approaches	Site and timing constraints; permitting; must be maintained	Low-Mod	$-$$
Beach scraping	Reduces impacts to structures using green approaches	Temporary response; site and timing constraints; permitting	Low-Mod	$-$$
Beach nourishment	Reduces impacts to structures using green approaches; creates habitat	Costly; permitting; site and timing constraints	Mod-High	$$-$$$

Table A1. Table summarizing beach, dune and coastal erosion and flooding response actions in terms of pros, cons, level of effort, and generalized costs. Note costs are for comparative purposes only.

1. Identify the hazard(s) and classify the level of risk

One of the first things that an individual can do in determining beach, dune, and coastal flood hazards for his or her property is to identify the hazard using the numerous resources described previously in conjunction with doing a field inventory of the property. Some of these "in the field" signs are outlined below, and may illustrate short-term erosion problems, while others indicate a long-term shoreline response. The next step is to classify the level of risk associated with each hazard. To aid in this, MGS created a summary checklist that asks the above questions and helps classify the level of risk for your property or structure (see Beach, Dune, and Coastal Flooding Checklist, Appendix A). This checklist helps simplify the questions below. *Especially in areas of high erosion and instability or flooding, it is recommended that you have a licensed geologist, licensed engineer, or a coastal floodplain expert investigate your property to help you further classify the risk*.

As you look at your property, ask yourself some of these questions:

How far from the highest astronomical tide (HAT) is the structure on your property? Distance from your structure to the HAT is an indication of how close your property might be to erosion and flood hazards. You can use the Highest Astronomical Tide Viewer to inspect this. Note that your property might be close to the HAT, but on a shoreline with a steeper slope which makes flooding less of an issue.

Is your property or structure located in a frontal dune, Erosion Hazard Area (EHA), back dune, or not a dune? Frontal dunes and EHAs are the most dynamic dune areas (subject to erosion and dynamic flooding), while back dunes tend to be more stable (but potentially exposed to flooding). Being in these areas also restricts development and may impose elevation requirements for a structure. Properties or structures outside of the mapped dune system are generally at less risk. Use the MGS Coastal Sand Dune Geology Web App to inspect this.

Is your property or structure located in a FEMA Special Flood Hazard Area? FEMA Coastal A, AO, V, and VE flood zones are the most dynamic and unstable flood zones, indicating that stillwater flooding *and* waves of a certain size will wash through the property in a larger storm. Your risk is slightly lower if you are in an A or AE zone, where waves are smaller. If you are in an X-zone or are not located in a mapped A, AO or V zone, you likely don't have flood insurance because your overall risk of coastal flooding is low. If your property is in an SFHA and is elevated, you should determine how high above or below the FEMA base flood elevation parts of the structure are. You can use the Maine Flood Hazard Map Viewer or the FEMA Map Service Center to determine if you are in a flood zone.

If your structure is in the FEMA Special Flood Hazard Area, is your structure elevated to at least 1 foot above the base flood elevation? If your property is located in an SFHA, is it elevated? You should determine how high above the FEMA BFE your property is and whether it meets your community's municipal floodplain management ordinance. Check with your municipal code enforcement officer to determine your community's standards. If your structure doesn't meet these standards, it is at much higher risk to flooding and possibly wave damage during storms.

In the past 2 decades, has your structure ever flooded? Flood frequency of a structure indicates its current level of risk to storms and potential future sea level rise.

How big is your structure? Greater than or less than 2,500 square feet? The size of your structure has implications on whether it can be easily moved or elevated in response to coastal erosion or flooding. Structures that are smaller are much easier (and less costly) to elevate or move back on a property.

Is your structure built to current coastal construction standards? Many of Maine's coastal waterfront properties are older and not necessarily built to current coastal construction standards like the Coastal Construction Manual. (FEMA 2011).

Over the last decade, is the dune on your property eroding, stable, or accreting? If your dune is consistently eroding at rates of 2 feet per year or greater, that means you likely have an ongoing erosion problem. If it's less than that but still negative, it warrants further monitoring and investigation. If your dune is stable or growing, that means there is adequate sediment supply to maintain the natural dune. You can use data from the Maine Beach Mapping Program to evaluate longer-term shoreline changes of your dune.

After big storms, does the beach and dune on your property recover after a season or two, or does it stay the same or continue to get worse? It is natural for a dune to erode or get scarped in response to storm event. Erosion of the frontal dune can be on the order of 10-15 feet from larger events. With scarping of the dune, it can take a season or two for a dune to recover. If your dune recovers and starts to grow seaward, that means that your property has adequate sediment supply. If your dune continues to erode, you may have an ongoing erosion problem. After storms, look for exposed tree roots or peat (former marsh deposits) in the surf zone. These are an indicator that the sand supply in front of your property may not be high enough to maintain the beach. If these features get covered relatively quickly, that's a sign that the sand supply is adequate.

Does your property undergo no flooding or overwash during larger storm events, or is that something you must deal with in every storm? Flooding and overwash are good indicators of a dune trying to move landward in response to storms and sea level rise. If your property only undergoes very infrequent flooding or overwash, this is a sign that the dune is relatively stable. If flooding and overwash occurs frequently (several times a year), this is a sign that your property might be at risk to erosion and flooding.

How high is your dune or seawall when compared to storm water levels? Sand dunes and seawalls with elevations that meet or exceed the shoreline's V-zone BFE are optimal. Larger dune systems form in areas with adequate sand supply. You can inspect your dune or seawall's elevation in reference to BFEs by using the Coastal Structure and Dune Crest Inventory and Overtopping Potential Viewer.

If you have a seawall, how frequently do you have to repair it? Once a decade after large storms? Every year or two? This is a good indication of the stability of the beach where your property is located. Chronic damage to a shore protection structure indicates that the beach is attempting to move in a landward direction.

Do you have a narrow or wide dry beach width? For Maine beaches, this means a seasonally recurring (i.e., summer to fall) wide, dry beach (generally a measurement of greater than 50 feet between the edge of high water and the edge of the dune vegetation). Larger dry beaches form in areas with adequate sediment supply. If you have a very narrow dry beach (<25 feet) with a seawall, you likely live along a stretch of coast with a recurrent erosion problem.

Is your property or structure located adjacent to a migrating tidal inlet? Proximity to a tidal inlet that migrates can increase the erosion hazard of the beach and dune.

2. Determine if the hazard(s) identified can be mitigated

In conjunction with your professional, determine what hazards can expectantly be mitigated, and at what cost. For example, if you have identified an existing flood hazard, can you elevate your structure so that it is above a base flood elevation? As part of this process, remember some of the goals, priorities, and expectations of the use of your property.

- **Be realistic**. It may not be technologically or economically feasible to protect a structure on a beach that is eroding dramatically.
- **Be neighborly**. Think about potential impacts on your neighbor's property that may result from an activity on your property. This is also required as part of the Natural Resources Protection Act review. Explore working with adjacent property owners if a common goal is found or regional approach is being adopted, such as dune restoration.
- **Consider the costs**. When comparing strategies, consider the short- and long-term costs of different strategies.
- **Consider the permit requirements**. Make sure to fully assess the local, state, and federal permitting requirements – and their associated review timeframes and costs.
- **Consider timeframes**. Some activities or strategies may have extended permit review processes, certain habitat types have time of year restrictions that extended construction timelines. Also think about the lifetime of expected use of your property.

3. Determine if the risks associated with known hazards are acceptable

Consider the information that you developed in terms of mitigation as part of #2. Determine *if the level of risk you are willing to accept* meets your goals, priorities, and expectations relating to the use of your property. For example, if you identified an erosion hazard, are you willing to accept the risk associated with potential damage or loss of the structure in 10 years or 30 years?

4. Determine setbacks or elevation standards

If contemplating new construction, determine minimum appropriate setbacks based on your Municipal Shoreland Zoning Ordinance, floodplain ordinances, and applicable state rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or elevate it so that the lowest structural member is a certain height above the minimum base flood elevation if in a flood zone or erosion hazard area. Check with your local Code Enforcement Officer for specific information relating to setbacks and elevation standards.

5. Get appropriate permits

Building in the Coastal Sand Dune System or a Flood Zone, include pursuing potential mitigation strategies that may be subject to regulation under the Natural Resources Protection Act and the Shoreland Zoning Act. Permits from the Maine DEP and your town may be required. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on local and state requirements for permits based on the activities you may be proposing on your property. Maine DEP is available for a pre-application meeting to explain the state standards. The Maine DEP has compiled a guidance document titled Common Questions and General Guidelines for Repair or Rebuilding in the Coastal Sand Dune System which would be helpful for answering regulatory questions.

6. Appropriately adapt to or mitigate the hazard

You can take action to manage or reduce the risk of beach and dune erosion or coastal flooding impacting your property but may require permits (see above). These should be developed in conjunction with the steps involved above, and input from appropriate local experts (licensed geologists, geotechnical engineers, landscape architects, etc.).

Mitigating a hazard or hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., beach or dune restoration, management or dune creation). The mitigation and adaptation strategies listed below can be undertaken one at a time or by using a multi-strategy approach that is most applicable to your case.

NOTE: *In 2006, Maine adopted planning for an expected two feet of sea-level rise over the next 100 years in Chapter 355 (Coastal Sand Dune Rules) and requires that sites show stability after two feet of sea-level rise. In 2020, Maine's Climate Council recommended that municipalities* ***plan to manage*** *for a 3.9-foot rise in sea level from 2000 to 2100 and* ***prepare to manage*** *for a potentially higher scenario. At the time of creation of this guide, these recommendations have not been adopted into regulatory language. However,* ***MGS recommends that adaptation and mitigation plans on beaches and dunes consider this new scenario***.

Do nothing: The "do nothing" alternative, in many cases, makes the most sense. In cases where erosion is minimal and a structure is located a more than adequate distance from an eroding dune, and a measured erosion rate has been determined (in consultation with local experts), coastal property owners can opt to do nothing. Doing nothing is typically a least-cost alternative and does not require permitting. The do nothing alternative must consider the level of risk you are willing to accept in conjunction with the expected uses of your property.

Avoid the hazardous area: Avoiding existing or potential hazards as much as possible can be a very efficient and cost-effective method of mitigation. This alternative is especially effective for the siting of new development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies and costs, and the level of risk you are willing to accept. A common avoidance technique for new or rebuilt structures is to build as far landward as possible, away from the hazard. You may need to request a variance from local setback ordinances in order to do so. Another method could include elevating a structure over and above the minimum base flood elevation standards.

As much as is practicable with your building considerations, consider moving back and moving up to avoid hazards. *Consideration should also be given to significant habitat resources or environmentally sensitive areas*, which are usually identified by shoreland zoning or state regulations. However, it is not always practical for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, property size, cost, or other factors.

Design and build properly: Proper construction techniques involve not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential wind and water forces associated with the dynamic coastal zone. Lot coverage requirements and building restrictions for different dune areas, including some flood hazard zones, are provided in the Coastal Sand Dune Rules (Chapter 355). Additional size limits may exist in your municipal shoreland zoning ordinance or other local regulations. The Federal Emergency Management Agency (FEMA) provides several comprehensive resources on proper coastal construction techniques including the Coastal Construction Manual (FEMA, 2011) and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets (FEMA 2010). Generally, consideration should be given to the following:

- construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- the extent of grading to achieve a stable building footprint;
- the level of engineering required to mitigate for hazards;
- potential hydrostatic and wind loading;
- siting of ancillary infrastructure; and
- general construction standards.

Relocate existing infrastructure: Where existing development is being threatened by coastal erosion or flooding, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction. Although relocation can be very effective in minimizing or mitigating the hazard, this alternative can be expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography and underlying geology, and distance the structure may need to be moved or elevated. Consultation with a local contractor is suggested, and local and state permits may be needed. Relocation of a structure can also be constrained by the size of a property and any applicable local or state setbacks, such as from other existing structures or roadways. In many cases, a property owner can request variances from local setback ordinances in order to relocate a structure.

Elevate structures: Existing structures that are threatened with coastal flooding or erosion can benefit from elevation. If a building is in a FEMA Flood Zone, you are likely required by your town's floodplain management ordinance to have the lowest structural part of your house be a minimum of 1 foot above the Base Flood Elevation (or BFE). This is the minimum standard in Maine, though your community may have higher standards. Chapter 5 – Protecting Structures – of the Maine Floodplain management Handbook provides many of the state requirements regarding the elevation of structures, including a review of techniques. Contact your local Code Enforcement Office for more information.

Any time you are doing substantial improvements to your structure, you may want to consider the cost of elevating the structure using a flow-through foundation or a pile foundation. This may be a requirement if structure improvements meet or exceed 50% of the value of the structure. Flow-through foundations are typically block or poured cement foundations with adequate spacing for floodwaters to flow through the foundation without damaging the supports. These structures are acceptable in the A-zone areas of back dune environments that are not considered to be Erosion Hazard Areas. Pile foundations, though more prevalent on the open ocean coastline, are typically used in more active flooding areas, and provide much more open space for floodwaters to travel through. Piles are required in the frontal dune and in areas of the back dune classified as Erosion Hazard Areas. The concept behind both these foundation types is that water, sediment, and debris can *travel through* the foundation, thus avoiding significant pressure and lateral force to the foundation which causes structural failure. Deep pilings support a structure if there is erosion of the dune surface. Both foundation types can significantly reduce potential flood damage to a structure. In some areas of the back dune, fill can be added below a foundation to increase the elevation of the structure to meet floodplain standards. Fill is generally not recommended, because it can potentially increase flood hazard to adjacent properties, and thus might not meet NRPA standards.

When considering elevating your home, be sure to investigate the cost-benefit of going over your town's minimum elevation standards. Elevating to minimum municipal floodplain ordinance standards (typically 1 foot above the Base Flood Elevation) can save you about 50% on your flood insurance costs. However, the higher you elevate your structure above the 100-year BFE, *the more money you can save on flood insurance* (up to about 70%). In many cases, with new construction or if you are rehabbing an existing structure to meet floodplain standards, the costs of going a foot or two higher are relatively small. By considering elevating your structure higher, you are being more resilient to today's storms, anticipating sea level rise, and saving money on flood insurance. Table A2 shows annual and 30-year cost savings related to elevating structures certain amounts above the floodplain, based on Maine flood insurance premiums. You will likely need a permit from your local municipality, in addition to Maine DEP, to elevate your structure. Check with your local Code Enforcement Office or the Maine DEP for more information.

Severe Damage and Reconstruction: Unfortunately, sometimes the best opportunity for hazard mitigation comes after significant damage to a structure has already occurred. In cases of severely damaged dune structures (those with damage that exceeds 50% of a buildings value), Chapter 355 outlines specific criteria that cover how reconstruction may be permitted within the coastal sand dune system. Requirements depend on the location of the structure (frontal dune, V-zone, back dune, Erosion Hazard Area), whether the structure was damaged by an ocean storm or a different cause, and other standards. Generally, a project is considered a "reconstruction" if rehabilitation*, replacement or other improvement to a building the cost of which equals or exceeds 50% of the building's value prior to the start of the reconstruction* (Chapter 355, 3EE). Reconstruction after severe damage, especially due to an ocean storm, is meant to allow for structures that were old and not necessarily built to modern coastal building standards to have a chance to be rebuilt on a coastal property while decreasing the overall risk to the structure, and its impact on the coastal sand dune system. General guidance relating to reconstruction in the sand dune system to a structure severely damaged by an ocean

Structure Elevation	FEMA A-Zone			FEMA V-Zone		
(in reference to BFE)	Avg. Annual Policy	Cost Savings (%)	30-year savings	Avg. Annual Policy	Cost Savings (%)	30-year savings
At or below BFE	$1,556	$0 (0%)	$0	$7,747	$0 (0%)	$0
1 ft above BFE	$799	$757 (49%)	$22,710	$5,331	$2416 (31%)	$72,480
2 ft above BFE	$574	$982 (63%)	$29,460	$3,648	$4,099 (53%)	$122,970
3 ft above BFE	$509	$1,047 (67%)	$31,410	$2,635	$5,112 (66%)	$153,360

Numbers based on 2012 rates for a one-floor residential structure, no basement, post-FIRM, $1,000 deductible with coverage of $250,000 structure and $100,000 contents
Flood policy rating quotes provided by the Chalmers Insurance Group

Table A2. Typical flood insurance premium savings in Maine from elevating structures in relation to the base flood elevation (BFE).

storm is found at Chapter 355, 6E and 6F.

Emergency Actions to Protect Property: If a local code enforcement officer, state-licensed professional engineer or state-licensed geologist determines that the integrity of a coastal engineering structure is destroyed or threatened, a coastal property owner may protect private infrastructure from storm damage by doing temporary, emergency fixes to an existing seawall. The specific activities are outlined in §480-W. Emergency actions to protect threatened property.

Seawall Reconstruction or Enhancement: No new seawalls may be constructed along Maine's beaches or sand dune system. However, if a seawall protecting property is damaged, a coastal property owner may replace or repair the seawall in-kind and in-place (i.e., same materials, same dimensions) as the previously existing structure with a Permit by Rule (Chapter 305, 16). Seawall repair or reconstruction requires a survey plan prepared by a licensed engineer, surveyor, or geologist. If a property owner proposes to change their seawall in some way, a full permit through the Coastal Sand Dune Rules (Chapter 355) would be required and the homeowner would have to prove that the replacement structure is *less damaging to the coastal sand dune system, existing wildlife habitat, and adjacent properties than replacing the existing structure with a structure of the same dimensions and in the same location* (Chapter 355, 5E).

Consider best management practices for dunes and green infrastructure approaches: Maine's open coastal beach and dune system are extremely dynamic and energetic. The features which have formed here have adapted to millennia of changes and continue to be some of the best protectors of the shoreline. Living shoreline approaches mimic the natural functionality – and natural protection – afforded by features such as dunes and beaches. The Maine DEP compiled a document titled Common Questions and General Guidelines for Repair or Rebuilding in the Coastal Sand Dune System which would be helpful for answering questions relating to activities in this section.

Coastal sand dunes provide a natural buffer from storm events and can help protect your coastal property. Dunes have a reservoir of sand that is released to the beach during such events. However, sand dunes can only offer so much protection in areas of long-term erosion or areas with chronic erosion problems. Sand dunes will naturally erode or move landward over time in response to long-term erosion and sea-level rise. Therefore, any dune management, enhancement or reconstruction activities need to keep in mind that the landform is dynamic and take into account dune migration in light of the short-term, long-term, storm, and inlet erosion at a particular site. For existing sand dunes – especially for those with lower long-term erosion rates – **dune management and enhancement** might be all that is needed to help maintain the storm protectiveness of the sand dune. MGS created a Beach and Dune Best Management Practices Handout for dune management. This includes "low hanging fruit" activities which can help dunes, including:

- post-storm driftwood, litter and washover sand management;
- seaweed management;
- simple dune fencing;
- enhanced dune fencing;
- cobble trapping fencing; and
- dune path and walkover management.

Several green infrastructure or "living shoreline" approaches for dune management include:

- dune restoration or creation;
- beach scraping; and
- beach nourishment.

Note that dune management projects are most effective and durable for longer stretches of the coastline as opposed to just individual properties. Therefore, this Guide recommends that projects be considered by multiple property owners when considering dune management strategies.

In Maine, dune management activities are limited by specific timing windows, mostly related to seasonality of seed germination and the presence of threatened or endangered species such as nesting least terns or piping plovers. Most activities will be constricted by these timing of year windows. Refer to Chapter 355 and Chapter 305 for current timing windows, and consult with Maine DEP and IF&W on windows that may impact your proposed activities.

Post-storm driftwood, litter management and washover sand management: Naturally occurring debris (such as logs, branches, etc.) deposited in natural dunes after storms should stay in dunes. Non-natural lumber and litter can be carefully removed without a permit and should be disposed of properly. Sand deposited in natural dunes help maintain or build elevations of sand dunes and should not be removed. Sand deposited onto roads and lawns can be moved back to the beach and spread to a depth of no greater than 3 inches without a permit. Larger volumes of sand movement may require a permit from the DEP.

Seaweed Management: Seaweed that washes up on a beach can become unsightly, emit odor, and may interfere with recreational activities. However, seaweed washing up on the beach is a natural occurrence and is a natural fertilizer for dune grass. Nuisance seaweed can be moved by hand (with a beach rake, pitchfork, etc.) and spread at the base of a dune scarp or on top of new dune grass to a maximum thickness of 6 inches (thicker will inhibit dune grass growth). Excess seaweed can also be placed and spread within the dune, mimicking the process of storm overwash when wrack is deposited over the dune crest due to wave overtopping. No permit is needed for moving seaweed by hand. Larger, municipal-based seaweed removal activities using tractors and rakes will likely require a permit from Maine DEP. Some municipalities that have permits to rake portions of beaches during the summer collect the seaweed and move it to a location where it is composted, then returned to the beach in the fall. Certain seaweed species, like the invasive *Dasysiphonia japonica*, are considered a nuisance by Maine DEP and are typically removed from the system and placed in a landfill.

Simple dune fencing: The simplest and least-cost dune fencing is a stake-and-twine fence that allows dune grass to grow seaward during the spring/summer months. This kind of fencing requires no permit, is easy to install and remove. Fences with a minimum open spacing of four inches between posts or slats can also be used but is more difficult to place and remove seasonally (Chapter 305, C(17)). Fencing should be set in the spring before April 15 at about 10-15 feet from the edge of the current dune, and at least 1 foot above the highest expected tides (Figure A8). In the summer, you can easily move this fence seaward as the dune grass grows. MGS recommends removing the stakes and twine in the winter months. Wooden stakes are recommended because if they wash away during a storm, they are less hazardous to the environment than metal stakes or plastic materials. On a regular basis, you can "fertilize" your dune by placing seaweed as described above. Simple dune fencing is considered a de minimus activity in the Sand Dune Rules, and does not require a permit (Chapter 355, 4A(5)).

Enhanced Dune Fencing. While simple dune fencing (stake and twine) depends on dune grass to trap sediment naturally, enhanced dune fencing can be used to help trap sediment adjacent to the current dune edge, thereby allowing it to grow seaward and higher in elevation. However, this type of fence, unless it meets the "open" classification based on slat spacing standards (i.e., the opening between pickets must be at least four inches wide, or at least double the width of the picket, whichever is greater), may require a permit from Maine DEP. Enhanced techniques tested by Bar Mills Ecological in Ogunquit, Maine used plastic snow fencing placed in several different configurations, including rows and zig-zag patterns, in addition to just a wooden stake matrix (Figure A9). Results showed that a zig-zag fence was most effective at trapping sand, followed by the wooden stake matrix. These techniques are further discussed in work by Schaller (2015) and Safe Harbor Environmental (2020) and summarized in the MGS Beach and Dune Best Management Practices Handout.

Cobble Trapping Fences. In certain locations dominated by cobble beaches, cobble trapping fences are permitted in order to limit cobble consistently washing over a seawall and threatening to damage private property such as homes. Cobble fences need to meet the "open" fence requirement and are considered temporary structures (in place for up to seven months in a year). Individual footings (not continuous footings) can be permanent. Sections of the coastline where these fences are permitted include those areas mapped as being adjacent to cobble or gravel beaches according to the Coastal Sand Dune Geology Maps and have developed areas between the building and the beach (such as lawn, Figure A10). Specific standards relating to these fences are described in Chapter 305, 16C (18)(19).

Dune Path Management. Typically, every single home located in the dunes has its own linear path that is

Figure A8. Simple stake-and-twine dune fence at Crescent Beach State Park, Cape Elizabeth.

Figure A9. Enhanced dune fencing examples from Ogunquit, ME (top 2 images) and Truro, MA (bottom image). Enhanced techniques are from Bar Mills Ecological (Schaller, 2015) and Safe Harbor Environmental.

Figure A10. Cobble-trapping fences along Drakes Island Beach, Wells, ME.

cut through the dunes perpendicular to the shoreline. Continued use of the path typically inhibits vegetative growth. Although this is typically the easiest way to access the beach, these paths can act as direct conduits for floodwaters, wave runup, and overwash. To mitigate for this, consider changing your dune path to be a slight "zig-zag" pattern, especially nearest the seaward edge of the dune. The seaward-most portion of the path should face away from the direction of prominent wave attack. This will slow erosion and help limit the path as a direct runway for scour and flooding in the back dunes. Dune paths for individual properties should be less than four feet wide. Note that path rerouting may require a permit from the Maine DEP since it impacts dune vegetation. Additionally, instead of using a path through the dunes for each individual property, *consider working with your neighbor(s) to use one path for every 2 properties (or more)*. Coupled with dune restoration or creation (see below), this minimizes the "holes" through the dune that allow for overwash and floodwater to penetrate during a storm (Figure A11). A continuous and high frontal dune ridge is the more resistant to storms than one with multiple paths.

Dune Walkovers. Dune walkovers are typically constructed of wood or composite wood, placed perpendicular to the natural sand dune. Some are temporary, in place less than seven months a year, and others are permanent. They are elevated, usually three feet, off the surface of the dune, with spacing between individual slats so that dune grass can receive needed sunlight.

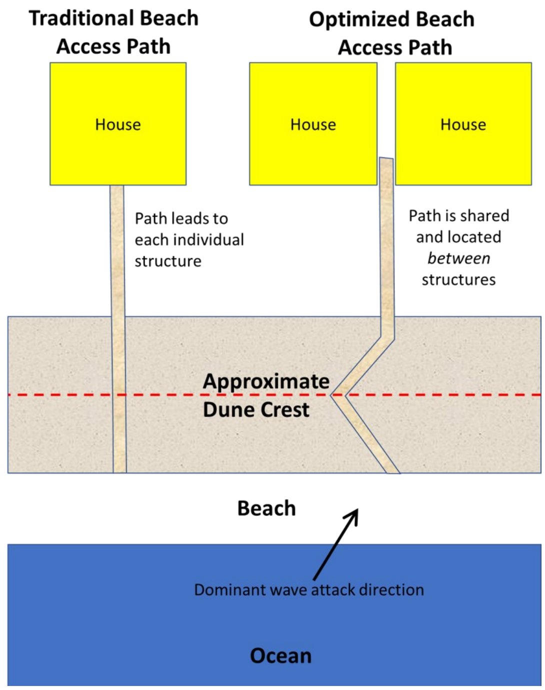


Figure A11. Examples of traditional beach access path (left) and optimized beach access path (right).

Most are constructed with handrails and steps, or if used for public access, have ADA-compliant ramps. Typically, they must be less than 10 feet wide for public use, and less than four feet wide for private use (Figure A12). In Maine, no specific guidance is provided by the DEP for construction of such structures in terms of elevation, slat spacing, or design, and is reviewed on a case- by-case basis. Maine DEP suggests contacting their Southern Maine Regional office to set up a pre-application conference if such a structure is proposed. A guide for construction guidance is available from FEMA.

Green Infrastructure or Living Shoreline Approaches.

"Living shoreline" is a broad term that encom-

Figure A12. Example of a raised dune walkover from Old Orchard Beach, ME. Image from S. Schaller, Bar Mills Ecological.

passes a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline:

- has a footprint that is made up mostly of native material;
- incorporates vegetation or other living, natural "soft" elements alone or in combination with some type of harder shoreline structure (e.g. oyster reefs or rock sills) for added stability; and
- maintains continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.

**Definition adapted from NOAA's Guidance for Considering the Use of Living Shorelines (2015)*

Living shoreline techniques are *typically* most suited for lower-energy environments – for example, those areas that are at least somewhat sheltered from direct wave attack during annualized conditions or storm events. However, dune restoration, creation, and beach nourishment are examples of living shorelines that mimic the natural coastal features present in higher-energy environments.

Living shorelines in Maine, and New England, are a relatively newer concept. They have been implemented widely in warmer climate, lower energy, lower tidal regime areas of the southeast and Gulf of Mexico coastlines for decades, and many of the techniques are transferable to Maine. Although it may seem counter-intuitive, living shorelines can be extremely effective at lessening erosion and property damage from coastal storms. A study in North Carolina after Hurricane Irene (Smith et al., 2017; Gittman et al., 2014) found that properties in estuaries fronted with living shorelines fared better than those fronted by traditional shoreline engineering structures.

Living shorelines are not suitable for all locations. The potential success of living shorelines approaches is dependent upon a variety of factors such as exposure to wave energy and icing, underlying geology, shoreline types, erosion rates, among other factors.

Over the past few years, a variety of resources have been created to help better understand living shorelines and their suitability and applicability in New England and Maine.

More general (not specific to beaches and dunes) New England-wide resources include:

Living Shorelines Stacker – created for the Northeast Regional Ocean Council, this interactive stacker provides fun yet insightful information about the use of living shorelines.

Living Shorelines in New England: State of the Practice – This report, prepared by Woods Hole Group, was the culmination of a NOAA-funded regional project amongst all five New England States, led by the Nature Conservancy and details a wide variety of information on living shorelines and their uses in New England.

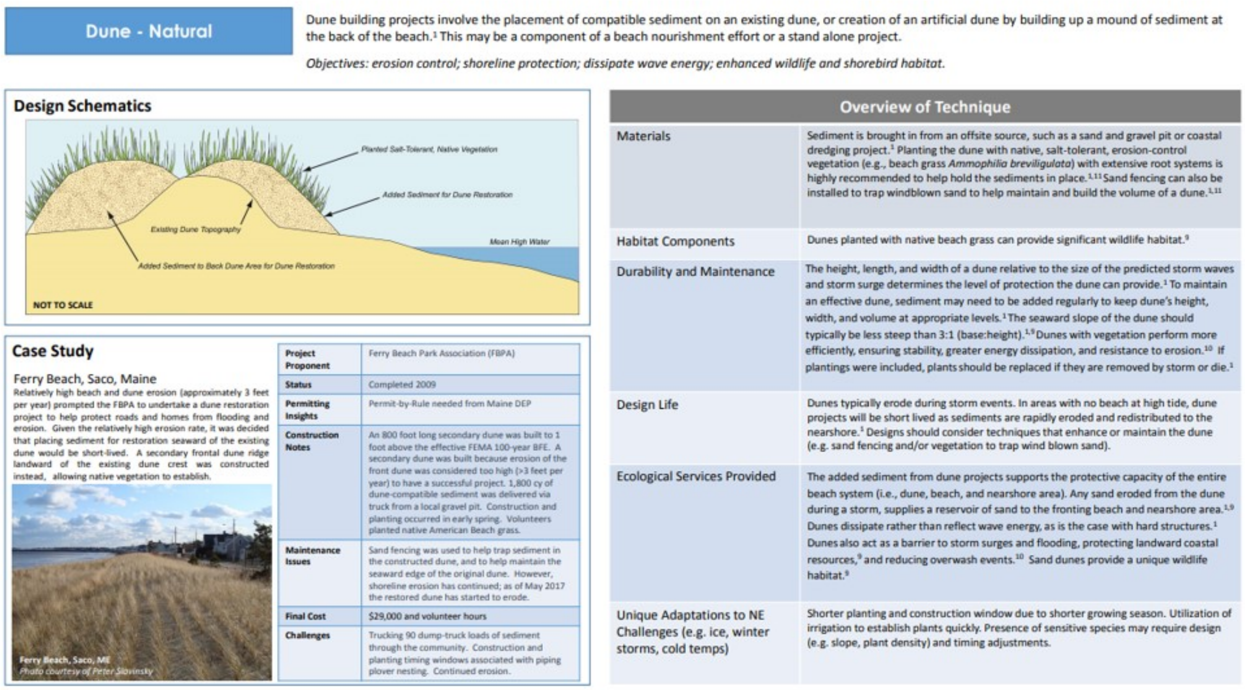
Living Shorelines Applicability Index – in conjunction with the above report, this is an excel-based matrix which accounts for a variety of factors such as energy, sensitive resources, tidal range, slope, and erosion and helps guide the user to a potentially appropriate living shoreline response.

Living Shoreline Combined Profile Pages – these "profile pages" provide information on common types of living shoreline approaches at dunes, beaches, coastal banks, and marshes. They relate to the living shoreline applicability index discussed above. These profile pages provide schematics, design overviews, case studies from New England, and siting and design considerations. Most applicable to this section include profile pages on dune creation/restoration, dune (with an engineered core), and beach nourishment. An example of a profile page on dune creation/-restoration is shown in Figure A13. More detailed information on a case study from Ferry Beach, Saco, ME is provided below.

Maine-specific living shoreline resources related to beaches and dunes include:

Living Shorelines Decision Support Tool for Casco Bay – MGS created this tool to show where in Casco Bay living shoreline approaches may be suited based on a variety of different factors including fetch, nearshore bathymetry, landward and seaward shoreline types, relief, slope, and aspect. This tool could be applicable to identifying areas in Casco Bay where dune restoration or beach nourishment might be suitable, in addition to coastal bluffs and wetlands. This tool uses a color-coded "stoplight" (red, yellow, and green) color scheme to identify least suitable to most suitable shoreline types. Note that this tool is for general planning purposes only and undertaking living shorelines at a specific location should be done in consultation with experts. Another tool, the Coastal Structure and Dune Crest Inventory and Overtopping Potential, is discussed below under dune restoration or creation.

Dune restoration or creation. If your dune has eroded so that it no longer provides protection from overwash or storms, it might be time to consider dune restoration. This is typically done by importing beach and dune-compatible sand and adding that sand to a current dune (and planting it), or constructing a new, artificial dune. If considering this, MGS suggests building the ridge crest to an elevation of *at least 1 foot above the FEMA 100-year Base Flood Elevation (BFE)*. As with many of the other activities, dune restoration or construction is best done in conjunction with neighboring properties. This will create a more storm-resistant dune that will provide much more protection for a longer stretch of the shoreline than if completed at one single property. Coordination can lead to efficiencies



Dune - Natural

Dune building projects involve the placement of compatible sediment on an existing dune, or creation of an artificial dune by building up a mound of sediment at the back of the beach.[1] This may be a component of a beach nourishment effort or a stand alone project.

Objectives: erosion control; shoreline protection; dissipate wave energy; enhanced wildlife and shorebird habitat.

Design Schematics

Case Study

Ferry Beach, Saco, Maine

Relatively high beach and dune erosion (approximately 3 feet per year) prompted the FBPA to undertake a dune restoration project to help protect roads and homes from flooding and erosion. Given the relatively high erosion rate, it was decided that placing sediment for restoration seaward of the existing dune would be short-lived. A secondary frontal dune ridge landward of the existing dune crest was constructed instead, allowing native vegetation to establish.

Project Proponent	Ferry Beach Park Association (FBPA)
Status	Completed 2009
Permitting Insights	Permit-by-Rule needed from Maine DEP
Construction Notes	An 800 foot long secondary dune was built to 1 foot above the effective FEMA 100-year BFE. A secondary dune was built because erosion of the front dune was considered too high (>3 feet per year) to have a successful project. 1,800 cy of dune-compatible sediment was delivered via truck from a local gravel pit. Construction and planting occurred in early spring. Volunteers planted native American Beach grass.
Maintenance Issues	Sand fencing was used to help trap sediment in the constructed dune, and to help maintain the seaward edge of the original dune. However, shoreline erosion has continued; as of May 2017 the restored dune has started to erode.
Final Cost	$29,000 and volunteer hours
Challenges	Trucking 90 dump-truck loads of sediment through the community. Construction and planting timing windows associated with piping plover nesting. Continued erosion.

Overview of Technique	
Materials	Sediment is brought in from an offsite source, such as a sand and gravel pit or coastal dredging project.[1] Planting the dune with native, salt-tolerant, erosion-control vegetation (e.g., beach grass *Ammophilia breviligulata*) with extensive root systems is highly recommended to help hold the sediments in place.[1,11] Sand fencing can also be installed to trap windblown sand to help maintain and build the volume of a dune.[1,11]
Habitat Components	Dunes planted with native beach grass can provide significant wildlife habitat.[9]
Durability and Maintenance	The height, length, and width of a dune relative to the size of the predicted storm waves and storm surge determines the level of protection the dune can provide.[1] To maintain an effective dune, sediment may need to be added regularly to keep dune's height, width, and volume at appropriate levels.[1] The seaward slope of the dune should typically be less steep than 3:1 (base:height).[1,9] Dunes with vegetation perform more efficiently, ensuring stability, greater energy dissipation, and resistance to erosion.[10] If plantings were included, plants should be replaced if they are removed by storm or die.[1]
Design Life	Dunes typically erode during storm events. In areas with no beach at high tide, dune projects will be short lived as sediments are rapidly eroded and redistributed to the nearshore.[1] Designs should consider techniques that enhance or maintain the dune (e.g. sand fencing and/or vegetation to trap wind blown sand).
Ecological Services Provided	The added sediment from dune projects supports the protective capacity of the entire beach system (i.e., dune, beach, and nearshore area). Any sand eroded from the dune during a storm, supplies a reservoir of sand to the fronting beach and nearshore area.[1,9] Dunes dissipate rather than reflect wave energy, as is the case with hard structures.[1] Dunes also act as a barrier to storm surges and flooding, protecting landward coastal resources,[9] and reducing overwash events.[10] Sand dunes provide a unique wildlife habitat.[9]
Unique Adaptations to NE Challenges (e.g. ice, winter storms, cold temps)	Shorter planting and construction window due to shorter growing season. Utilization of irrigation to establish plants quickly. Presence of sensitive species may require design (e.g. slope, plant density) and timing adjustments.

Figure A13. Example profile page schematic and support information for dune (natural) creation or restoration from the Living Shorelines in New England: State of the Practice Combined Profile Pages.

that reduce construction costs. Dune creation requires, at a minimum, a Permit by Rule from Maine DEP, though larger projects may require one or more individual permits. Refer to Permit-by-Rule Chapter 305, (C).

For open coast communities along the York and Cumberland County shorelines, MGS created a Coastal Structure and Dune Crest Inventory and Overtopping Potential which allows for stakeholders to view several different important coastal features, including the linear extent of protective coastal sand dune crests and coastal engineering structures. For this viewer, coastal engineering structures include riprap, bulkheads (or a combination of the two), breakwaters, and jetties. This viewer can be very useful in identifying those dune areas that are not of sufficient elevation to protect structures (and thus, where restoration and creation would be beneficial), as shown in Figure A14. The viewer identifies dune crests at or below the 100-year FEMA Base Flood Elevation (FBFE) by using a color-coded "stoplight (red, yellow, green) color-scheme.

Planting vegetation to help stabilize existing sand dunes – especially in areas with low long-term erosion rates - can help build the elevation or width of a dune, and thus increase its storm protectiveness. Dune planting typically uses species of vegetation that are native to the coastal sand dune system. In Maine, this includes American beach grass (*Ammophila breviligulata*), which is the dominant dune plant. Other common species include coastal panic grass (*Panicum amarum*), rugosa rose (*Rosa rugosa*), seaside goldenrod (Solidago *sempervirens*), and beach pea (*Lathyrus japonicus*).

If you already have a vegetated sand dune and only have small areas to revegetate or where you would like to start new plants growing, native American beach grass can be transplanted from a location at or near where you are doing your plantings (on-site, not from a different beach system). This method is sometimes preferred because it uses plants which have grown and adapted to site-specific conditions at your location over periods of hundreds of years. Transplanting beach grass is permissible without a permit if you are not damaging the site from which transplanting is occurring. If you're unsure, check with Maine DEP. The following protocol has been developed by University of New Hampshire Sea Grant for harvesting American beach grass:

- Use a narrow spade to uproot plants to maintain the integrity of the root structure
- Position spades at the midpoint between two shoots to sever the rhizome at the midpoint and leave the roots intact
- Shake soil/sand from the roots and rhizomes and replace it to the donor site
- Do not select newest shoots
- Remove shoots from areas of high density
- Do not remove more than 10% of the population in each area
- Store plants immediately in bags to limit desiccation to roots and leaves

Figure A14. Example of dune crest elevation vs. 100-year FEMA Base Flood Elevation analysis from the Coastal Structure and Dune Crest Inventory and Overtopping Potential Viewer. Yellow and red circles indicate dune crest elevations below the 100-year BFE.

The Lake Huron Centre for Coastal Conservation put together a video on transplanting dune grass.

If your dune grass has died and you need to plant new grass, American beach grass can be ordered and shipped from some of the larger nurseries which specialize in its cultivation. There are many sources of beach grass, however, most are from out-of-state:

- Pierson's Nursery, Biddeford, ME
- Cape Coastal Nursery, MA
- Church's Beachgrass & Nursery, Cape May, NJ
- Octoraro Native Plant Nursery, PA
- Cape Farms, Inc., DE

The USDA Natural Resources Conservation Service Cape May Plant Materials Center has some information on dune grass planting standards. American beach grass is normally planted in late winter or early spring while the plants are still dormant. The grass can be planted using many tools, but many people prefer the broom stick method. A broomstick is inserted 8-12 inches into the sand, and two sprigs of grass are placed in each hole. American beach grass is typically planted in staggered rows 12-18 inches apart, depending on the application. The plants can be fertilized using a 10-10-10 mix, or by simply moving dried seaweed from the beach and spreading the seaweed into a layer that is less than 6 inches thick (optimally only a few inches thick). Discontinue using artificial fertilizer after the plants thrive otherwise, they will become dependent on the overabundant nutrients. A fun informative video on planting dune grass has been compiled by the Friends of Island Beach State Park, New Jersey.

The Maine DEP also provides good guidance on dune restoration techniques in its Maine Erosion and Sediment Control Best Management Practices (BMPs) Manual for Designers and Engineers (see p. 107).

Ferry Beach in Saco, Maine provides an excellent case-study of dune restoration and construction. The dune along the shoreline north of the northern jetty of the Saco River has been eroding at about 2-3 feet per year over the past few decades. Following the Patriots' Day Storm of 2007, the primary frontal dune ridge, which protects Surf Street, was eroded, scarped, and flattened substantially. The Ferry Beach Park Association (FBPA) approached MGS for some initial recommendations on dune creation/restoration at this site. Because of the long-term erosion rate along this shoreline, MGS recommended that instead of rebuilding the primary dune crest (along the seaward side of the dune, which had been completely eroded), the FBPA focus on building a higher, wider, more protective secondary dune ridge on the landward slope of the natural frontal dune. In doing so, this would allow for the restored area of the dune to stabilize over a long period of time, accumulate more sediment volume and height, before being attacked by winter storm waves. The project imported 90 truckloads (1,800 cubic yards) of beach-compatible sediment in March 2009 and constructed an

800-foot long secondary dune ridge that exceeded the 100-year BFE by 1 foot. Volunteers from FBPA planted the sand ridge with American beach grass. By the following winter, the beach grass was well established, and the dune ridge continued to stabilize (Figure A15; Wurst, 2009). The constructed dune survived the January 4, 2018 winter storm (Grayson; Slovinsky, 2018, p. 23), limited inland flooding, and continues to protect Surf Street.

Beach Scraping. Beach scraping uses mechanical equipment to scrape sand from the lower portion of the beach into the upper portion of the beach, typically just below the sand dune or seawall, or in some cases, for sand dune enhancement, restoration, or creation. Beach scraping for the purpose of pushing sand from the lower portion of the beach to the upper portion of the beach is only a temporary measure to try to protect upland property and is not necessarily effective beyond a single storm event, as sand from scraping is generally quickly dispersed. However, beach scraping in conjunction with coastal sand dune creation/restoration efforts have proven to be successful. Bar Mills Ecological worked with homeowners along the Saco shoreline to undertake beach scraping and dune restoration, as outlined in Figure A16. Depending on the size and impact of proposed scraping activities, a Maine DEP Permit-by-Rule or Individual Permit may be needed. Additional restrictions will likely be required for beach scraping, and additional restrictions may be imposed in terms of timing (typically prohibited between April 1 and September 1) by the Maine Department of Inland Fisheries and Wildlife. Also, note that if scraping is proposed below the high-water mark, additional permits may be required since the intertidal area is a coastal wetland.

Beach Nourishment. Beach nourishment is defined as *the artificial addition of sand, gravel or other similar natural material to a beach or subtidal area adjacent to a beach* (Chapter 355, 3(D)) and is governed by Chapter 355, Coastal Sand Dune Rules. Beach nourishment can be an effective but temporary response to coastal erosion. Nourishment tends to be costly and its effectiveness is generally short-lived (five years or less), especially in areas with high erosion rates. Two sources of beach compatible material in Maine have been used for beach nourishment:

- "Beneficial reuse" of dredged material, usually in conjunction with a U.S. Army Corps of Engineers dredging project of a federal navigation project. This can include either placement of sediment on the beach or in the nearshore; and
- Upland sourcing of material, typically from a sand and gravel pit, where trucks are used to transport sand from an upland source to the

Dune Restoration and Creation – Ferry Beach, Saco, ME. Long-term erosion and the Patriots' Day Storm of 2007 substantially flattened and eroded the dune along Ferry Beach, Saco, ME. The Ferry Beach Park Association, with input from MGS, undertook a dune restoration and project in 2009. The goal was to construct a secondary dune ridge (due to the high 2-3 feet/year) erosion rate and plant it with dune grass. An 800-foot long dune was built to 1 foot above the FEMA BFE by importing 1,800 cubic yards of beach-compatible sediment and American Beach grass. The project required a Permit-by-Rule from Maine DEP. Images by P. Slovinsky and S. Dickson, MGS.

Figure A15. Case study of dune restoration and secondary dune ridge creation at Ferry Beach, Saco, ME. Images by P. Slovinsky, MGS.

Beach Scraping and Dune Restoration – Bayview, Saco, ME. In 2013, a series of contiguous property owners banded together to complete a beach scraping and dune restoration/creation project along a section of dunes in the Bayview neighborhood of Saco. This use of beach scraping (combined with dune restoration) is much more effective than simply scraping sand up the beach profile. Local (City of Saco) and State (Maine DEP Permit-by-Rule and Maine IFW review) permitting was required. All images courtesy of Sue Schaller, Bar Mills Ecological.

Figure A16. Beach scraping activities were undertaken as part of dune restoration in Bayview neighborhood of Saco, ME. Scraped sand was pushed up the profile to create a mound, which was then planted with American Beach Grass, fertilized with seaweed, and fenced using a simple stake-and-twine fencing. Images from S. Schaller, Bar Mills Ecological.

beach.

Historically, when the U.S. Army Corps of Engineers dredged a federal harbor or navigation channel, material was "disposed" of using a low-cost analysis – in most cases, this meant hauling sediment offshore and dumping it. Since the 1990s, if dredged sediment is clean, beach-compatible sand, the USACE began to "beneficially reuse" dredged materials as beach nourishment. More recently, the USACE also considers "nearshore placement," an option. Strategic placement of material on the subtidal beach instead of directly onto the intertidal or supratidal beach. If beach nourishment or nearshore disposal is considered the least-cost alternative for disposal of the dredged material, the costs of dredging and material placement are borne by the federal government. If not, the additional cost must be paid by a local sponsor (typically the receiving community) in order for the Corps to proceed with a project.

In Maine, three locations have seen relatively extensive beach nourishment and nearshore placement projects undertaken since the early-to-mid-1970s: Western Beach, Scarborough (dredging of the Scarborough River); Camp Ellis Beach, Saco (dredging of the Saco River); and Wells Beach, Wells (dredging of the Webhannet River). At the Scarborough and Saco rivers, dredging has occurred even longer but is not included in this analysis. Several smaller projects have also been undertaken at Goochs Beach, Kennebunk (dredging of the Kennebunk River). At these 4 locations, over 1.0 million cubic yards of sediment have been dredged and beneficially reused; about 75% as on-the-beach beach nourishment, and 25 % as nearshore placement (Table A3). A recent beach nourishment project which placed approximately 62,000 cubic yards of sediment dredged from the Saco River onto the beach in adjacent Camp Ellis was completed in spring 2019. Aerial imagery of before (October 2018) and immediately after nourishment (March 2019) show the immediate positive impact of nourishment (Figure A17). However, within 2 years, the sediment placed was lost from the nourishment area, but benefited much of the downdrift Saco beaches.

Maine's Solid Waste Regulations (Chapter 418, July 2018) by Maine DEP outline a reduced procedure sampling and testing of materials prior to dredging. However, certain conditions may require extensive testing of materials including total metals (arsenic, cadmium, chromium, lead, and mercury), semi-volatile organic compounds, PCBs, and potentially other parameters. If a community is unclear on testing requirements, consultation with Maine DEP is recommended. Private beach nourishment projects using dredged material – either from an adjacent river channel

Federal Navigation Project	Year	Volume (cubic yards)	Disposal Location	Intertidal Gain
Scarborough River, Scarborough	1996	90,000	Nearshore (Camp Ellis)*	No
	2005	82,048	Onshore - Western Beach	Yes
	2015	116,325	Onshore - Western Beach	Yes
	Onshore	198,373		
	Nearshore	0		
	Scarborough Total	**198,373**		
Saco River, Saco	1973	37,000	Nearshore	Unknown
	1978	130,000	Onshore - Camp Ellis	Yes
	1982	7,300	Onshore - Camp Ellis	Yes
	1992	99,014	Onshore - Camp Ellis	Yes
	1992	24,990	Nearshore - channel	No
	1996	90,000	Nearshore (from Scarborough River)	No
	2019	62,000	Onshore - Camp Ellis	Yes
	Onshore	298,314		
	Nearshore	151,990		
	Saco Total	**450,304**		
Kennebunk River, Kennebunk	2004	8,000	Nearshore - Goochs Beach	No
	2,014	22,000	Nearshore - Goochs Beach	Yes
	2020	20,000	Nearshore - Goochs Beach	Yes
	Kennebunk Total	**50,000**		
Webhannet River, Wells	2000	180,000	Onshore - Wells and Drakes Island	Yes
	2004	10,000	Nearshore - Wells	Unknown
	2012	10,000	Nearshore - Wells	Yes
	2014	5,000	Nearshore - Wells	Unknown
	2014	138,000	Onshore - Wells and Drakes Island	Yes
	2018	20,000	Nearshore - Wells	Yes
	2020	30,000	Nearshore - Wells	Yes
	Onshore	318,000		
	Nearshore	75,000		
	Wells Total	**393,000**		
Overall Totals	**Onshore**	**814,687**	** material dredged from Scarborough River and placed at Camp Ellis is counted as nearshore placement at Camp Ellis*	
	Nearshore	**276,990**		
	Total	**1,091,677**		

Table A3. Summary of river dredging and beneficial reuse of dredged materials as beach nourishment (onshore placement) or nearshore disposal in Scarborough, Saco, Kennebunk, and Wells since the early-to-mid 1970s. Data compiled from a variety of sources, including personal communications with USACE officials, and the Program for the Study of Developed Shorelines (1996), Kelley et al. (1995), Normandeau Associates (1994), Kelley and Brothers (2009), and Kelley and Anderson (2000).

Figure A17. Aerial orthoimages of Camp Ellis Beach, Saco, prior to beach nourishment (October 2018), and immediately after beach nourishment (March 2019). Over the period of the next two years, the sand from the beach nourishment area was eroded and distributed downdrift along the Saco beaches. Images from NearView, LLC.

or other offshore source – have not been undertaken in Maine. One of the reasons for this is cost. Costs of finding, dredging, and transporting material can run between $10-20 per cubic yard of sand, depending on source and its proximity to the nourishment site. However, the Woods Hole Group (2018) completed a Feasibility Study for the purchase and operation of a hydraulic dredge for 10 federal navigation channels which are dredged in southern Maine communities. This was completed for the Southern Maine Planning and Development Commission at the request of several Cumberland and York County communities and follows an existing shared-dredge model implemented in Barnstable County, Massachusetts. Upland sources for beach nourishment (and dune restoration) have also been used, most extensively at Camp Ellis Beach, Saco. As a condition of a permit from Maine DEP, the City of Saco is required to maintain sand on several of its existing geotube structures, which were placed within the Surf Street right-of-way after the Patriots' Day Storm of 2007. Compatible grain-size and textured sediment is sourced from a gravel pit and trucked to the nourishment site. The cost of this type of source is generally around $10-15 per cubic yard, but transportation costs and road improvements may add additional costs based on the amount of material used.

Work in 2017 by the Integrated Beach Management Program Work Group (2017) updated an original report *Protecting Maine's Beaches for the Future* (Beach Stakeholder Group, 2006), and provided specific recommendations to the State of Maine on how to potentially implement a state-wide Comprehensive Beach Nourishment Program. This proposed program was modeled from a program used in Florida to competitively rank proposals by municipalities requesting funds to support beach nourishment activities.

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B. COASTAL BLUFFS, EROSION AND LANDSLIDE HAZARDS

Introduction

A coastal bluff is a steep shoreline slope formed in rock or sediment (clay, sand, gravel) that generally has three feet or more of vertical elevation above the high tide line. Approximately one-third of Maine's 5,408-mile coastline is classified as unconsolidated or "soft" bluff, comprised of materials that are prone to erosion (Maine Coastal Program, 2020, Figure B1).

Unconsolidated bluffs are formed and modified in a dynamic coastal environment by both terrestrial and marine processes. Bluff erosion is part of a natural cycle with consequences for the land below and above the bluff. Fine-grained silt and clay eroded from bluffs may be deposited on mud flats or salt marshes and help reduce wave energy at the base of a bluff and slow the overall rate of bluff erosion. Coarse-grained sediments, such as sand and gravel, eroded from bluffs become part of a beach at the base of the bluff and help stabilize the shoreline position. *Transfer of sediment from the land to the sea is natural and is essential to sustain adjacent resources such as beaches, mud flats, or salt marshes*.

Bluff erosion can result in a landward shift of the top edge of the embankment. This inland movement is a natural process that, by itself, is not a coastal hazard and has been happening for thousands of years. Only when erosion threatens something of value, such as a building near the bluff edge, does bluff retreat become a hazard. Thus, the responses that coastal property owners take in order to mitigate for bluff erosion hazards needs to delicately balance property protection with the fact that bluff erosion is what supplies sediment to adjacent natural habitats.

Bluff erosion is a natural response to sea-level rise. One of the big differences between coastal bluff erosion and that of coastal sand dune and beaches, is that bluff erosion is generally one way – landward. We don't expect "new" bluffs to accrete during our lifetimes, but bluffs can slow down their own erosion and partially "heal" through the formation of slumps and in more extreme cases, landslides (discussed below), as part of the bluff erosion cycle.

Bluffs typically respond to short term events such as storms and long-term sea level rise by undergoing an erosional cycle as shown below. As part of this process, as shown Figure B2, at time A, the water level increases, and currents and waves attack the base of the bluff causing localized erosion at time B. This causes subsequent bluff instability, which can lead to a slump or a landslide at time C. Slumped sediment forms a higher intertidal mudflat or salt marsh, and by time D, has helped stabilize the base of the bluff from wave erosion.

Local bluff erosion rates affect the vulnerability, and perhaps longevity, of coastal development along a bluff edge. Even where steep banks line the shore, some bluffs may not change much over many years. Bluffs may not lose much ground in any one year, but instead slump a large amount of sediment once every few years. The bluff erosion rate will vary from year to year, much like the weather. When data are available, a long-term average erosion rate is the most meaningful measure of bluff retreat and to project the future hazard to development on or above the bluff. Once the risk is evaluated, then appropriate solutions to reduce the risk can be considered and balanced with cost and environmental consequences to nearby habitats.

Types of Bluffs Based on Stability

In general, the sediments, slope, shape, and amount of vegetation covering a coastal bluff and the adjacent

Figure B1. Example of an unconsolidated, unstable bluff along the Brunswick, ME shoreline. Image by P. Slovinsky, MGS.

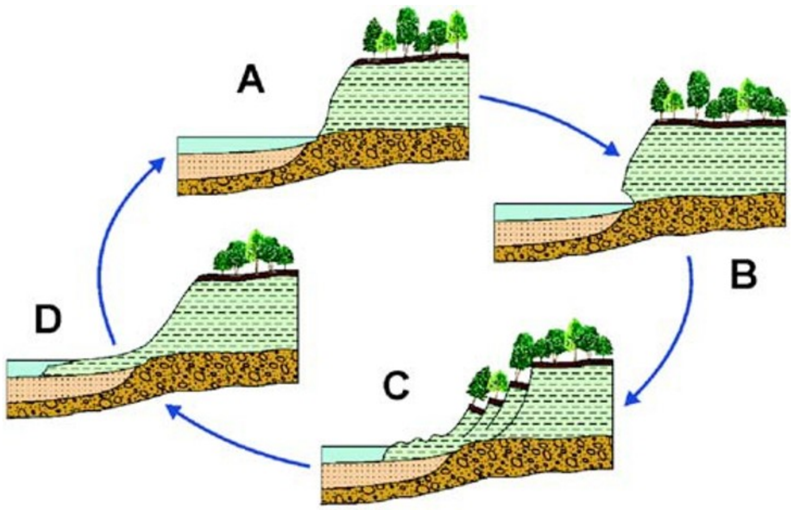


Figure B2. Bluff erosion and landslide cycle. A stable bluff exists at time A. At time B, the bluff toe is undercut. At time C, undercutting results in slumping or a landslide. By time D, the bluff toe is protected by slump blocks. Image from Kelley et al. (1989).

shoreline are directly related to the susceptibility of the bluff face to ongoing erosion. Unconsolidated "soft" bluffs can be categorized as being highly unstable, unstable, or stable.

Highly Unstable Bluff. Highly unstable bluffs have near vertical or very steep (greater than 20 degree) slopes with little vegetation and common exposure of unstable, bare sediment. Fallen trees and displaced blocks of sediment are common on the bluff face and at the base of the bluff. There is typically a coastal wetland, mudflat, or beach at the base of the bluff that is derived from erosion of the bluff. Figure B3 shows an example of a highly unstable bluff at Lane's Island in Yarmouth, Maine.

Unstable Bluff. Unstable bluffs have steep to gently sloping slopes (10 to 20 degrees) and are mostly covered by shrubs with a few bare spots with soil exposed. Bent or tilting trees may be present. There may or may not be an adjacent mudflat, beach, or salt marsh. The bluff can show undercutting and root creep, which is gradual downslope movement of the tree that leaves roots trailing up slope. A section of unstable bluff from York, Maine is shown in Figure B4.

Stable Bluff. Stable bluffs have gentle (less than 10 degree) slopes with continuous cover of grass, shrubs, or mature trees with a relatively wide zone of ledge or sediment at the base of the bluff (Figure B5). A stable bluff may also have a shoreline engineering structure at high-tide and above. A licensed engineer might certify the structure as stable (Figure B6). This category implies stability in the short term, based on observations at the time of mapping or field inspection. Over time, stable bluffs can become unstable to cyclic changes (Figure B2 and described above) or destabi-

Figure B3. Example of a highly unstable bluff at Lanes Island, Yarmouth, ME. Note fallen trees and exposed sediments in the face of the bluff. Image by P. Slovinsky, MGS.

Figure B4. Example of unstable bluff along the York River, York, ME. Note undermining of bluff, leaning trees, and root creep. Image by P. Slovinsky, MGS.

Figure B5. Example of stable bluff along the York River, York, ME. Note large vertical trees and vegetated slopes. Image by P. Slovinsky, MGS.

Figure B6. Example of a stable-armored bluff that has been stabilized with coastal engineering structures along the Belfast shoreline. Image by P.A. Slovinsky, MGS.

lized by natural or human events such as storms or groundwater management.

Types of Landslides

One of the most dangerous hazards associated with coastal bluffs is the threat of landslides. In a landslide, earth materials move rapidly downslope under the force of gravity, usually in high coastal bluffs composed of muddy sediment. Many landslides have occurred along the Maine coast in the last few centuries and more landslides will happen in the future. Based on geologic history and field evidence, a variety of scenarios and possible events, from large to small and fast to slow, can threaten property and, in a few cases, put human life at risk. It is not possible to predict exactly where, when, and how large the next coastal landslide will be. Landslides have occurred frequently enough that geologic analysis and informed land use can lead to risk reduction and improved emergency response.

The general term “landslide” is used to describe many types of earth “mass wasting” movements, but in formal terms landslide should be used to refer only to mass movements, where there is a distinct zone of weakness that separates the displaced material from more stable underlying material. Landslides are classified into different types described below and as shown in Figure B7 (Highland and Bobrowsky, 2008). Maine landslides are explained further in a Maine Geological Survey story map and in a guide (Spigel, 2020).

- Rotational slide (A). This is a slide in which the surface of rupture is curved concavely upward, and the slide movement is roughly rotational.
- Translational slide (B). In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting.
- Rockfalls (D). Rockfalls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs.
- Debris flow (F). A debris flow is a form of rapid mass movement, without a defined zone of weakness, in which a combination of loose soil, rock, organic matter, and water mobilize as a slurry that flows downslope.
- Earthflow (H). An earthflow is a downslope viscous flow of fine-grained materials that have been saturated with water and move under the pull of gravity.
- Creep (I). Creep is the imperceptibly slow, steady, downward movement of slope- forming soil or rock. Movement is caused by shear stress sufficient to cause permanent deformation, but too small to cause shear failure.

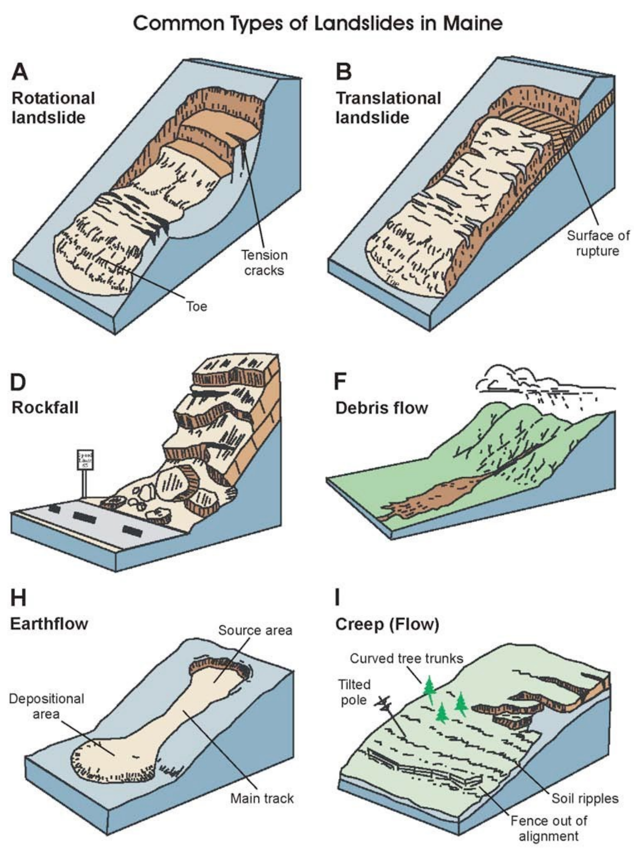


Figure B7. Types of landslides common in Maine. Images from Highland and Bobrowsky, 2008.

Factors Influencing Coastal Bluff Stability and Landslides

Numerous, interconnected factors influence the overall stability of a bluff, bluff erosion, and the formation of landslides. Understanding these factors and looking for certain telltale characteristics associated with those factors can help you better understand the stability of your bluff. Many of the same factors that influence the formation of unstable coastal bluffs also affect landslide risk, including:

- Hydrology
- Sediment Type
- Height
- Slope
- Aspect and Microclimate
- Topography
- Vegetation
- Land Use
- Hydrodynamics
- Land Use
- Earthquakes

Hydrology. Water in and on a coastal bluff, are common factors influencing bluff instability. This includes groundwater flow and seepage within a bluff as well as surface runoff on the bluff face. Observations of drainage are sometimes best made during or directly after periods of heavy rainfall, when surface runoff and groundwater discharge are at their peak. Water tables, and hence discharge, tend to be highest in spring as the ground thaws (Caswell, 1987). Sometimes around March or April when air temperatures fluctuate around freezing, groundwater will freeze on the bluff face leaving ice at the point of discharge. Freeze thaw cycles within bluff sediment can also reduce the strength of the bluff face. The two key things to look for include *surface water* and *groundwater* influences.

Surface Water. Wetlands, ponds, and streams above the bluff can supply water to the bluff face and recharge groundwater. Surface water, collected by roofs, driveways, paths, and lawns, sometimes flows toward and down the bluff face. Water that runs over the face of a bluff can wash soil to sea, expose roots, increase the bluff face slope, and weaken the remaining sediment holding up the bluff. Direct rainfall to a bluff is sometimes the deciding factor influencing bluff stability. However, wind and frost wedging do act upon some exposed slopes.

Groundwater. Groundwater within a bluff comes from surface sources, such as rain or a stream, uphill in the local watershed. Groundwater tends to flow horizontally beneath the surface and may seep out the face of a bluff. Seeps and springs on the bluff face contribute to surface water flow and destabilize the bluff face. In addition, a high-water table can saturate and weaken muddy sediment and make the ground more prone to slope failure.

Sediment Type. As discussed previously, bluffs comprised of bedrock are eroding slowly, and their associated hazard is relatively low. But unconsolidated bluffs in Maine are comprised of a combination of materials. *Rock or ledge* is much more stable than any sediment bluff and not likely to erode or slide. The elevation of bedrock at the shore and inland beneath a bluff is important in determining landslide risk. Bedrock exposures along the shoreline may slow erosion and make sediment less susceptible to land sliding. Beneath a sediment bluff, bedrock may rise toward the surface and reduce the overall thickness of sediment and thus reduce the risk of deep-seated movement below the ground surface. *Clay and silt (mud)* are the most unstable materials that can make up a bluff. These fine-grained sediments are weak and prone to slow-motion creep, moderate-sized slumping, or large landslides. Many bluffs in Maine are underlain with a gray clay known as the Presumpscot Formation. Weathering (aging) in clay and silt can affect the strength of bluff sediment and stability of the bluff face. Drying of clay can increase resistance to sliding. The seasonal cycle of freezing and thawing of the bluff face can lead to slumping after a thaw. *Sand and gravel deposits* tend to be stronger and better drained than muddy sediment. Landslides can occur in coarse-grained bluffs although they are less frequent than muddy landslides along the Maine coast.

Height. The height of an unconsolidated "soft" bluff can indicate its overall stability and potential landslide risk, especially when taken into account with other factors. In general, the thicker (taller) the sediment deposit, the more likely its weight will cause subsurface movement or slippage that leads to a landslide. The risk of an unstable coastal bluff or landslide increases when mud bluffs have a height of 20 feet or more. The higher the exposed bluff face, the greater the risk of slope failure and a landslide.

Slope. Coastal bluffs have a relatively steep ocean-facing slope. The angle of a bluff face varies due to factors such as the sediment type and rate of erosion at the base of the bluff. Slope is also affected by the history of slumps and landslides at the site. Some slopes are uniformly straight while others are terraced or uneven due to prior earth movements. In general, the steeper the slope, the easier it is for gravity to initiate a landslide. Concave surface topography will tend to concentrate the flow of surface water and ground water, raising ground-water pressures and reducing the strength of the soil. As a result, concave slopes are more susceptible to failure than straight slopes or convex slopes. To determine the slope of a bluff, purchase an inclinometer or clinometer. The quickest, but least accurate, way to estimate slope height is to visually estimate the height of some nearby vertical structure on the slope (i.e., tree or bluff face) and then estimate how many tree heights would equal the overall slope height.

Aspect and Microclimate. Aspect is the direction toward which the surface of the soil faces. South-facing slopes undergo more extensive freeze/thaw cycles in winter months than slopes with other aspects. Repeated freeze-thaw cycles preferentially reduce the shear strength of the shallow soil material and increase the likelihood of shallow soil slumps. Ultimately, small movements may steepen the slope and lead to larger slope failures. The weather along Maine's diversely shaped coastline is strongly influenced by changing topographic and atmospheric conditions. The degree of precipitation, available sunlight, temperature, and wind can change radically from one section of coastline to another along the numerous bays, rivers, and headlands along the coast. The factors of microclimate and aspect (which direction a bluff faces) should be recognized in site evaluations and planning efforts which includes both planting and drainage control elements.

Topography. The presence of swales, gullies, or drainage channels on or adjacent to a shore site can affect surface water movement. These features can direct surface water flow towards or away from the bluff face and slope. They also affect the recharge of subsurface water and groundwater. The steep sides of such features can concentrate and accelerate runoff, increasing surface erosion. These features often indicate the site of past erosion or landslides. Modifications of existing topography should not be undertaken lightly.

Vegetation. The type, age, health, and abundance of vegetation growing on a bluff can offer valuable clues to slope stability. Even the presence of stumps and fallen trees can tell a story to a knowledgeable observer. This section discusses these clues and what they may indicate. Vegetative indicators are best interpreted in combination with soil and geological data. In areas where the soil has shifted, either due to previous landslides or to gradual surface creep, tree trunks can become tilted or twisted in the same direction. Curved tree trunks near the roots often indicate land movement down the face of a bluff. Trees that appear to be jumbled in groups on slump blocks that have slid down a slope are called jackstrawed trees. Evidence of jackstrawed trees usually indicates that a groundwater problem or slope instability exists, which caused the mass of soil and associated vegetation to move downslope as a single unit or block. Distinct lines of trees growing across a slope may indicate one of two different conditions. If the trees are young, fast-growing species, such as alder or willow, a previous landslide may have occurred, allowing these opportunistic species to colonize the slide site. The age of trees growing in this manner can be a clue to when the slide occurred. A distinct line of water-loving ("hydrophilic") tree species may indicate an area of perched water or groundwater seepage that in turn may indicate a layer of impervious material underlying a deposit of sandy soil. The presence of such trees may indicate site instability and should be investigated by a geologist.

Clearing vegetation from the bluff face can sometimes lead to greater bluff erosion and a steeper bluff that is more prone to landslide. Vegetation tends to remove ground water, strengthen soil with roots, and lessen the impact of heavy rain on the bluff face. Vegetation removal in the Shoreland Zone typically requires a permit from Maine DEP and your municipality.

Hydrodynamics. Wave action during storm events can undercut the toes of bluffs and make them unstable, potentially leading to landslides. Tides can wash away eroded bluff sediment, allowing waves to move inland. The gradual but ongoing rise in sea level at a rate of about an inch per decade is causing chronic erosion along the base of many bluffs. As sea level rises, wave action and coastal flooding can reach higher and farther inland and scour more sediment from a bluff. Sea ice can also erode protective fringe marshes and the base of bluffs by abrasion and freezing sediment in ice blocks.

Land use. Human activity and land use may contribute to or reduce the risk of a landslide. Actions that increase surface water flow to a bluff face, watering lawns or grading slopes, add to natural processes destabilizing the bluff face. Walkways down the face of a bluff can lead to greater erosion from foot traffic or the concentration of surface water flow. Elevated stairs can shade the slope and prevent vegetation from stabilizing the slope. Both surface and ground water above a bluff can be supplied by pipes, culverts, surface drains, and septic systems. Increased water below ground can weaken a bluff and contribute to internal weakness that leads to a landslide. Greater seepage of water out of the bluff face can also increase the risk. Adding weight to the top of a bluff can increase the risk of a landslide. Buildings, landscaping, or fill on the top of the bluff can increase the forces that result in a landslide. Saturating the ground with water that raises the water table also adds weight. Even ground vibration, such as well drilling or deep excavation, may locally increase the risk of a landslide. Shoreline engineering in the form of seawalls, rip-rap, or other solid structures used to reduce wave erosion at the toe of a bluff can increase the rate of beach or tidal flat erosion, undermine engineering, and result in less physical support of the base of the bluff by natural sediment. Where coastal engineering ends along a shoreline, "end effect" erosion can cause worse erosion on adjacent properties. Engineering alone cannot prevent some large landslides.

Earthquakes. Landslides can be triggered by earthquakes. Ground vibration loosens sediment enough to reduce the strength of material supporting a bluff and a landslide can result. Most landslides triggered by earthquakes in sediment like that found in Maine have been of Richter magnitude 5 or more. These are relatively rare events, but a few have occurred in historical time in Maritime Canada.

Resources to help identify coastal bluffs and landslide hazards

Numerous resources are available to help understand coastal bluff and landslide hazards in Maine. These include:

Maine Geological Survey Viewers and Data

- Maine Coastal Bluffs and Landslide Hazard Maps
- Combined hazard mapping data viewer
- Building Resiliency Along Maine's Bluff Coast
- Maine Landslide Guide (Spigel, 2020)
- Maine Landslide Story Map
- Living Shoreline Decision Support Tool for Casco Bay
- Maine Floodplain Management Program FEMA Flood Insurance Rate Maps Viewer
- Maine Highest Astronomical Tide Line Viewer
- Maine Sea Level Rise and Storm Surge Viewer

Other Useful Resources

- Cumberland County Soil and Water Conservation District Bluff Products
    - Shoreline Management Assessment
    - Shoreline Management Decision Tree
    - Instability Assessment Rating Form
    - Case Studies
    - Coastal Planting Guide
- Maine Flood Resilience Checklist

Maine Geological Survey Viewers and Data

Coastal Bluffs and Landslide Hazard Maps – MGS produced Coastal Bluffs and Landslide Hazard Maps to help identify coastal bluff and landslide hazards. Coastal Bluff Maps describe the stability of the *face of the bluff* while landslide hazard maps describe the *internal* stability of bluff sediments. These maps also provide information about the slope, shape, and amount of vegetation covering a coastal bluff and the adjacent shoreline. These factors are directly related to the susceptibility of the bluff face to ongoing erosion and subsequent formation of landslides. These maps were developed to represent approximate 150-foot sections of the shoreline and may be too generalized to depict conditions along a shorter stretch of property. Also, please note that bluff stability since the mapping was completed *could have changed* due to a variety of factors that influence bluff stability, as described above. Although these are good sources for information on bluff stability and landslide hazard, they are snapshots in time and could be outdated. Thus, it's *very important* to ensure that you adequately document *existing* bluff conditions when considering development along coastal bluffs. Combined mapping data available from MGS show coastal bluff and landslide hazards in relation to other influencing factors, such as the highest astronomical tide, surficial and bedrock geology, groundwater characteristics, and topography.

Maine Landslide Guide – MGS also released a Maine Landslide Guide which looks at both inland and coastal landslide hazards in Maine, their locations, and underlying causes. It includes an interactive ArcGIS Story Map for Landslides in Maine, which describes historic slides, causes, and different landslide types. It also links to points where Maine Inland Landslides have occurred, including locations and ages.

Building Resiliency along Maine's Bluff Coast – MGS, along with partners from the Maine Coastal Program, Municipal Planning and Assistance Program, Department of Marine Resources, University of Maine, Cumberland County Soil and Water Conservation District, and NOAA, completed a 2-year project on coastal bluffs in Casco Bay. The final report summarizes project outcomes, many of which are described in this section, including the living shoreline decision support tool and CCSWCD bluff management products.

Living Shoreline Decision Support Tool for Casco Bay – MGS developed a decision support tool to help guide planning-level decisions relating to the siting of living shorelines in Casco Bay. This tool accounts for a variety of factors, such as fetch, bathymetry, landward and seaward shoreline types, relief, slope, and aspect and provides an overall ranking of the general suitability (using a stop light red, yellow green color-coding approach) of a shoreline for green infrastructure approaches. Note that this tool is a planning-level guidance tool only, and site-specific decisions should be made in conjunction with trained professionals.

Maine Floodplain Management Program's FEMA Flood Insurance Rate Maps Viewer – Areas along the open coast, including coastal bluffs, are susceptible to coastal flooding and are defined by the Federal Emergency Management Agency (FEMA) as Special Flood Hazard Areas, or SFHA. SFHA are areas that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. The elevation of the 1% annual chance flood is also referred to as the base flood elevation (BFE) or 100-year flood elevation. These flood zones are mapped by FEMA in a series of maps called the Flood Insurance Rate Maps (FIRMs). FIRMs are used to identify flood insurance risk and insurance premiums in areas associated with different flooding events. Maps include areas of the SFHA in addition to areas of minimal flood hazard, which are areas outside of the SFHA and higher than the elevation of the 500-year (0.2% chance of being equaled or exceeded each year) flood elevations. Most flood zones have a determined base flood elevation, or BFE, which is the elevation to which flooding is expected during a 1% flood event. Most FEMA FIRMs are now available as digital FIRMs, or DFIRMs and can be viewed at the Maine Floodplain Management Program's Online Viewer or from the FEMA Map Service Center. The Maine Floodplain Management Office's Maine Floodplain Management Handbook (2019) can also be a great resource for property owners.

The most commonly defined flood zones include the "VE" or "Velocity zone" (with a defined base flood elevation) and "AE" or "A-zone" with a defined base flood elevation. Velocity zones, or V-zones, are dynamic hazard zones where the BFE has been determined and includes waves of 3 feet or larger, while A-zones are considered more "static" flood zones. A-zones can include "Coastal A" zones, which are typically landward of a V-zone along the open coast and can have waves of between 1.5 and 3 feet. Figure B8 depicts a profile view of the different flood zones in reference to a transect along the coastline.

Maine Highest Astronomical Tide (HAT) Viewer – MGS created a mapping tool representing the limits of the Highest Astronomical Tide, or HAT, which enables users to view the approximate limits of the highest astronomical tide, which is a regulatory boundary for Maine's Shoreland Zone (for the Maine Department of Environmental Protection) and for the U.S. Army Corps of Engineers jurisdiction. The limits of HAT have been estimated by adjusting tidal predictions at NOAA tide stations with a tool called VDATUM and interpolating tidal elevations along sections of the coastline with no tide predictions. This allows for an estimation of the value and limits of the HAT. Note that this tool doesn't account for tidal restrictions (besides those allowed for by tide predictions) and should only be used for general planning purposes. Site-specific HAT measuring and mapping may still be needed for certain sites along the Maine coast, especially those with tidal restrictions or up at the heads of rivers/estuaries. A Frequently Asked Questions section is included with the data. Along coastal bluffs, the HAT is used to help determine setbacks. Along stable bluffs, a minimum setback (75 feet) is established from the *HAT elevation* along that section of shoreline. Along unstable bluffs, the minimum setback is from the *top of the bluff*.

Maine Sea Level Rise and Storm Surge Viewer – Using the HAT as the starting point, MGS created a mapping tool representing potential sea level rise and/or storm surge scenarios along the Maine coast. The sea level rise scenarios were developed by using available long-term sea level rise data from Portland, Bar Harbor, and Eastport tide gauges and the U.S. Army Corps of Engineers Sea-Level Change Curve Calculator (v. 2017.55) and sea level rise scenarios established by NOAA et al. (2017) prepared for the U.S. National Climate Assessment. Scenarios were averaged for all three tide gauges and include low, intermediate low, intermediate, intermediate high, high, and extreme sea level rise at the 50% confidence interval. These scenarios can be viewed as future sea level rise on top of the HAT, or storm surge on top of the current HAT, or a combination of a future sea level rise and storm surge.

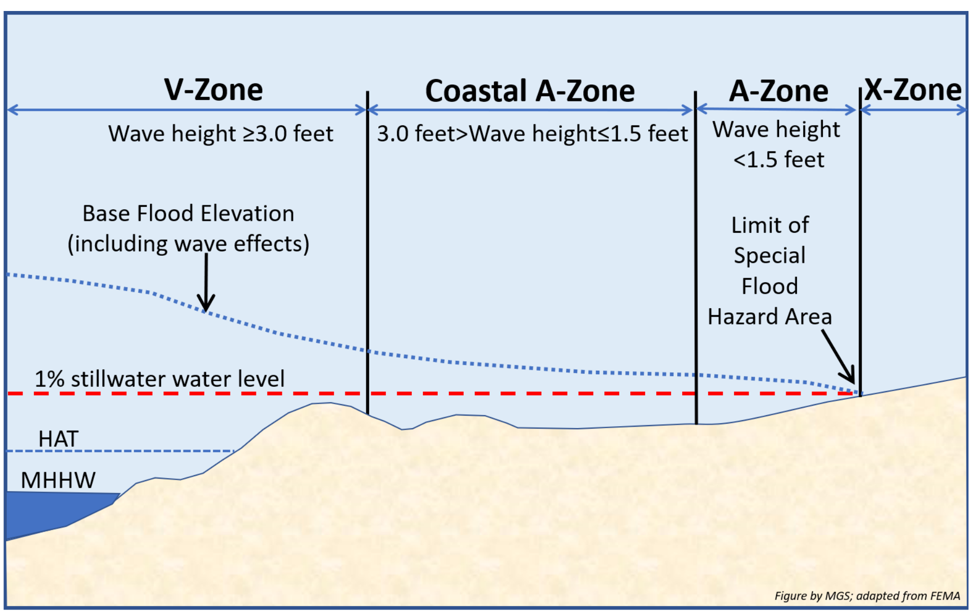


Figure B8. Schematic showing commonly defined Special Flood Hazard Areas (SFHA) along the coastline. Adapted from FEMA.

A Frequently Asked Questions section is included with the data.

Other Useful Resources

Cumberland County Soil and Water Conservation District Bluff Products – As part of a NOAA funded project, MGS, MCP, and the Cumberland County Soil and Water Conservation District (CCSWCD) developed a series of documents that can help homeowners assess stability of coastal bluffs and make decisions on their management. One of these documents is discussed below, while others are meant to help decide how to respond to bluff instability and are discussed under *Adaptation Options*.

The Bluff Instability Assessment Rating Form allows for homeowners to self-assess their bluffs for stability, taking into account many of the major factors that impact bluff stability (and indirectly, landslide hazard). This assessment uses a simplified scoring of Good (1), Fair (2), and Poor (3), such that the *higher the score, the more at-risk the bluff is for being unstable*. It includes the following factors:

- Hydrology
    - Changes in Upland Runoff – evidence of surface drainage, etc.
    - Nature of Flow – channelized flow, etc.
    - Upland Land Use – developed vs. vegetated, etc.
    - Distance to Roads
    - Seepage – evidence of water seepage along the bluff
- Vegetation at Toe of Bluff – evidence of vegetation density along toe of bluff
- Sediment Supply – evidence of bluff erosion
- Bank Slopes – slope ranges of the bluff face
- Bank Height vs. High Tide Elevation – bluff elevation in reference to the high tide
- Soil and Geology – what kinds of soils make up the bluff face
- Bank Surface Protection – ratio of root depth vs. bank height
- Biology/Landscape Connectivity – evidence of shoreline armoring vs. natural vegetation

CCSWCD also completed several different case studies assessing the stabilities of bluffs and developing adaptation strategies using the tools described above, which could help in working through each factor in identifying the factors influencing the stability of your bluff. Case studies were completed at Mackworth Island, Falmouth; Mere Point, Brunswick, and Mitchell Field, Harpswell. A separate, in-depth study of bluff adaptation, including management of groundwater and surface flow, was completed for Bustins Island, Freeport.

Maine Flood Resilience Checklist – Though not specific to bluffs and landslides, the Maine Coastal Program created the Maine Flood Resilience Checklist as a non-regulatory self-assessment tool designed to assist Maine communities evaluate how well positioned they are to prepare for, respond to, and recover from flooding events and sea level rise. It offers an integrated and practical framework for examining local flood risk, evaluating vulnerability of the natural, built, and social environments, and identifying opportunities to enhance flood resilience. Additionally, it allows communities to identify specific intervention points where local decision-makers can develop policy, strategies, and actions to address areas of vulnerability. The Checklist can help communities integrate sea level rise considerations into comprehensive plans, strengthen local floodplain ordinances, and incorporate resilience activities into capital improvement plans. It is recommended that the Checklist be completed at the municipal level in conjunction with support staff.

Regulations Applicable to Activities on or near Coastal Bluffs

There are many local, state, and federal regulations that apply to activities on or adjacent to coastal bluffs relating to erosion and landslides. To help guide property owners, the Maine DEP has released A Homeowner's Guide to Environmental Laws Affecting Shorefront Property in Maine's Organized Towns (Maine DEP, 2000). Please note that this document may be slightly dated. A general summary of applicable regulations to activities at Coastal Bluffs and Landslides are listed below.

Erosion and Sediment Control Law – The Erosion and Sediment Control Law erosion control provision is a very brief and basic standard requiring that a person who conducts an activity involving filling, displacing or exposing earthen materials take measures to prevent unreasonable erosion of soil or sediment beyond the project site or into a protected natural resource. Maine DEP provides several different manuals to help implementation of Best Management Practices for Erosion and Sediment Control:

- Maine Erosion and Sediment Control Practices Field Guide for Contractors
- Maine Erosion and Sediment Control Best Management Practices Manual for Designers and Engineers

Maine's Shoreland Zoning – By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 feet of the normal high-water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance. In coastal areas, the shoreland zone is defined by a distance from the Highest Astronomical Tide (HAT).

Specific setbacks along coastal bluffs are required and based on bluff stability as follows:

- Stable Bluffs – the setback for principal structures is a minimum of 75 feet from the highest *astronomical tide*;
- Unstable or Highly Unstable Bluffs – the setback for principal structures is a *minimum* of 75 feet from the *top of the bluff*.

Shoreland Zoning also creates different types of districts within which you might be located that regulate certain activities within those districts, based on the presence of specific resources and uses. It is also used to establish certain setbacks from resources. Maine DEP maintains a Mandatory Shoreland Zoning page which has a lot of pertinent information including Chapter 1000 guidelines, statutory sections, and contacts within Maine DEP for questions. The same page also includes information on clearing vegetation in the shoreland zone (an issue for bluff management) and establishing starting points for measuring setbacks, and other information. Consult your municipal Code Enforcement or Planning Department to determine the specific regulations within your Municipal Shoreland Zone.

Maine Natural Areas Protection Act (NRPA) – Maine's NRPA governs activities within or adjacent to protected natural resources in Maine. Activities within 75 feet of the Highest Astronomical Tide (HAT) will require an NRPA permit. This includes Permit-by-Rule (PBR) permitting for *de minimus* activities, and full Individual Permits for certain activities.

Permit-by-Rule (Chapter 305) – Some activities on coastal bluffs can be undertaken with a Chapter 305, Permit-by-Rule (PBR). A PBR activity is considered one that will not significantly affect the environment if carried out in accordance with Chapter 305 standards, and generally has less of an impact on the environment than an activity requiring an individual permit. A PBR satisfies the Natural Resources Protection Act (NRPA) permit requirement and Water Quality Certification requirement. Note that any coastal rip-rap stabilization will require a full NRPA permit. As part of these reviews, based on the proposed project, the Maine DEP may request review and comment by Maine Department of Inland Fisheries and Wildlife (MEIFW) through a Request for Approval of Activity. Similarly, they may request review and comment from Maine's Department of Marine Resources (MEDMR) through a Request for Approval of Timing of Activity.

Maine Wetland Protection Rules (Chapter 310) – Portions of Maine NRPA regulate activities that occur in coastal wetlands, which typically exist at the base of coastal bluffs. Coastal wetlands are defined as:

all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the highest tide level for the year in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes. (Title 38 M.R.S. §480-B, 2).

Activities that extend into defined coastal wetlands, based on the HAT, will likely require a permit from Maine DEP under Chapter 310.

Assessing and Mitigating Impacts to Existing Scenic and Aesthetic Uses (Chapter 315) – For some projects which may impact scenic and aesthetic uses, Maine DEP may require visual impacts assessments and mitigation under Chapter 315 if a project is deemed to unreasonably interfere existing and aesthetic uses of scenic resources including national, state or local scenic significance. Scenic resources include, but are not limited to:

- National Natural Landmarks and other outstanding natural and cultural features;
- State or National Wildlife Refuges, Sanctuaries, or Preserves and State Game Refuges;
- A State or federally designated trail;
- A property on or eligible for inclusion in the National Register of Historic Places;
- National or State Parks; and
- Public natural resources or public lands visited by the general public, in part for the use, observation, enjoyment and appreciation of natural or cultural visual qualities.

Coastal Sand Dune Rules (Chapter 355) – In some coastal bluff locations, coastal sand dunes may exist adjacent to coastal bluffs. If activities extend into these areas, Chapter 355, Coastal Sand Dune Rules governs activities within the Coastal Sand Dune System. The Coastal Sand Dune Rules, administered by Maine DEP, have specific guidelines for activities that require permits, or for *de minimus* activities, those not requiring permits. For more information on beaches, sand dunes and the Coastal Sand Dune Rules, please refer to the *Beaches, Dunes, and Coastal Erosion and Flooding Hazards* section of this guide.

Water Quality Certification – An application for a federal license or permit to conduct an activity that may result in a discharge to a navigable water of the United States must supply the federal licensing authority with a water quality certification from the MEDEP that any such discharge will comply with State water quality standards. The federal license or permit may not be issued until water quality certification has been issued or waived.

Federal Clean Waters Act and Rivers and Harbors Act – Sections of the federal Clean Water Act and Rivers and Harbors Act govern activities within coastal wetlands (and therefore waters associated with bluffs) and tidal creeks and adjacent rivers. Permits are administered by both the U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (U.S. EPA). Section 10 of the Rivers and Harbors Act requires a USACE permit for any work in navigable (tidal) waters below the mean high-water line. Section 404 of the Clean Water Act requires a USACE permit for the discharge of dredged or fill material into waters of the United States.

In Maine, regulated activities which occur in the waters of the United States within the boundaries of the State of Maine will require permitting through a USACE Maine General Permit, which was updated in October 2020. Activities for which a General Permit is applicable is provided in Appendix A of the General Permit. Common activities occurring on coastal bluffs for which permits will be required include:

1. Repair, replacement, expansion, and maintenance of authorized structures and fills;
5. Dredging, disposal of dredged material, beach nourishment, and rock removal and relocation;
7. Bank and shoreline stabilization including living shorelines;
18. Survey activities;
21. Habitat restoration, establishment and enhancement activities.

Maine General Permits fall into two different categories:

- Category 1 (Self-Verification) – requires completion of a Self-Verification Notification Form (Appendix B of the General Permit). This is for minor activities and only requires notification to the USACE of the activity within 2-weeks of commencement.
- Category 2 (Pre-Construction Notification) – if an activity is not eligible for self-verification, then it will require an application to the USACE in the form of a Pre-Construction Notification (PCN) and a permit from the appropriate USACE office. Permitting through a PCN usually includes review and comment by the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the U.S. Environmental Protection Agency. In Maine, notification of Tribal Historic Preservation Officers is also required. Appendix C of the General Permit includes the required content of the Pre-Construction Notification.

Eroding or Unstable Coastal Bluffs: What can I do?

The steps below summarize how coastal property owners can address problems associated with eroding coastal bluffs or landslide hazards.

1. Identify the hazard(s) and classify the level of risk.
2. Determine if the hazard(s) identified can be mitigated.
3. Determine if the risks associated with known hazards are acceptable.
4. Determine setback standards.
5. Get appropriate permits.
6. Appropriately adapt to or mitigate the hazard.
   a. Do nothing.
   b. Avoid the hazardous area.
   c. Design and build properly.
   d. Relocate existing infrastructure.
      i. Consider mitigating erosion hazards using sequence minimization techniques, including:
      ii. Divert water flow (surface and groundwater);
      iii. Plant erosion-resistant vegetation;
      iv. Adopt living shoreline and green infrastructure approaches;
      v. Change the slope of the land surface;
      vi. Stabilize the eroding slope.

These actions, along with pros and cons, the effort and comparative costs involved, are summarized in Table B1.

1. Identify the hazard(s) and classify the level of risk.

One of the first things that an individual can do in determining bluff hazards for their property is to *identify your hazard by using the numerous resources listed above* in conjunction with *doing a field inventory* of your property. Use available resources, including but not limited to the MGS series of maps and additional applicable information, to preliminarily determine the stability of your bluff and the potential landslide hazard. Once you have determined the presence or absence of hazards at your property, the next step is to classify the level of risk associated with each hazard. That is, if your bluff is showing evidence of being unstable, if bluff erosion is occurring, at what rate in the short term? Can you determine a short-term erosion rate? How close is your structure (or footprint if you are planning to build) next to the edge of the bluff? The Cumberland County Soil and Water Conservation District's Bluff Instability Assessment Rating Form can help you better classify your level of risk.

CCSWCD's Shoreline Management Assessment (SMA) is a Chart with three different levels of analysis which is meant to guide one through the process of determining if a living shoreline, or a more traditional shoreline protection structure, should be implemented at a site:

- Reconnaissance (Level I) – developing a basic understanding of bluff stability;
- Prediction Level Assessment (Level II) – using more in-depth tools, like GIS mapping, to better understand the factors that might be influencing

Coastal Bluffs, Erosion and Landslide Hazards Response Actions				
Action	**Pros**	**Cons**	**Effort**	**Cost**
Do Nothing	No to low cost; easy to implement	Must accept a level of risk; uncertainty	Low	$
Avoid Hazardous Area	Reduces hazard to new structures; part of design phase	Applicable to new construction only; site constraints	Low	$
Design and build properly	Reduces hazards to new structures; part of design phase	Applicable to new construction only; site constraints	Low-Mod	$-$$
Relocate	Reduces hazards to structures	Site constraints; hard and expensive	Mod-High	$$-$$
Divert water flow or improve drainage	Reduces hazards to structures and bluff stability	Site constraints; can be expensive	Low-Mod	$-$$
Plant erosion-resistant vegetation	Green approach; relatively easy to implement	Site constraints	Low	$
Living shoreline approaches	Green approach; helps maintain natural connectivity	Site constraints; can be expensive; permitting	Low-High	$-$$
Regrade the slope	Reduces instability of shoreline	Site constraints; can be expensive; permitting	Mod-High	$$-$$$
Stabilize eroding slopes	Reduces instability of shoreline	Site constraints; expense; permitting; impacts to neighboring properties	Mod-High	$$-$$$

Table B1. Table summarizing coastal bluff, erosion and landslide response actions in terms of pros, cons, level of effort, and generalized costs. Note costs are for comparative purposes only.

bluff stability; and
- Design Level Assessment (Level III) – flow chart to develop specific recommendations for shoreline stabilization, including living shoreline approaches and green infrastructure.

The SMA has a supporting Decision Tree to help walk through the process of determining whether or not a living shoreline or more hybrid green/gray infrastructure. *Because the SMA assessment materials can be quite complex, MGS recommends that you consider completing them in consultation with appropriate experts such as licensed engineers or licensed geologists*.

2. Determine if the hazard(s) identified can be mitigated.

In conjunction with your professional(s), determine what hazards can expectantly be mitigated, and at what cost. For example, if you have identified an existing bluff erosion hazard, can you locate your structure so that it is well outside an expected future erosion line? Can an unstable bluff be stabilized with a living shoreline, or do you need a rip-rap seawall?

The CCSWCD's Shoreline Management Assessment Chart can help you through this process, though MGS recommends completing this with the help of a licensed professional since the details can be confusing. As it relates to landslide hazards, the MGS Maine Landslide Guide recommends several *general steps* related to landslide hazard mitigation (typically to be completed in conjunction with a licensed professional):

- Investigate underlying geological materials and their engineering characteristics;
- Manage water on slopes;
- Manage vegetation on slopes;
- Avoid undermining slopes;
- Adjust slopes; and
- Monitor slopes.

As part of this process, review some of the goals, priorities, and expectations for the use of your property in conjunction with risk.

- **Be realistic**. It may not be technologically or economically feasible to stabilize certain types of slopes.
- **Be neighborly**. Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted.
- **Consider the costs**. When comparing strategies, consider the short and long-term costs of different strategies.
- **Consider the permit requirements**. Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs.
- **Consider timeframes**. Some activities or strategies may have extended permit review

processes, certain habitat types or timing restrictions, and extended construction timeframes. Also think about the timeframe of expected usage of your property.

3. Determine if the risks associated with known hazards are acceptable.

Consider the information that you developed in terms of mitigation as part of #2, determine the *level of risk you are willing to accept* to meet your goals, priorities, and expectations for the property. For example, if there is a high landslide hazard, are you willing to accept the risk associated with the potential damage or loss of the structure to a large slope movement?

4. Determine setback standards

If contemplating new construction or a reconstruction of an existing property, determine minimum appropriate setbacks based on your municipal shoreland zoning ordinance, other ordinances, and applicable state and federal rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or use certain types of setback construction techniques. The minimum setback along stable coastal bluffs is 75 feet from the highest astronomical tide, while the minimum setback along unstable bluffs is 75 feet from the top of the bluff. MGS recommends that you check with the municipal Code Enforcement Officer for specific information relating to setbacks and possible construction standards. MGS also recommends, if you have room on your property, to consider setbacks which *are farther than minimum standards*, since coastal bluffs can change in terms of their stability over time, and erosion hazards can increase (due to storm impacts and sea level rise).

5. Get appropriate permits

Building or engineering on Maine's coastal bluffs is likely subject to regulation under the Natural Resources Protection Act and the Mandatory Shoreland Zoning Act. Permits from the Maine Department of Environmental Protection or your town may be required for site modifications. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on municipal and state requirements for permits based on the activities you may be proposing on your property. Maine DEP is available for a pre-application meeting to explain the state standards.

6. Appropriately adapt to or mitigate the hazard

You can take action to manage or reduce the risk of bluff erosion or landslide hazards impacting your property. These efforts should be developed in conjunction with the steps involved above, and input from appropriate local experts (licensed geologists, licensed geotechnical engineers, landscape architects, etc.). Addressing hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., bluff stabilization through plantings or construction or dewatering efforts).

Mitigation and adaptation strategies listed below can be undertaken one at a time, or using a site-specific, multi-strategy approach. From an environmental impact standpoint, MGS generally recommends that alternatives be considered in the order listed. However, in many cases a combination of several or all the listed alternatives can and should be considered in order to create a resilient coastal property. Appropriate mitigation strategies should be developed in conjunction with appropriate local experts. Once again, the CCSWCD's Shoreline Management Assessment Chart can help you through the process of selecting different mitigation strategies, though we recommend completing this with the help of a licensed professional.

To aid with development of appropriate mitigation alternatives, Maine DEP has a guide to Maine Erosion and Sediment Control Best Management Practices for Engineers, with techniques applicable to coastal bluff and landslide sites. In support of this section on mitigating Coastal Bluffs and Landslides, specific attention should be given to Slope and Shoreline Stabilization (starting on p. 99) and Vegetative Buffers. Many of the techniques summarized in the guide may require permitting from the Maine DEP.

Doing nothing. Doing nothing makes the most sense where there is no structure on an eroding bluff, or if a structure is located a more than adequate distance from an eroding bluff or landslide site, and the bluff has a well-determined and steady erosion rate (determined in consultation with experts). Doing nothing is sometimes considered last, after other, more expensive and intensive options have had no success. Doing nothing is *typically* a least-costly alternative and does not require permitting, unless erosion causes damage to property or infrastructure. The do nothing alternative *must* consider the level of risk you are willing to accept in conjunction with the expected uses of your property. Coastal property owners located along eroding bluffs or near landslide prone areas should check their insurance policy coverage. Many homeowner policies do not cover earth movements.

Avoid the hazardous area. In general, avoiding existing or potential hazards as much as possible is usually the most efficient and cost-effective method of mitigation, especially when siting new development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies, and the level of risk you are willing to accept. A common avoidance technique is to build a structure as far landward as possible. You may need to request a variance from local setback ordinances in order to do so. MGS recommends siting new construction as far landward as possible from the edge of the bluff, even farther than minimum setback standards, if possible. *Increasing the distance from the hazard is one tried-and-true method of hazard avoidance*. Note that in doing so, you might be constrained by significant upland habitat resources or environmentally sensitive areas, which are usually identified by shoreland zoning or state regulations. However, it is not always practical for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, lot size, cost, or other factors.

Relocate existing infrastructure. Where existing development is being threatened by bluff erosion or landslides, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction. Although this method can be very effective in minimizing or mitigating the hazard, this alternative can be expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography, and distance the structure may need to be moved. Consultation with a local engineer or contractor is suggested, and local and state permits may be needed. Relocation of a structure can also be constrained by the size of a property and local or state setbacks, such as from other existing structures or roadways. In many cases, variances from local setback ordinances can be requested by a homeowner so that relocation may be undertaken.

Design and build properly. Following proper construction techniques involves not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential land, wind, and water forces associated with the dynamic coastal zone.

Give consideration to:

- The construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- Maintaining appropriate buffers, both vegetative and from a setback standpoint;
- The extent of grading to achieve a stable building footprint;
- Elevating of structures (if in a floodplain);
- The level of engineering required to mitigate for hazards;
- Potential hydrostatic and wind loading;
- Water diversion;
- Siting of ancillary infrastructure; and
- General construction standards.

Many of the coastal construction techniques from the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets are applicable to sound construction in coastal bluff areas.

Consider Mitigating Bluff Erosion Hazards. Once you have identified hazards on a property and worked through the list of ways to minimize your exposure to risk, you may have to mitigate identified bluff erosion hazards. MGS recommends following a sequence minimization approach to this; that is, determine the *least invasive* way of mitigating an identified hazard. This process is something that will likely be required as part of a state or federal permit review as well. Several of the techniques below may be needed together to address certain bluff erosion issues. Sequence minimization should consider:

- Diverting surface and groundwater discharges (if applicable);
- Planting erosion-resistant vegetation;
- Implementing living shoreline and green infrastructure approaches;
- Regrading an unstable slope; and
- Stabilizing the toe of the bluff.

Diverting water flow (if applicable). Along some bluff areas, instability is directly caused by (or a significant component is contributed by) surface or subsurface drainage patterns. Installing surface and subsurface drainage devices within and adjacent to potentially unstable slopes can mitigate these problems. Surface and subsurface drainage design must include consideration of the effects of surface runoff and groundwater migration on the stability and water quality of adjacent sites. An option, if appropriate at the site, is to consider the use of green infrastructure to either catch or divert water. This can be done using step pools (Moses, 2010) and low-impact rain gardens (Seattle Public Utilities, 2015) or similar infrastructure (Figure B9). Although much more invasive, surfaces can be regraded to drain surface water on a site away from a bluff – this can substantially reduce infiltration and groundwater adjacent to a bluff face. Water flow issues can be identified by using the CCSWCD's self-assessment tools mentioned previously.

Planting erosion-resistant vegetation. Stabilization of slightly eroding bluffs can potentially be achieved through specific bluff planting techniques. MGS recommends consultation with a licensed arborist if considering planting, either by itself, or in conjunction with other stabilization methods. The Cumberland County Soil and Water Conservation District developed a Maine-specific Coastal Planting Guide which details plant species native to Maine which would thrive on coastal bluffs. It is broken up into herbaceous grasses, low perennials and ferns, woody low, medium and tall shrubs, and woody small and tall trees. Each individual species includes information on their salt-tolerance,

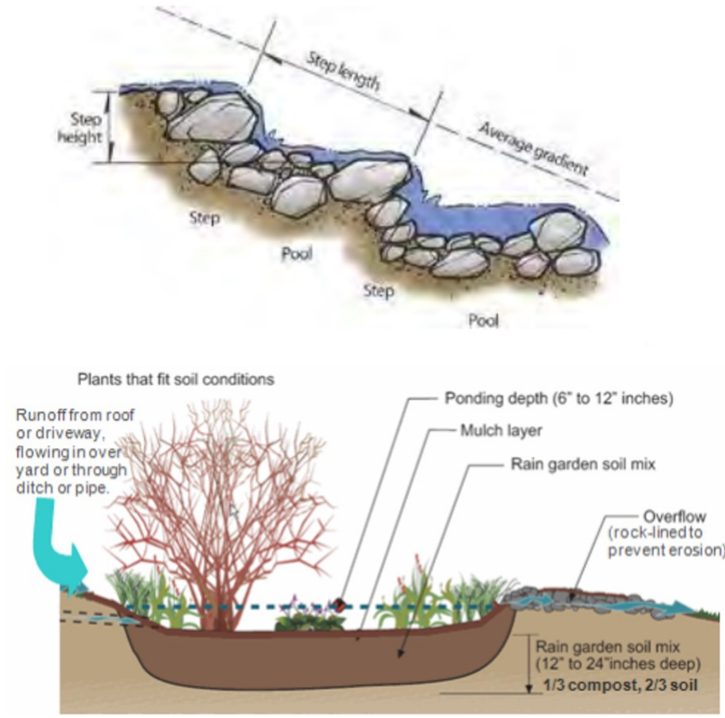


Figure B9. Examples of step pools and raingarden designs to help dewater unstable bluffs. Step pool image from Moses (2010) and raingarden design from Seattle Public Utilities, 2015.

recommended location on the bank or bluff, resiliency, sun requirements, and wave tolerance. The University of Maine Cooperative Extension also includes a list of plants for the Maine landscape.

Implementing Living Shoreline and Green Infrastructure Approaches. Although planting of erosion-resistant vegetation is considered a living shoreline approach, "living shoreline" is a broad term that encompasses a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline:

- has a footprint that is made up mostly of native material;
- incorporates vegetation or other living, natural "soft" elements alone or in combination with some type of harder shoreline structure (e.g. oyster reefs or rock sills) for added stability; and
- maintains continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.

**Definition adapted from NOAA's Guidance for Considering the Use of Living Shorelines (2015)*

Living shoreline techniques are typically most suited for lower-energy environments – for example, those areas that are at least somewhat sheltered from direct wave attack during annual conditions or storm events. Living shorelines are designed to mimic or work with natural features in slowing erosion of bluffs and coastal wetlands. Examples of living shorelines include planting vegetation at the toe of a bluff (salt marsh), along a bluff slope, or mixing vegetative plantings with toe stabilization structures, such as coir (natural fiber) envelopes, downed trees, or even rip-rap or other engineering structures.

Living shorelines in Maine, and New England, are a relatively new concept. They have been implemented widely in warmer climate, lower energy, lower tidal regime areas of the southeast U.S. and Gulf of Mexico coastlines for decades. Many of the techniques are transferable to Maine. Although it may seem counter-intuitive, living shorelines can be extremely effective at lessening erosion and property damage from coastal storms. A study in North Carolina after Hurricane Irene (Gittman et al., 2014; Smith et al., 2017) found that properties in estuaries fronted with living shorelines fared better than those fronted by traditional shoreline engineering structures.

Living shorelines are not suitable for all locations. The potential success of living shorelines approaches is dependent upon a variety of factors such as exposure to wave energy and sea ice, underlying geology, shoreline types, and erosion rates, among other factors.

Over the past few years, a variety of resources have been created to help better understand living shorelines and their suitability and applicability in New England and Maine.

New England-wide resources include:

Living Shorelines Stacker – created for the Northeast Regional Ocean Council, this interactive stacker provides fun yet insightful information about the use of living shorelines.

Living Shorelines in New England: State of the Practice – This report, prepared by Woods Hole Group, was the culmination of a NOAA-funded regional project amongst all five New England States, led by the Nature Conservancy and details a wide variety of information on living shorelines and their uses in New England.

Living Shorelines Applicability Index – in conjunction with the above report, this is a spreadsheet-based matrix which accounts for a variety of factors such as energy, sensitive resources, tidal range, slope, and erosion and helps guide the user to a potentially appropriate living shoreline response.

Living Shoreline Combined Profile Pages – these “profile pages” provide information on common types of living shoreline approaches at dunes, beaches, coastal banks, and marshes. They relate to the living shoreline applicability index discussed above. These pages provide schematics, design overviews, case studies from New England, and siting and design considerations.

Maine-specific resources include:

Living Shorelines in Maine – A website maintained by MGS which details (in chronological order, from newest to oldest), current and completed living shoreline efforts and projects in Maine. This includes project summaries and numerous products and outcomes from several NOAA-funded efforts in Maine and New England, including some of those discussed above. The website also documents an ongoing project to design, permit, and construct living shoreline demonstration treatments at three different locations in Brunswick and Yarmouth, Maine. Several different living shoreline approaches using downed trees and bagged aged oyster shell – in biodegradable bags and plastic mesh gabions (and sometimes in combination) – are being implemented at eroding bluff and coastal wetland edges (Figure B10). These techniques would be transferable to eroding coastal bluffs and wetlands throughout Casco Bay, and in different regions of Maine. Monitoring of the installed projects will occur for 5 years, paying close attention to their efficacy in curtailing erosion and durability of the installed materials. This website is being revised as additional information becomes available from the project. The Greater Portland Council of Governments (GPCOG) put together an informational video on the construction of these demonstration treatments in Brunswick, Maine. This website is updated on a regular basis.

Living Shorelines Decision Support Tool for Casco Bay – MGS created this tool to show where in Casco Bay living shoreline approaches may be suited based on a variety of different factors including fetch, nearshore bathymetry, landward and seaward shoreline types, relief, slope, and aspect. This tool is for general planning purposes only and undertaking living shorelines at a specific location should be done in consultation with experts.

The previously discussed Living Shorelines in New

Figure B10. Example of a hybrid living shoreline at Maquoit Bay Conservation Lands, Brunswick, ME, along an eroding marsh edge which beneficially uses woody debris (logs) and integrates biodegradable bags and synthetic baskets filled with aged oyster shell. Image by R. Harbison, GPCOG.

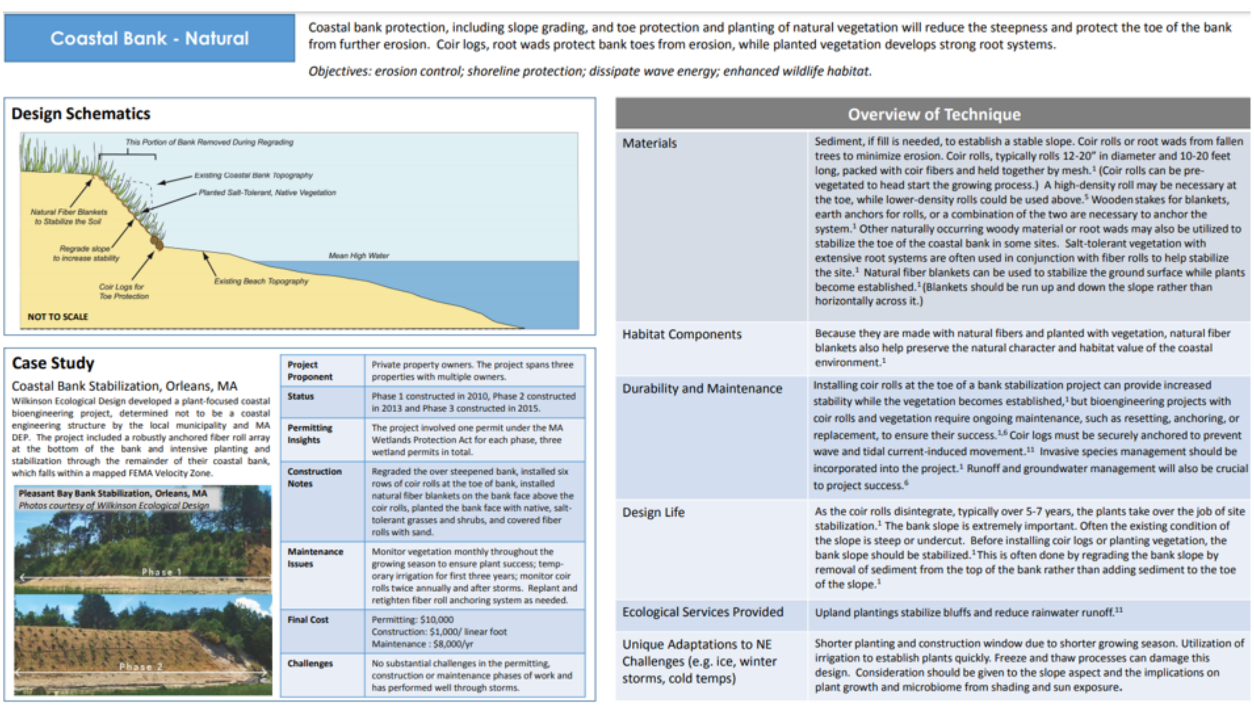
England: State of the Practice report has several profile pages that are bluff-specific, including stabilization of a coastal bluff naturally and stabilization of a coastal bluff with an engineered core. The schematic for natural bluff stabilization, along with supporting information, is provided below in Figure B11.

Regrading an unstable slope to stabilize the bluff. Reducing the overall slope or overhangs by grading the bluff to a lower angle can significantly decrease the erosion and landslide hazard and is usually done with vegetative plantings or toe stabilization. Some slopes can be stabilized by building terraces into the bluff instead of regrading at a consistent slope. Living shoreline or green infrastructure techniques described below can be undertaken either individually, or in combination. In many cases, a bluff will need to be regraded in order to create a more amenable slope for planting vegetation or implementing living shoreline approaches. MGS recommends consultation with qualified professionals (arborists, geotechnical engineers, licensed geologists) when undertaking such efforts.

Stabilizing the bluff. In locations where other strategies such as regrading, planting and implementation of living shorelines or green infrastructure cannot be implemented, especially those with high wave energy, bluff stabilization could be considered. Bluff stabilization with armoring can also take a minimization approach; that is, minimizing the amount of armoring in order to stabilize the bluff. The first option to consider is whether the unstable bluff can be stabilized by regrading the slope (as described above), and then stabilizing only the toe of the regraded slope with an engineering structure. This can be coupled with replanting of vegetation along the regraded bluff (Figure B12). The costs associated with bluff stabilization can be quite high depending on the size and project design specifications. Permitting may be required for not only the actual activity, but also for staging or seasonal use of equipment, especially if it occurs from the seaward side of the project and is within the "coastal wetland" or below highest astronomical tide. Refer to the Maine DEP BMP guide for more specific information.

Case Study: Bustins Island, Freeport, Maine. The Cumberland County Soil and Water Conservation District completed an analysis of bluff instability along a section of shoreline at Bustins Island, Freeport, Maine. This in-depth study included bluff stability assessments and developed a range of adaptation solutions, including dewatering using step pools, rain gardens, and green infrastructure approaches. The study resulted in 11 different treatment concepts for 11 different sections of the study shoreline, ranging from increasing buffer width, to placement of toe rock and woody debris, to maintaining existing rip-rap areas. The holistic study also looked at upland run-off problems contributing to bluff instability and developed both step pool structures and rain gardens for stormwater retention.

A note on rocky shores ("consolidated bluffs"). In the face of rising sea levels, a homeowner may experience waves overtopping a rock-lined shore, causing erosion of upland soil landward of the bluff


Coastal Bank - Natural

Coastal bank protection, including slope grading, and toe protection and planting of natural vegetation will reduce the steepness and protect the toe of the bank from further erosion. Coir logs, root wads protect bank toes from erosion, while planted vegetation develops strong root systems.

Objectives: erosion control; shoreline protection; dissipate wave energy; enhanced wildlife habitat.

Design Schematics

Case Study

Coastal Bank Stabilization, Orleans, MA

Wilkinson Ecological Design developed a plant-focused coastal bioengineering project, determined not to be a coastal engineering structure by the local municipality and MA DEP. The project included a robustly anchored fiber roll array at the bottom of the bank and intensive planting and stabilization through the remainder of their coastal bank, which falls within a mapped FEMA Velocity Zone.

Project Proponent	Private property owners. The project spans three properties with multiple owners.
Status	Phase 1 constructed in 2010, Phase 2 constructed in 2013 and Phase 3 constructed in 2015.
Permitting Insights	The project involved one permit under the MA Wetlands Protection Act for each phase, three wetland permits in total.
Construction Notes	Regraded the over steepened bank, installed six rows of coir rolls at the toe of bank, installed natural fiber blankets on the bank face above the coir rolls, planted the bank face with native, salt-tolerant grasses and shrubs, and covered fiber rolls with sand.
Maintenance Issues	Monitor vegetation monthly throughout the growing season to ensure plant success; temporary irrigation for first three years; monitor coir rolls twice annually and after storms. Replant and retighten fiber roll anchoring system as needed.
Final Cost	Permitting: $10,000 Construction: $1,000/ linear foot Maintenance : $8,000/yr
Challenges	No substantial challenges in the permitting, construction or maintenance phases of work and has performed well through storms.

Overview of Technique	
Materials	Sediment, if fill is needed, to establish a stable slope. Coir rolls or root wads from fallen trees to minimize erosion. Coir rolls, typically rolls 12-20" in diameter and 10-20 feet long, packed with coir fibers and held together by mesh.[1] (Coir rolls can be pre-vegetated to head start the growing process.) A high-density roll may be necessary at the toe, while lower-density rolls could be used above.[5] Wooden stakes for blankets, earth anchors for rolls, or a combination of the two are necessary to anchor the system.[1] Other naturally occurring woody material or root wads may also be utilized to stabilize the toe of the coastal bank in some sites. Salt-tolerant vegetation with extensive root systems are often used in conjunction with fiber rolls to help stabilize the site.[1] Natural fiber blankets can be used to stabilize the ground surface while plants become established.[1] (Blankets should be run up and down the slope rather than horizontally across it.)
Habitat Components	Because they are made with natural fibers and planted with vegetation, natural fiber blankets also help preserve the natural character and habitat value of the coastal environment.[1]
Durability and Maintenance	Installing coir rolls at the toe of a bank stabilization project can provide increased stability while the vegetation becomes established,[1] but bioengineering projects with coir rolls and vegetation require ongoing maintenance, such as resetting, anchoring, or replacement, to ensure their success.[1,6] Coir logs must be securely anchored to prevent wave and tidal current-induced movement.[11] Invasive species management should be incorporated into the project.[1] Runoff and groundwater management will also be crucial to project success.[6]
Design Life	As the coir rolls disintegrate, typically over 5-7 years, the plants take over the job of site stabilization.[1] The bank slope is extremely important. Often the existing condition of the slope is steep or undercut. Before installing coir logs or planting vegetation, the bank slope should be stabilized.[1] This is often done by regrading the bank slope by removal of sediment from the top of the bank rather than adding sediment to the toe of the slope.[1]
Ecological Services Provided	Upland plantings stabilize bluffs and reduce rainwater runoff.[11]
Unique Adaptations to NE Challenges (e.g. ice, winter storms, cold temps)	Shorter planting and construction window due to shorter growing season. Utilization of irrigation to establish plants quickly. Freeze and thaw processes can damage this design. Consideration should be given to the slope aspect and the implications on plant growth and microbiome from shading and sun exposure.

Figure B11. Example of profile page for natural coastal bluff stabilization from the Living Shorelines in New England: State of the Practice Combined Profile Pages.

Figure B12. Example of bluff regrading, placement of toe armor, and planting with native vegetation from Freeport, ME. Image by Maine DEP.

face. There is no clear statutory or rule language on consideration of sea-level rise regarding seawalls outside of the coastal sand dune system. Existing seawalls located along a consolidated bluff or on ledge *may potentially be expanded in height with an appropriate permit* on a case-by-case basis if regular flooding and overtopping and subsequent erosion can be proven. New seawalls are not permitted if they will adversely affect the Coastal Sand Dune System (see the section on beaches and dunes). The use of riprap on a consolidated bluff may be permitted by the Maine DEP. In these instances, activities would require permitting under the Maine NRPA, and Shoreland Zoning if they were 75 feet from the highest annual tide (see the section on regulations above).

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C. COASTAL WETLANDS AND FLOODING HAZARDS

Under Maine Law, "coastal wetlands" are defined as

"*…all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the highest tide level for the year in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes*." (38 M.R.S. Sec. 480-B (2)).

Maine's coastline contains approximately 22,400 acres (Cameron and Slovinsky, 2014) of coastal wetland, which is the most of any New England state, New York, or Canadian province on the Gulf of Maine (Jacobson and others, 1987). Marsh systems vary within Maine, generally based on the four different geomorphic compartments used to classify the Maine coast (Kelley et al., 1988) as outlined in the *Introduction to the Maine Coastline Section* of this Guide. These include, from southwest to northeast:

- Southwest Arcuate Embayments
- South-central Indented Shoreline
- North-central Island Bay Coast
- Northeast Cliffed Coast

Coastal wetlands (or tidal marshes) systems within each of these compartments differ due to geology and tidal ranges. About 34% of Maine's marshes are found within the Arcuate Embayment compartment, which is dominated by extensive coastal barrier and marsh systems. Over 35% of Maine's marshes are located in the Indented Shoreline compartment, lending to the narrow embayments and tidal rivers that dominate this area. About 26% of marshes are located in the Island Bay Coast, which is dominated by high tidal ranges and large bays. Finally, only about 5% of Maine's marshes are located in the Northeast Cliffed Coast compartment due to the frequency of bedrock coast and few tidal rivers (Bryan et al., 1997).

The following resources were heavily consulted for this section of the guide:

Maine Citizen's Guide to Evaluating, Restoring, and Managing Tidal Marshes (Bryan et al., 1997)

Maine Salt Marshes: Their Function, Values, and Restoration (Dionne et al., 2003)

Salt Marshes in the Gulf of Maine, Human Impacts, Habitat Restoration, and Long-term Change Analysis (Taylor, 2008)

Potential for Tidal Marsh Migration in Maine (Cameron and Slovinsky, 2014)

Typical Coastal Wetland Features

Coastal wetlands within the State of Maine are typically comprised of several different zones of vegetation that are common to most coastal marsh systems. These features are dependent on the influence of tidal elevations, and include (Figure C1):

Low marsh, typically a sloping fringe of smooth cordgrass (*Spartina alterniflora*) between the high marsh and a tidal creek, is flooded twice daily by tidal action. Low marsh is much less common than high marsh in Maine.

High marsh is at or just above mean high tide, and therefore is flooded only on monthly high tides (which occur for a few days during full and new moons) and irregularly by storm tides. Salt-hay grass (*Spartina patens*), and black grass (*Juncus gerardii*) are the dominant plants in most high marshes. In brackish marshes with a strong freshwater influence, plants such as prairie cordgrass (*Spartina pectinata*), narrow-leaved cattail (*Typha angustifolia*) or rushes (*Scirpus sp.*) may dominate. The high marsh is usually substantially level and occurs between the low marsh and uplands. Most of Maine marsh systems are dominated by high marsh.

Pannes and Pools are shallow "ponds" that form in the high marsh peat. Flooded periodically, pannes and pools provide an abundance of food for waterfowl and migrating shorebirds. Pannes tend to drain seasonally while pools hold water in the summer. A short form of smooth cordgrass frequently occurs in these areas. Common glasswort (*Salicornia europaea*) and other non

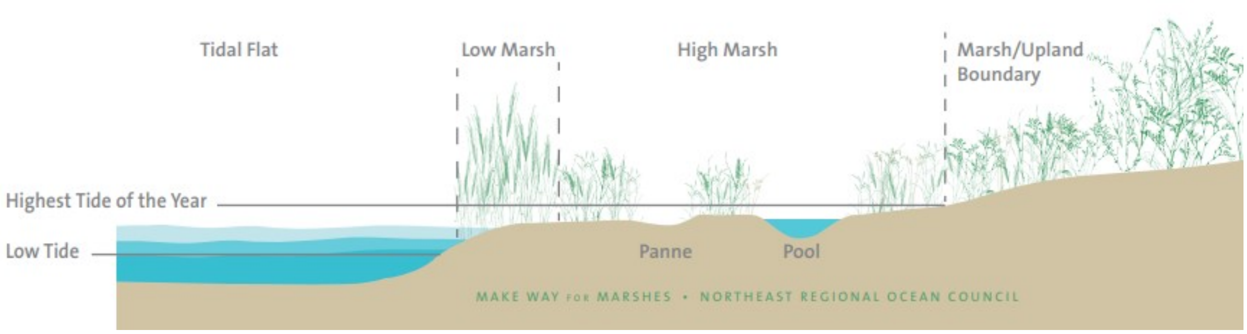


Figure C1. Typical northeastern salt marsh zonation. Make Way for Marshes/Northeast Regional Ocean Council.

-grassy plants often colonize shallow pannes that dry out. Much of the plant diversity on the salt marsh is associated with these shallow pannes. Deeper pannes or pools that remain water filled may support widgeon grass (*Ruppia maritima*), which is valuable forage for waterfowl.

Tidal creeks, open water, and tidal flats are all-important components of the marsh ecosystem. Open water is generally defined as a permanently flooded (i.e., below mean low water) water body greater than 100 meters (330 feet) wide. Tidal creeks are less than 100 meters wide at mean low water. Tidal flats are nearly level to gently sloping unvegetated areas within the intertidal zone. Tidal flats may support commercially significant marine worm and clam populations.

Together, these different environments form a marsh ecosystem. Marsh systems in Maine can generally be classified into three different types based on their overall geomorphology and shape, including coastal/back barrier marshes, finger marshes, and fringe marshes (Figure C2).

Why are Coastal Wetlands Important to the Maine Coast?

Wetlands provide a variety of valuable ecological (e.g., habitat) and societal (e.g., economic) benefits, and these values are closely related (e.g., wildlife habitat and recreation). Some important functions of marshes include:

- **Shoreline anchoring** – coastal wetlands generally "anchor" barrier beaches to the mainland. To an extent, their accreting surfaces maintain elevation as sea level rises.
- **Storm surge protection** – coastal wetlands provide vital storm surge protection by slowing wind-driven waves over the marsh, thereby helping to protect low-lying uplands and erodible shorelines during storms. Fifteen feet of marsh can decrease wave energy by 50% (NOAA).
- **Natural pollutant buffer** - pollutants entering aquatic systems are attached to sediment particles that are deposited on the marsh, limiting their transport to other ecosystems. Some pollutants may then bind with soil particles and become unavailable for uptake by plants or animals.
- **Carbon sequestration** – coastal wetlands are extremely efficient at capturing carbon from the atmosphere, called "blue carbon," which is vital in decreasing the impacts of climate change (Wang et al., 2019; Johnson et al., 2016).
- **Vital habitat** - Salt marshes are used for food and shelter by a diverse animal community, including many species of birds, fish, and shellfish, many of which are endangered or threatened.
- **Recreational and commercial potential** – coastal wetlands support activities such as hunting, fishing, birdwatching, clamming, etc.
- **Aesthetic quality** – coastal wetlands enhance the

Figure C2 (Top to bottom). Examples of coastal/back barrier marsh system from Goose Rocks Beach, Kennebunkport; finger marsh on the Saco River, Saco; and fringe marsh on the Saco River, Saco. Images courtesy of Screaming Eagle Aviation.

aesthetic qualities of the coastal landscape.

Many of these ecological functions have *tremendous societal value through economics*. For example, two-thirds of commercial shellfish and finfish landed in the U.S. depend on coastal wetlands for nursery and breeding habitat or on forage fish that breed in our coastal wetlands (Gosselink et al., 1974). Recreational fishing, hunting, wildlife watching, and boating in coastal wetlands also contribute significant economic value (Dionne et al., 2003).

Threats to Coastal Wetlands

The threats to coastal wetlands are many, both natural and human-made. Historically, coastal wetlands in Maine have been able to maintain themselves in relation to sea level because the rate of sedimentation (i.e., input of sediment to the marsh system) has generally met or exceeded the rate of sea-level rise. Long-term sea-level rise in Maine has been around 1.9-2.2 mm/year (7.5-8.7 inches per century) and coastal marshes have generally been able to keep pace. However, over the past 25 years or so, those rates have about doubled to 3.2-4.0 mm/year (12.6-15.7 inches per century). If rates of sea-level rise increase as predicted to near 4 mm/year, there is a chance that marsh drowning and loss could occur if sedimentation rates cannot keep up with the rate of sea-level rise (Wood et al., 2009).

Humans have drastically altered the coastal environment and wetland habitat, either through direct ditching for mosquito control or salt hay farming, to filling of wetlands, or bulkheading (with a wall or other barrier) the upland/wetland interface. Damming of rivers that empty into salt marshes, combined with engineering of the wetland/upland interface to protect from flooding and marsh encroachment, has decreased the amount of sediment available to the system. Wakes from motorboats can cause tidal bank erosion. Construction of roadways or the use of undersized culverts have caused tidal restrictions and inhibited required tidal flow for adequate flushing of coastal wetlands. Coastal wetlands are also significantly impacted by adjoining land uses and activities, including potential nutrient loading from lawn fertilization, and runoff from road surfaces and paved areas.

Coastal Wetland Hazards

Just like on the open coast, the boundary between coastal wetlands and adjacent uplands is not static, and changes in response to daily and annual high tides, storm events, and sea level rise. Understanding and considering the natural functionality of the system – and the associated hazards – in conjunction with your intended uses of your property, is vital to developing an appropriate management and adaptation plan for the coastal wetlands on or adjacent to your coastal property. At a minimum, you might balance the natural, landward migration of coastal wetlands with the protection of your property from coastal erosion and coastal flooding, the two major hazards associated with this coastal environment. In many cases, significant balancing or trade-offs associated with other factors need to be considered, including the use of the property, costs, and impacts to adjacent properties or habitats.

Coastal Wetland Erosion

Erosion of marsh surfaces can be caused by tidal currents, wind-driven waves, boat wakes, foot traffic, and ice floes.

Tidal currents. Ebbing and flooding tidal currents can be fast enough to erode marsh surfaces, especially along the edges of tidal channels where a channel meanders or bends sharply.

Wind-driven waves. Waves, especially those associated with storms, can erode marsh surfaces, especially at lower tides (at high tides during a storm, waves travel over the marsh surface). This relates to the aspect (or direction) that a marsh faces and the fetch (distance) that the wind can blow over open water to create waves. A larger fetch will allow larger waves with more energy to form. Typically, those marsh surfaces or channels that face to the northeast are most susceptible to erosion during Maine’s common northeast storm events.

Boat wakes. Marsh banks along tidal channels can be impacted by wakes from heavy motorboat usage, which causes abnormally large, energetic waves to erode the edges of the marsh.

Foot traffic. In some areas where people walk across marsh surfaces to access fishing, fowling, or recreational locations, heavy foot traffic, even for a short amount of time, can damage marsh vegetation and erode the surface of the marsh.

Ice floes. In winter, high tides can lift frozen blocks of sea ice and transport them across the marsh. This process can erode sections of the marsh surface. In other instances, the ice floes actually transport sediment from one area of the marsh to another. For example, a ice laden with frozen sediment from the side of a tidal channel, can be carried by a spring tide or coastal flood over the high marsh and deposit sediment on the marsh surface when it melts.

Coastal Wetland Flooding

The flooding of uplands adjacent to coastal wetlands is a common occurrence, but usually limited to times of highest tides (“King Tides”), heavy inland rain or spring melt, or during periods of storm surge. Low-lying areas that are inundated periodically during highest annual tide conditions, from a regulatory standpoint, are part of a coastal wetland since they are at or below the reach of the tides. "Chronic" coastal flooding is when property is flooded on a regular basis by normal high tides or minimal storm surges, during periods of heavy rain or spring snow melt. "Acute" coastal property flooding typically occurs only in larger storm events from storm surges and does not occur on a regular (annual or semi-annual) basis. The Maine Geological Survey sea level rise dashboard (see below) can be used to inspect flood frequency above King Tides at 5 tide gauge stations along the Maine coast.

Resources to Help Identify Coastal Wetlands and Coastal Flood Hazards in Maine

The following are resources to identify coastal wetlands and flooding hazards in Maine:

- National Wetlands Inventory Maps
- Maine Flood Insurance Rate Maps
- Maine Current Maine Tidal Marshes Map
- Maine Potential Tidal Marsh Migration Map
- Maine Coastal Undeveloped Habitat Blocks Map
- Maine Coastal Marine Geologic Environment (CMGE) Maps
- Maine Coastal Sand Dune Geology Maps
- Maine Highest Astronomical Tide Map
- Sea Level Rise and Storm Surge Maps
- Maine Sea Level Rise Dashboard
- Maine Coastal Structure and Dune Crest Inventory and Overtopping Potential Maps
- Maine Sea, Lake and Overland Surges from Hurricanes Maps
- Maine Flood Resilience Checklist

National Wetlands Inventory (NWI) Maps – The National Wetlands Inventory created by the U.S. Fish and Wildlife Service (USFWS) provides a good source for identification of coastal wetlands on a macro-scale. These maps, produced at a 1:24,000 scale, provide *general* wetland characteristics for areas that coincide with the U.S. Geological Survey 7.5 Minute Quadrangle maps. The series uses a wetlands classification scheme identified by codes on the maps. These codes identify wetland types. Most tidal or intertidal wetlands are classified as E2EM (Estuarine Intertidal Emergent, salt or brackish marsh) or R1EM (Riverine Intertidal Emergent, tidal freshwater marsh). NWI maps are available online via the U.S. Fish and Wildlife Service's National Wetland Inventory Wetland Mapper.

Maine Floodplain Management Program's FEMA Flood Insurance Rate Maps Viewer – Low-lying coastal areas along the open coast are susceptible to coastal flooding and are defined by the Federal Emergency Management Agency (FEMA) as Special Flood Hazard Areas, or SFHA. SFHA are areas that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. The elevation of the 1% annual chance flood is also referred to as the base flood elevation (BFE) or 100-year flood elevation. These flood zones are mapped by FEMA in a series of maps called the Flood Insurance Rate Maps (FIRMs). FIRMs are used to identify flood insurance risk and insurance premiums in areas associated with different flooding events. Maps include areas of the SFHA in addition to areas of minimal flood hazard, which are areas outside of the SFHA and higher than the elevation of the 500-year (0.2% chance of being equaled or exceeded each year) flood elevations. Most flood zones have a determined base flood elevation (BFE) which is the elevation to which flooding is expected during a 1% flood event. Most areas of coastal wetlands would be defined within an "AE" zone, which is considered a relatively static flood zone (with waves less than 1.5 feet). Some coastal wetlands may be part of a "Coastal A" zone, which can have waves between 1.5 and 3 feet. Coastal wetlands are usually not mapped as "VE" zones, which are velocity zones (with waves greater than 3 feet). Maine's Floodplain Management Program provides an online viewer for visualizing FEMA FIRMs or FIRMs can be accessed from the FEMA Map Service Center. The Maine Floodplain Management Office's Maine Floodplain Management Handbook can also be a great resource for property owners. An example of these floodplain features is provided in Figure C3.

Maine Natural Areas Program Current Maine Tidal Marshes Map – The Maine Natural Areas Program (MNAP) created a viewer which maps existing tidal marshes in Maine. This mapping product provides the spatial boundaries of mapped tidal marshes, along with classification of dominant marsh community (e.g., *Spartina*) and marsh types (salt or brackish marsh, freshwater tidal marsh). Mapping was completed using low-tide aerial imagery from 2013 and 2014, with field verification and classification.

Maine Natural Areas Program Potential Tidal Marsh Migration Map – The Maine Natural Areas Program (MNAP), with the help of MGS, created a viewer which shows areas of potential marsh migration in Maine in response to 1, 2, 3.3 and 6 feet of sea level rise (sea level rise numbers are being updated in 2021 to coincide with newer MGS scenarios). This mapping product assumes a "bathtub" sea level rise and does not account for marsh accretion or erosion.

Maine Natural Areas Program Coastal Undeveloped Habitat Blocks Map – The Maine Natural Areas Program (MNAP) created a viewer which shows areas undeveloped habitat blocks after 1 meter (3.3 feet) of sea level rise. Features included in this layer depict future tidal wetlands and coastal environments as well as a non-tidal buffer and exclude current tidal areas.

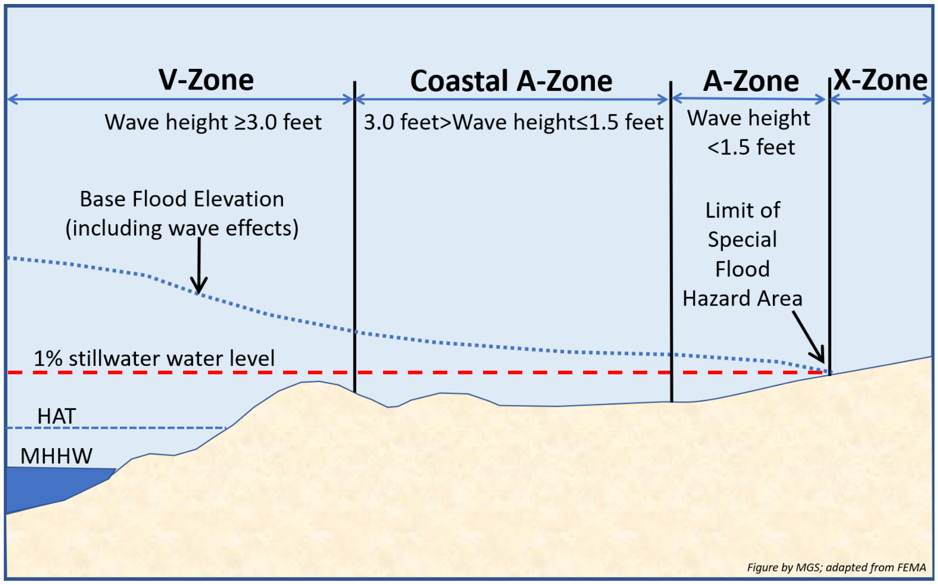


Figure C3. Schematic showing commonly defined Special Flood Hazard Areas (SFHA) along the coastline. Adapted from FEMA.

Future tidal wetlands in this layer are defined as the areas between existing (current) highest annual tide and highest annual tide + 3.3 ft (HAT3) of sea level rise. These include (1) freshwater tidal marsh, salt marsh, and "unknown" classifications derived from MNAP mapped tidal marsh data and NWI mapping? and (2) manmade land, non-tidal buffer, rocky shoreline, and sand or gravel beach and dune future coastal environment classifications derived from the MGS Coastal Marine Geologic Environments data. *Non-tidal buffer* includes areas 300 meters (985 feet) inland from the HAT3 line. All areas within 76.2m (250 ft) of impervious surface were removed using high resolution impervious data provided by the Maine Department of Inland Fisheries and Wildlife in order to further direct attention towards the future marsh and buffer areas. The non-tidal buffers were also classified using the Coastal Marine Geologic Environments where applicable.

Maine Geological Survey Coastal Marine Geologic Environment (CMGE) Maps – The MGS Coastal Marine Geologic Environment (CMGE) maps show regional characteristics of the Maine coast. They illustrate which areas are rocky, muddy, sandy, etc. along the shoreline between the high- and low-tide lines. These maps include coastal wetlands in areas of the state where MGS has not published more detailed Coastal Sand Dune Geology Maps for use in the Maine DEP permitting process. These maps illustrate the location of salt marshes and other tidal wetlands for evaluation of coastal habitats, impact of dredging, and siting of coastal facilities. CMGE maps are available for download.

Maine Geological Survey Coastal Sand Dune Geology Maps – The MGS Coastal Sand Dune Geology Maps identify the dominant features of the coastal sand dune system – frontal and back dunes - but also show other features of the beach and dune system, including coastal wetlands. Note that not all coastal sand dunes in Maine are included in this map series. Additional areas have been mapped but, as of 2020, have not been released yet online. Existing mapped areas are also available for viewing through ArcGIS Online.

Maine Geological Survey Highest Astronomical Tide (HAT) Maps – The MGS Highest Astronomical Tide Maps show the inland limits of the HAT. This boundary is a proxy for the inland extent of the coastal wetland, a regulatory line used in Maine Municipal Shoreland Zoning. Note that the mapped HAT is derived from interpolation of HAT elevations on topography and should be used for general purposes only. Topographic surveying on a particular property can provide a more accurate position of the HAT. In areas inland of tidal restrictions, site-specific water level observations, in addition to site-specific observations of coastal wetland vegetation, should be used to accurately delineate the highest astronomical tide boundaries.

Maine Geological Survey Sea Level Rise and Storm Surge Maps – The MGS Sea Level Rise and Storm Surge Maps help indicate those low-lying areas which might be inundated under highest astronomical tide (HAT) conditions, from current storm surges, and potential sea level rise scenarios. Mapping includes the HAT, plus scenarios of 1.2, 1.6, 3.9, 6.1, 8.8, and 10.9 feet of storm surge and/or sea level rise above the HAT.

Maine Geological Survey Sea Level Rise Dashboard – The MGS Maine Sea Level Rise Dashboard includes a variety of information on monthly water levels and sea level rise at five locations along the Maine coast: Eastport, Cutler, Bar Harbor, Portland, and Wells. At the bottom left of the dashboard is information on the frequency of inundation above the "King Tide" level. This information indicates the frequency of flooding, how it has changed over time, and how it might change in the future with sea level rise. This flood frequency only relates to flooding above the published King Tide level. Your property might be well above this elevation.

Maine Geological Survey Coastal Sand Dune Crest and Coastal Engineering Structure Viewer – For open coast communities along the York and Cumberland County shorelines, MGS created a Coastal Structure and Dune Crest Inventory and Overtopping Potential which allows for stakeholders to view several different important coastal features, including the linear extent of protective coastal sand dune crests and coastal engineering structures, including structures located in coastal wetlands. For this viewer, coastal engineering structures include riprap, bulkheads (or a combination of the two), breakwaters, and jetties. The viewer allows users to inspect the linear extent of sand dune crests and coastal engineering structures. It also allows closer inspection of the elevations of sand dune and coastal engineering structures in relation to FEMA Base Flood Elevations (BFEs) from preliminary Digital Flood Insurance Rate Maps (DFIRMS), which are discussed above.

Maine Geological Survey Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Maps – MGS created SLOSH Maps in conjunction with NOAA, FEMA, and the U.S. Army Corps of Engineers. These maps show potential inundation associated with land-falling Category 1 to 4 hurricanes hitting the Maine coastline at mean high tide. They include the spatial extent of inundation, along with potential depths of coastal flooding from these events. SLOSH maps do not account for extreme tides, freshwater flow, rainfall, waves, or sea level rise. SLOSH maps are typically used for emergency response and evacuation purposes but can be used for general planning of potential inundation from tropical storm events.

Maine Flood Resilience Checklist – The Maine Coastal Program created the Maine Flood Resilience Checklist as a non-regulatory self-assessment tool designed to assist Maine communities evaluate how well positioned they are to prepare for, respond to, and recover from flooding events and sea level rise. It offers an integrated and practical framework for examining local flood risk, evaluating vulnerability of the natural, built, and social environments, and identifying opportunities to enhance flood resilience. Additionally, it allows communities to identify specific intervention points where local decision-makers can develop policy, strategies, and actions to address areas of vulnerability. The Checklist can help communities integrate sea level rise considerations into comprehensive plans, strengthen local floodplain ordinances, and incorporate resilience activities into capital improvement plans. It is recommended that the Checklist be completed at the municipal level in conjunction with support staff.

Regulations Governing Coastal Wetlands and Coastal Flooding

Wetlands and Waterbodies Protection (Chapter 310) – The Maine Natural Resources Protection Act (NRPA) includes Chapter 310, Wetlands and Waterbodies Protection, which governs activities in or adjacent to wetlands of Maine, including coastal wetlands. This Chapter describes the value of wetlands, and reviews activities for which a permit may be required, outlines information required for permit applications, and information on mitigation, compensation, and enhancement. No permit is required if activities in coastal wetlands impact less than 500 square feet of intertidal or subtidal area and has no adverse effect on marine resources or on wildlife habitat as determined by Maine DMR or Maine IF&W (Chapter 310, C., 6., (b)).

Coastal Sand Dune Rules (Chapter 355) - The Maine Natural Resources Protection Act (NRPA) includes Chapter 355, Coastal Sand Dune Rules, which govern activities within the mapped Coastal Sand Dune System, which can include coastal wetlands. The Coastal Sand Dune Rules are administered by Maine DEP and have specific guidelines for activities that require permits or for *de minimus* activities that do not requiring permits. Specific sections of the Rules will be referenced below in relation to mitigation activities and potential permits required.

Permit-by-Rule (Chapter 305) - Some activities within the coastal sand dune system can be undertaken with a Chapter 305, Permit By Rule (PBR). A PBR activity is considered one that will not significantly affect the environment if carried out in accordance with Chapter 305 standards, and generally has less of an impact on the environment than an activity requiring an individual permit. A PBR satisfies the Natural Resources Protection Act (NRPA) permit requirement and Water Quality Certification requirement. Many activities within a coastal wetland can be permitted under Chapter 305.

Maine's Mandatory Shoreland Zoning - By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act (Chapter 1000). Generally, areas within 250 feet of the normal high-water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance. Maine DEP has released a Citizen's Guide to Shoreland

Zoning which helps explain zoning districts and regulations. For most areas, applicable shoreland zoning maps for your community typically identify coastal wetlands within your town's boundaries, which are then used to establish buffers and setbacks. These maps may use the NWI wetland maps for base information or may incorporate more updated information. Check with your town office to find the most recent shoreland zoning map and with your local municipal Code Enforcement or Planning Department to determine the specific regulations within the Shoreland Zone.

Federal Clean Waters Act and Rivers and Harbors Act – Sections of the federal Clean Water Act (Section 404) and Rivers and Harbors Act (Section 10) govern activities within coastal wetlands and tidal creeks and adjacent rivers. Section 10 of the Rivers and Harbors Act requires a USACE permit for any work in navigable (tidal) waters below the mean high-water line. Section 404 of the Clean Water Act requires a USACE permit for the discharge of dredged or fill material into waters of the United States. Permits are administered by both the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE). Federal permitting includes comments provided by the U.S. Fish and Wildlife Service and National Marine Fisheries Service. Text supporting both of these Acts pertaining to coastal wetlands can be seen at the Wetlands Regulation Center.

Eroding Wetlands and Coastal Flooding: What can I do?

Whether you are considering buying or building on a coastal property, or already own coastal property, there are several overall strategies for addressing coastal wetlands and associated erosion and flooding hazards:

1. Identify the hazard(s) and classify the level of risk.
2. Determine if the hazard(s) identified can be mitigated.
3. Determine if the risks associated with known hazards are acceptable.
4. Determine setbacks or elevation standards.
5. Get appropriate permits.
6. Appropriately adapt to or mitigate the hazard.
   a. Do nothing.
   b. Avoid the hazardous area.
   c. Design and build properly.
   d. Elevate or relocate existing infrastructure.
   e. Consider best management practices for wetlands and green infrastructure approaches
      i. Upland/wetland fringe vegetation management.
      ii. Marsh restoration or creation
      iii. Implementing living shorelines and green infrastructure approaches
   f. Riprap or bulkheads

These actions, along with pros and cons, the effort and comparative costs involved, are summarized in Table C1.

Coastal Wetlands and Flooding Response Actions				
Action	**Pros**	**Cons**	**Effort**	**Cost**
Do Nothing	No to low cost; easy to imple-	Must accept a level of risk;	Low	$
Avoid Hazardous Area	Reduces hazard to new struc-	Applicable to new construction	Low	$
Design and build properly	Reduces hazards to new	Applicable to new construction	Low-Mod	$-$$
Elevate or relocate	Reduces hazards to structures	Site constraints; hard and expensive to elevate or relocate large struc- tures	Mod-High	$$-$$
Upland/wetland fringe vegetation management	Helps stabilize and enhance habitat; green approach	Site constraints; takes time to establish and maintain	Low	$
Create or restore marshes	Helps stabilize and enhance	Site constraints; takes time to	Low-Mod	$-$$
Living shoreline approaches	Green approach; helps maintain	Site constraints; can be expensive;	Low-High	$-$$
Install riprap or bulkheads	Reduces instability of shoreline	Site constraints; can be expensive; permitting; impacts to neighboring properties	Mod-High	$$-$$$

Table C1. Table summarizing coastal wetland and flooding response actions in terms of pros, cons, level of effort, and generalized costs. Note costs are for comparative purposes only.

1. Identify the hazard(s) and classify the level of risk

One of the first things that an individual can do in determining hazards associated with coastal wetlands for their property is to identify the hazard by using the numerous resources listed above in conjunction with *doing a field inventory* of your property. Field identification of general coastal wetlands characteristics is outlined well in Section 4 of the Maine Citizens Guide to Evaluating, Restoring, and Managing Tidal Marshes (Bryan et al., 1997). Once you have identified presence, absence, and extent of coastal wetlands on or adjacent to your property using the resources described here (e.g., NWI maps, Coastal Sand Dune Geology Maps, shoreland zoning maps), the next step is to classify the types and features of coastal wetlands on your property. This can include confirming information from the listed resources, and steps outlined in the Maine Citizens Tidal Marsh Guide. Additional assessments to identify existing hazards associated with the wetlands on or adjacent to your property may include the aspect of the property, elevation in relation to highest astronomical tide or base flood elevation, etc. Think about how existing wetlands, and their associated hazards like erosion and flooding, may respond to sea-level rise or increased storm events. Although many levels of assessment can be done on your own, it may make sense to hire qualified experts. Once you have determined the presence or absence of hazards at your property, the next step is to classify the level of risk associated with each hazard. That is, if tidal marsh or bank erosion is occurring, at what rate in the short term? The long term? How close is your structure to the highest astronomical tide. We have created a summary checklist that can aid property owners in determining the level of hazard posed due to erosion and coastal flooding (Coastal Wetland and Coastal Flooding Checklist, Appendix A). *It is recommended that you have a licensed geologist, licensed geotechnical engineer, or coastal floodplain expert investigate your property to help you further classify the risk associated with identified hazards, including erosion and coastal flooding.*

As you look at your property, ask yourself some of these questions:

How far from the highest astronomical tide (HAT) is the structure on your property? Distance from your structure to the HAT is an indication of how close your property might be to flooding hazards. You can use the Highest Astronomical Tide Viewer to inspect this. A property might be close to the HAT, but on a shoreline with a steep slope above the tides, flooding may be less of an issue.

How wide is the marsh in front of your property? Even relatively narrow marshes can break up wave energy. NOAA suggests that 15 feet of marsh can decrease wave energy by 50%. If you don't have a marsh and do have a beach, determine how wide that is.

Over the last decade, is the marsh on your property eroding, stable, or accreting? If your marsh is consistently eroding at rates of 1 foot per year or greater, you may have an ongoing erosion problem. If it's less than that but still negative, it warrants further monitoring and investigation. If your marsh is stable or growing, that means there is adequate sediment supply to maintain the marsh.

After big storms, does the marsh on your property recover after a season or two, or does it stay the same or continue to get worse? It's natural for a marsh to erode in response to a large storm event, and it can take a season or two to recover. If a marsh recovers and maintains itself or starts to grow seaward, that means that it has adequate sediment supply. If your marsh continues to erode, there may be an ongoing erosion problem.

Is your property or structure located in a frontal dune, Erosion Hazard Area (EHA), back dune, or not a dune? Frontal dunes and EHAs are the most dynamic dune areas (subject to erosion and dynamic flooding), while back dunes tend to be more stable (but potentially exposed to still-water flooding) and immediately adjacent to salt marshes. These areas have some Maine DEP restrictions on development (Ch. 355) that may include elevation requirements for a structure being rebuilt or significantly improved. Properties or structures outside of the mapped dune system are generally at less risk but may be on lowlands adjacent to salt marshes. Use the MGS Beach and Dune Geology Maps or Coastal Sand Dune Geology Web App to inspect this. For more details see the Beaches, Dunes, and Coastal Erosion and Flooding Hazards section of the Guide.

Is your property or structure located in a FEMA Special Flood Hazard Area? FEMA Coastal A, AO, V, and VE flood zones are the most dynamic and unstable flood zones, indicating that stillwater flooding *and* waves of a certain size will wash through the property in a larger storm. Risk is slightly lower if you are in an A or AE zone, where waves are smaller. If you are in an X zone or are not located in a mapped A, AO or V zone, you may not have flood insurance because your overall risk of coastal flooding is low. If your property is in an SFHA and is elevated, you should determine how high your structure is above the FEMA base flood elevation. You can use the Maine Flood Hazard Map Viewer or the FEMA Map Service Center to determine if you are in a flood zone.

If your structure is in the FEMA Special Flood Hazard Area, is your structure elevated to at least 1 foot above the base flood elevation? If your property is in an SFHA, is it elevated? You should determine how high above the FEMA BFE your property is and whether it meets your municipal floodplain management ordinance. Check with your municipal code enforcement officer to determine your community's standards. If your structure doesn't meet these elevation standards, it is at much higher risk to flooding and damage during storms.

In the past 2 decades, has your structure ever flooded? Flood frequency of a structure indicates its current level of risk to storms and potential future sea level rise.

How big is your structure? Greater than or less than 2,500 square feet? The size of your structure has implications on whether it can be easily moved or elevated in response to coastal erosion or flooding. Structures that are smaller are much easier (and less costly) to elevate or move back on a property, making them more resilient.

Is your structure built to current coastal construction standards? Many coastal waterfront properties are older and not necessarily built to current coastal construction standards like those in the FEMA Coastal Construction Manual. There are construction techniques to reduce both wind and flood damage.

How often over the past 2 decades has your structure flooded? If your property only undergoes very infrequent flooding, this is a sign that it is in a lower hazard area or elevated properly. If flooding occurs frequently, this is a sure sign that your property is low and at risk for flooding again.

If you have a seawall or bulkhead, how high is it when compared to storm water levels? Seawalls with elevations that meet or exceed the shoreline's base flood elevation (BFE) are most effective at reducing upland flooding. You can inspect your dune or seawall elevation in reference to BFEs by using the Coastal Structure and Dune Crest Inventory and Overtopping Potential Viewer or measuring its elevation and comparing it with published FEMA BFEs.

If you have a seawall, how frequently do you have to repair it? A few times over the last 20 years? Every year or two? This is a good indication of the stability of your property. Chronic damage to a shore protection structure indicates a high hazard area.

Is your property or structure located adjacent to a tidal inlet or a tidal channel? Close proximity to a tidal inlet or channel puts your property and structure at greater risk if that inlet or channel migrates over time.

How do you plan to use your property? Primary residence or commercial properties mean there is likely to be more risk to inhabitants and contents than a seasonal property or a property that is to be used for conservation purposes.

2. Determine if the hazard(s) identified can be mitigated.

In conjunction with your licensed professional, determine what hazards can expectantly be mitigated, and at what cost. For example, if there is an existing flood hazard, can you elevate your structure so that it is well above a base flood elevation? Or, if you identify that a portion of your property is below the highest astronomical tide, can you relocate development outside of this low-lying area? As part of this process, remember some of the goals, priorities, and expectations of the use of your property.

- **Be realistic.** It may not be technologically or economically feasible to protect a structure on a coastal lowland that is eroding or flooding frequently.
- **Be neighborly.** Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted.
- **Consider the costs.** When comparing strategies, consider the short and long-term costs of different strategies.
- **Consider the permit requirements.** Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs.
- **Consider timeframes.** Some activities or strategies may have extended permit review processes, limited activities in certain habitat types or time-of-year restrictions, or extended construction timeframes. Also think about the timeframe of expected usage of your property and the potential impacts of sea-level rise.

3. Determine if the risks associated with known hazards are acceptable

Considering the information that you developed in terms of mitigation, determine *the level of risk you are willing to accept* to meet your goals, priorities, and expectations relating to the use of your property. For example, if you identified a flood hazard that includes where your structure is (or will be) located, are you willing to accept the risk associated with potential damage or loss of the structure due to flooding?

4. Determine setbacks or elevation standards

If contemplating new construction, determine minimum appropriate setbacks based on your municipal Shoreland Zoning Ordinance, floodplain ordinances, and applicable state rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or elevate it so that the lowest structural member is at least 1-foot above the 100-year base flood elevation if in a flood zone. Check with your town's code enforcement office for specific information relating to setbacks and elevation standards.

5. Get appropriate permits

Building in or adjacent to a coastal wetland, in the coastal sand dune system, or a flood zone, including pursuing potential mitigation strategies, may be subject to regulation under the Natural Resources Protection Act (Chapters 310, 355, 305) and the Shoreland Zoning Act. Permits from the Maine DEP and your town may be required. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on local and state requirements for permits based on the activities you may be proposing on your property.

6. Appropriately adapt to or mitigate the hazard

You can take action to manage or reduce the risk of upland property erosion or coastal flooding impacting your property. These activities should be developed in conjunction with the steps involved above, and input from appropriate local experts (licensed geologists, geotechnical engineers, landscape architects, floodplain experts, etc.). Mitigating a hazard or hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., wetland creation or restoration). The mitigation and adaptation strategies listed here can be undertaken one at a time or using a multi-strategy approach that is most applicable to your case. In general, the process of sequential minimalization is recommended (e.g., analyze the least intrusive option first before considering a more intrusive option).

Doing nothing. In cases where tidal bank erosion is minimal and a structure is located a more than adequate distance from the edge of a wetland, and a defined erosion rate has been determined (in consultation with experts), a coastal property owner simply can opt to do nothing. Doing nothing is sometimes considered a last alternative – after other, more expensive and intensive options have been undertaken with no success but doing nothing is *typically* a least-cost alternative and does not require permitting, unless erosion or flooding causes damage to property or infrastructure. The do nothing alternative *must* consider the level of risk you are willing to accept in conjunction with the expected uses of your property.

Avoid the hazardous area. Avoiding existing or potential hazards as much as possible can be a very efficient and cost-effective method of mitigation, especially when siting new development or considering future development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies, and the level of risk you are willing to accept. A common avoidance technique is to build a structure as far away from the identified hazard as possible. You may need to request a variance from local setback ordinances in order to do so. Another method could include elevating a structure over and above minimum base flood elevation standards.

As much as is practicable with your building considerations, consider **moving back and moving up to avoid some hazards. Consideration should also be given to significant habitat resources or environmentally sensitive areas**, which are usually identified by shoreland zoning or state regulations**.** However, it is not always practicable for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, lot size, cost, or other factors.

Design and build properly. For construction in flood-prone areas, in the coastal sand dune environment, or on or adjacent to coastal wetlands, it is vital to follow proper construction techniques. This involves not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential wind and water forces associated with the dynamic coastal zone. Sizing restrictions may also be required if your property is located in the Shoreland Zone, a flood zone, or a Coastal Sand Dune. The Federal Emergency Management Agency (FEMA) provides several comprehensive resources on proper coastal construction techniques including the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets. Consideration should be given to the following:

- the construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- the extent of grading to achieve a stable building footprint;
- the level of engineering required to mitigate for hazards;
- potential hydrostatic and wind loading;
- siting of ancillary infrastructure; and
- general construction standards.

Relocate existing infrastructure. Where existing development is being threatened by coastal erosion or flooding, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction, or elevate the structure higher. Although this method can be very effective in minimizing or mitigating the hazard, this alternative can be quite expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography and underlying geology, and distance the structure may need to be moved or elevated. Consultation with a local contractor is suggested, and local and state permits may be needed. Relocation of a structure also can be constrained by the size of a property and any applicable local or state setbacks, such as from other existing structures or roadways. In many cases, variances from local setback ordinances can be requested by a homeowner in order to relocate a structure.

Elevate structures. Existing structures that are threatened with coastal flooding or erosion can benefit from elevation. If a building is in a FEMA Flood Zone, you may be required by your town's floodplain management ordinance to have the lowest structural part of your house be a minimum of one foot above the base flood elevation (this is typically the minimum standard). If your structure is older and has been flooded and does not meet current standards, any time you are doing substantial improvements to your structure, you may want to consider the cost of elevating the structure using a flow-through foundation or a pile foundation. This may be a requirement if structure improvements meet or exceed 50% of the value of the structure. Flow-through foundations are typically block or poured cement foundations with adequate spacing for floodwaters to flow through the foundation (Figure C4) without damaging the supports. These structures are acceptable in the A-zone areas of back dune environments that are not considered to be Erosion Hazard Areas.

Pile foundations, though more prevalent on the open ocean coastline, are typically used in more active flooding areas, and provide much more open space for floodwaters to travel through. Piles are required in the frontal dune and in areas of the back dune classified as Erosion Hazard Areas (Figure C5). Note that structures that are within front dunes and VE zones will require elevation to whichever standard (Coastal Sand Dune Rules vs. Floodplain Management Ordinance) is higher.

The concept behind both these foundation types is that water, sediment, and debris can *travel through* the foundation, thus avoiding significant pressure and lateral force to the foundation which causes structural failure. Both foundation types can significantly reduce potential flood damage to a structure.

Many of the state requirements regarding elevation of structures, including a review of techniques, are outlined in Chapter 5 of the Maine Floodplain Management Handbook. Your town may have additional requirements that meet or exceed minimum state standards. Contact your local Code Enforcement Office for more information. We also recommend review of the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets.

You will likely need a permit from your local municipality, in addition to Maine DEP, to elevate your structure. Federal permits from the U.S. Army Corps of Engineers and US EPA may be required if impacts to navigable waters or discharges into waters of the United States occurs. Check with your local Code Enforcement Office or the Maine DEP for more information. Refer to Chapter 305 (Permit by Rule), Chapter 310 (Wetlands) and Chapter 355 (Coastal Sand Dune Rules) for additional requirements relating to impacts to coastal wetlands associated with elevating structures.

If you are considering elevating your structure, include improvements to make your home more storm and flood resilient. Consider elevating your structure over and above the elevation required by your floodplain ordinance, in order to consider expected rates of sea-level rise and their impacts on future floodplain elevations. One consideration for adaptation and mitigation is the potential position of the future coastal wetland; that is, where the wetland boundary might be after sea-level rise. Currently, Maine has adopted an expected two feet of sea-level rise over the next 100 years in the Coastal Sand Dune System (Chapter 355, Coastal Sand Dune Rules). However, no sea level rise standards currently exist for other areas. In December

Figure C4. Example of a flow-through foundation from a structure located in the back dune and within a flood zone, adjacent to a marsh. Image by P. Slovinsky, MGS.

Figure C5. Example of a pile-supported foundation from a structure located in the front dune and within a flood zone. Image by P. Slovinsky, MGS.

2020, Maine's Climate Council released the Maine Won't Wait report, which recommends *committing to manage for 1.5 feet of sea level rise by 2050 and 3.9 feet by 2100*. This will likely be integrated into Maine's regulations governing hazardous areas, such as coastal wetlands, in the future. We recommend that any adaptation and mitigation plans relating to coastal wetlands take potential changes of the elevation of the highest annual tide (upper boundary of the coastal wetland) into consideration when planning new infrastructure or infrastructure improvements in coastal wetland areas.

Consider Best Management Practices for Wetlands and Green Infrastructure Approaches

Upland/wetland fringe vegetation management. A naturally vegetated upland boundary adjacent to coastal wetlands is vital to maintaining healthy wetland habitat. Studies have shown that development and associated adjacent upland land uses can significantly impact coastal wetland plant diversity (Silliman and Bertness, 2004). Degradation of marsh vegetation and colonization by invasive species is related to fringe boundary disturbance, and nitrogen loading due to fertilizer usage. Subsequently, a best management practice for property adjacent to coastal wetlands includes maintaining, to the maximum width practicable, a naturally vegetated buffer between the "developed" (e.g., planted lawn or infrastructure) portion of the property, and adjacent coastal wetlands. Minimum distance buffers will be required per Maine's Shoreland Zoning Act and Wetlands protection. Other practices include:

- enhancing the width of existing buffers with native vegetation;
- minimizing disturbances adjacent to coastal wetlands;
- limiting planting and maintenance of lawns and subsequent usage of nitrogen-rich fertilizers;
- removing invasive species within the buffer, especially common reed
- (*Phragmites australis*); and
- limiting the amount of unnatural freshwater runoff directed into coastal wetland from the adjacent uplands.

Although slightly more related to lakefront properties, Maine DEP has a buffer planting list and guide and Cumberland County Soil and Water Conservation District released a Coastal Planting Guide which would apply to coastal wetlands. A great additional resource for buffer management is Save the Bay Narragansett Bay Bay-friendly tips: in your home and backyard.

Marsh restoration or creation. In many cases, adjacent uplands that might be prone to slight erosion or flooding can be protected with fringing salt marsh. Much of the following marsh restoration information was adapted from Managing Erosion on Estuarine Shorelines (Rogers and Skrabal, 2001), which was prepared for estuarine shorelines in North Carolina. However, much of the information and techniques outlined transfer to Maine's marshes. The Gulf of Maine Association also maintains a website which provides detailed information on marsh restoration and creation, including information on funding, permitting, monitoring, and more.

Fringing marshes protect property by gradually dissipating wave energy and serving as erosion control surfaces that absorb or dissipate the force of breaking waves, stabilizing the soft, underlying soil. Planting marsh grass is particularly effective on sites where previous marshes were destroyed by dredging and filling. Where appropriately sited, a planted marsh can be one of the most cost-effective erosion solutions. Planted marshes are generally considered to be one of the most environmentally desirable erosion-control approaches.

Marsh planting success depends heavily on shoreline exposure to wind, waves and boat wakes, and is most successful where the shoreline is exposed to less than one mile of fetch (distance of open water for wind to build waves). A marsh fringe at least 10 feet wide is necessary for erosion control, but 20 feet or more is preferred. Marsh fringes benefit the ecosystem by providing productive biological habitat and an additional vegetative buffer, which protects water quality by reducing the impact of stormwater runoff. If the marsh is not established continuously along the shoreline, erosion can continue on the unprotected beaches. The most common cause of failure is planting in an area that experiences severe wave conditions or planting that occurs at inappropriate elevations or inappropriate species being used.

Marsh planting by-itself is generally considered a low-cost, relatively easily undertaken effort. In some cases, two or more planting attempts may be required for the marsh to take hold. Commonly used grasses include species native to Maine salt marshes, such as saltmeadow hay (*Spartina patens*) and smooth cordgrass (*Spartina alterniflora*). In estuaries dominated by wind-driven tidal effects, planting elevations can vary but can be determined by observing the elevations of healthy native marshes nearby. Marsh grasses may be purchased from specialized commercial nurseries (or can be potentially transplanted from existing marshes with a permit), including but not limited to:

- Pierson Nurseries, Inc., Biddeford, ME, https://www.piersonnurseries.com/
- Cape Coastal Nursery, South Dennis, MA, http://www.capecoastalnursery.com/
- Great Meadow Farm, Rowley, MA, http://www.marshmadness.org/GreatMeadowFarm.html
- Sylvan Nursery, Inc., Westport, MA, http://sylvannurseries.com/

From a regulatory standpoint, marsh creation or restoration will likely require permitting on several levels (local, state, and federal) because activities will be occurring below regulatory boundaries (the highest astronomical tide, or HAT). From the state standpoint, permits from Maine DEP will be required. A Permit by Rule (Chapter 305) may be used to restore coastal wetlands (Chapter 305, 12, Restoration of natural areas); larger projects may need an Individual Permit from Maine DEP and a Maine General Permit or Individual Permit from the US Army Corps of Engineers. Note that restoration and creation activities may also be limited by municipal shoreland zoning ordinances.

Another way to restore or create a marsh is to remove or replace inadequately functioning road culverts. Enlarging or replacing culverts can dramatically increase tidal flow into marsh areas and help facilitate the proliferation of marsh species. Adequate tidal flushing is required for marsh growth and will help eliminate invasive species that are not salt-tolerant. Note that permitting is likely required from Maine DEP and the U.S. Army Corps of Engineers for work associated with road culverts.

More information related to marsh restoration and planting is provided below in living shoreline approaches.

Implementing Living Shoreline and Green Infrastructure Approaches. Although planting of erosion-resistant vegetation is considered a living shoreline approach, "living shoreline" is a broad term that encompasses a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline:

- has a footprint that is made up mostly of native material;
- incorporates vegetation or other living, natural "soft" elements alone or in combination with some type of harder shoreline structure (e.g. oyster reefs or rock sills) for added stability; and
- maintains continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.

**Definition adapted from NOAA's Guidance for Considering the Use of Living Shorelines (2015)*

Living shoreline techniques are typically most suited for lower-energy environments – for example, those areas that are at least somewhat sheltered from direct wave attack during annualized conditions or storm events. This makes them very effective in coastal wetland areas. Living shorelines are designed to mimic and/or work with natural features in slowing erosion of bluffs and coastal wetlands. Examples of living shorelines include planting vegetation at the edge of a salt marsh or mudflat, or mixing vegetative plantings with toe stabilization structures, such as coir envelopes, downed trees, or even riprap or other engineering structures.

Living shorelines in Maine, and New England, are a relatively newer concept. They have been implemented widely in warmer climate, lower energy, lower tidal regime areas of the southeast and Gulf of Mexico coastlines for decades, and many of the techniques are transferable to Maine. Although it may seem counter-intuitive, living shorelines can be extremely effective at lessening erosion and property damage from coastal storms. A study in North Carolina after Hurricane Irene (Gittman et al., 2014; Smith et al., 2017) found that properties in estuaries fronted with living shorelines fared better than those fronted by traditional shoreline engineering structures.

Living shorelines are not suitable for all locations. The potential success of living shorelines approaches is dependent upon a variety of factors such as exposure to wave energy and icing, underlying geology, shoreline types, erosion rates, among other factors.

Over the past few years, a variety of resources have been created to help better understand living shorelines and their suitability and applicability in New England and Maine.

New England-wide resources include:

Living Shorelines Stacker – created for the North-east Regional Ocean Council, this interactive stacker provides fun yet insightful information about the use of living shorelines.

Living Shorelines in New England: State of the Practice – This report, prepared by Woods Hole Group, was the culmination of a NOAA-funded regional project amongst all five New England States, led by the Nature Conservancy and details a wide variety of information on living shorelines and their uses in New England.

Living Shorelines Applicability Index – in conjunc-tion with the above report, this is an excel-based matrix which accounts for a variety of factors such as energy, sensitive resources, tidal range, slope, and erosion and helps guide the user to a potentially appropriate living shoreline response.

Living Shoreline Combined Profile Pages – these "profile pages" provide information on common types of living shoreline approaches at dunes, beaches, coastal banks, and marshes. They relate to the living shoreline applicability index discussed above. These profile pages provide schematics, design overviews, case studies from New England, and siting and design considerations. Specific to marshes, three different profile pages are provided: natural marsh creation/enhancement, marsh creation/enhancement with toe protection, and a living breakwater. An example of the profile page for natural marsh creation/enhancement with toe protection is provided in Figure C6.

Maine-specific resources include:

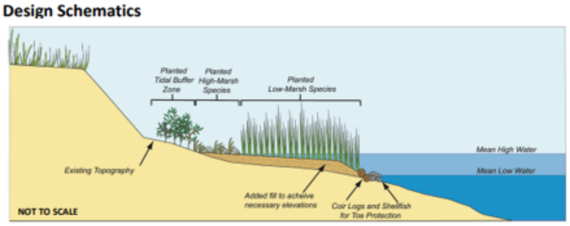
Living Shorelines in Maine – A website maintained by MGS which details (in chronological order, from newest to oldest), current and completed living shore-line efforts and projects in Maine. This includes project summaries and numerous products/outcomes from several NOAA-funded efforts in Maine and New England, including some of those discussed above. The website also documents an ongoing project to design, permit, and construct living shoreline demonstration treatments at three different locations in Brunswick and Yarmouth, ME. Several different living shoreline approaches using downed trees and bagged aged oyster shell – in biodegradable bags and plastic mesh gabions (and sometimes in combination) – are being implement-ed at eroding bluff and coastal wetland edges (Figures C7 and C8). These techniques would be transferable to

Marsh Creation/Enhancement w/Toe Protection

Marsh vegetation that is planted along the shoreline often benefits from toe protection to assist with marsh stabilization. Toe protection materials may include natural fiber rolls, shell bags or, in some cases, stone. The toe protection may also allow the design to achieve the appropriate grade in lieu of seaward fill, thereby decreasing the project footprint.

Objectives: dissipates wave energy, habitat creation, shoreline stabilization

Design Schematics



Case Study

North Mill Pond, Portsmouth, NH

This project involved restoration of low and high marsh along North Mill Pond, with about half of the area consisting of new marsh creation, and the other half of the area consisting of restoration of degraded low and high marsh through sediment addition (thin layer deposition).

Project Proponent	City of Portsmouth, Stantec (wetlands consultant), UNH (assisted plan development)
Status	Construction complete May 2016. Beginning year two of monitoring in 2017.
Permitting Insights	NHDES and USACOE permits needed for drainage outfall into pond. Project impacted 600 sf of coastal wetland. Salt marsh restoration was compensatory mitigation.
Construction Notes	Imported fill to raise 12,060 sf to suitable elevation for salt marsh (low marsh); planted 3,055 sf of high marsh area. Created micro-topography and interior drainage channels. 12-in diameter coir logs staked at seaward edge of marsh to stabilize toe. Placed large boulders to break-up winter ice sheets.
Maintenance Issues	Long term monitoring and maintenance efforts are scheduled. Survival of low marsh plants is good; survival of high marsh salt hay is fair to poor. Survived 2016-2017 winter well.
Final Cost	$60,000 (construction, monitoring & maintenance)
Challenges	Construction did not have a provision for within plot drainage; many plants were washed out by runoff gullies in the first year. More time needed for filled sediment to settle before planting.

Design Overview	
Materials	Native marsh plants appropriate for salinity and site conditions. Plugs of marsh grass can be planted to augment bare areas.[11] Sediment may be necessary if area needs to be filled to obtain appropriate elevations. Toe protection materials may include natural fiber rolls, oyster/mussel shells bags, or in some cases, stone. Filter cloth placed prior to added fill and/or sill materials.[16] Bird exclusion fence to avoid predation while plants develop.[16]
Habitat Components	Salt marsh; Tidal buffer landward of the salt marsh; Coastal beach; Mud flat.
Durability and Maintenance	Plants that are removed or die during the early stages of growth must be replaced immediately to ensure the undisturbed growth of the remaining plants. The removal of debris and selective pruning of trees is also a good maintenance practice to ensure that sunlight reaches plants. After significant growth has occurred only periodic inspections may be necessary. Protection measures, such as fencing, can keep water-fowl from eating the young plants. Toe protection materials should also be replaced or re-installed if they are moved by a storm.[6] Coir logs must be securely anchored to prevent wave and tidal current-induced movement.[11] Ongoing maintenance of invasive species and runoff issues will be important to the long-term success of the project.[10]
Design Life	It is important to recognize that design life may be shorter in the future given changes in sedimentation rates, accelerating sea-level rise and other climate change impacts.
Ecological Services Provided	Increases water infiltration, uptake of nutrients, filtration, denitrification and sediment retention.[2,3] The extensive root systems of marsh vegetation help to retain the existing soil, thus reducing erosion while plant stems attenuate wave energy.[11] Marshes provide habitat for many species of plants and animals, and maintain the aquatic/terrestrial interface.[2] Sill mitigates erosive waves and stabilizes shoreline.[10] Marine animals can access the marsh through gaps in the sill.[12] Marshes also provide better water quality, recreation and education opportunities, and carbon sequestration (blue carbon).[12]
Unique Adaptations to NE Challenges (e.g. ice, winter storms, cold temps)	Including roughened surfaces, such as logs, stones or emergent vegetation can break up ice sheets.[4,10] Fringing marsh projects will respond better to ice if designed with gentler slopes (6:1-10:1) and by incorporating shrubs.[9,13] Planting in the spring will allow vegetation to become established before it has to withstand ice.[8] Hardy, salt-tolerant shrubs are well-suited shorelines that are affected by ice.[13] Need to consider where in the tidal range oysters will be placed if they're used: too high may result in freezing.

Figure C6. Sample profile page of marsh creation/enhancement with toe protection from the living shoreline combined profile pages created by Woods Hole Group for The Nature Conservancy and the Northeast Regional Ocean Council.

Figure C7. Example of a demonstration living shoreline treatment at an eroding marsh edge that utilizes aged oyster shell placed in coconut-fiber biodegradable bags (left side of image) and plastic-mesh gabion baskets (right side of image). The treatment also beneficially utilizes an in-place tree trunk as toe protection. Image by P. Slovinsky, MGS.

Figure C8. Example of a demonstration living shoreline treatment at an eroding marsh edge that utilizes aged oyster shell placed in coconut-fiber biodegradable bags (center and right side of image) and plastic-mesh gabion baskets (left side of image). The treatment also beneficially utilizes tree trunks to provide protection from winter icing. Image by P. Slovinsky, MGS.

eroding coastal wetlands throughout Casco Bay, and in different regions of Maine. Monitoring of the installed projects will occur for 5 years, paying close attention to their efficacy in curtailing erosion and durability of the installed materials. This website is being revised as additional information becomes available from the project. The Greater Portland Council of Governments (GPCOG) put together an informational video on the construction of these demonstration treatments in Brunswick, ME. This website is updated on a regular basis.

Living Shorelines Decision Support Tool for Casco Bay – MGS created this tool to show where in Casco Bay living shoreline approaches may be suited based on a variety of different factors including fetch, nearshore bathymetry, landward and seaward shoreline types, relief, slope, and aspect. Note that this tool is for general planning purposes only and undertaking living shorelines at a specific location should be done in consultation with experts.

From a regulatory standpoint, proposed living shorelines will likely require permitting on several levels (local, state, and federal). From the state standpoint, permits from Maine DEP under the Natural Resources Protection Act will be required. a Permit-by-Rule (Chapter 305) may be appropriate, with completion of a simple notification form to Maine DEP. Larger projects may need an Individual Permit from Maine DEP. Federally, a Maine General Permit or Individual Permit from the US Army Corps of Engineers may be needed, depending on impacts and the size of the project.

Riprap or bulkheading. The placement of riprap or bulkheads should be considered the last alternatives as it relates to stopping erosion along coastal wetlands. These structures typically have much more of an impact on adjacent coastal wetlands and resources than living shorelines because they limit coastal wetland migration and the transfer of sediment from uplands. However, in some cases, rip-rap can be placed in or adjacent to a coastal wetland to protect property less than 100 feet of an eroding shoreline under Chapter 305, Permit-by-Rule, *as long as the wetland does not have mudflats or salt marsh vegetation, or is within the Coastal Sand Dune System* (Chapter 305, 8, A, (1)-(6). Specific standards, outlined in Chapter 305, 8, C, need to be followed in terms of rip-rap placement. Otherwise, an individual permit under the NRPA will likely be required from Maine DEP in order to pursue stabilization that impacts coastal wetlands. Rip-rap best management practices for placement and construction techniques are available from Maine DEP through its Maine Erosion and Sediment Control Best Management Practices Manual for Designers and Engineers (Maine DEP, 2016).

The placement of a bulkhead adjacent to a coastal wetland will require permitting from Maine DEP. Similar to riprap, bulkheads limit the landward migration of wetlands, and cut off the natural transfer of sediment from eroding banks into the wetland (Figure C9). They are also more reflective, e.g., reflect more wave energy back onto the marsh, than riprap. However, in some cases, their placement might be a necessity.

Rip-rap and bulkheads will also require permitting from the US Army Corps of Engineers through their Maine General Permit program and potentially an Individual Permit, depending on the proposed activity size and impact.

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Figure C9. Example of a bulkhead placed adjacent to an eroding marsh edge. Bulkheads generally result in the squeezing out of coastal marshes and limit sediment supply from the upland to the wetland. Image by P. Slovinsky, MGS.

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APPENDIX A: CHECKLISTS

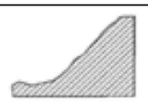
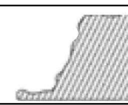
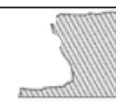
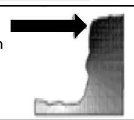
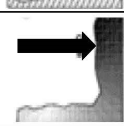
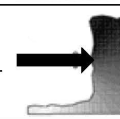
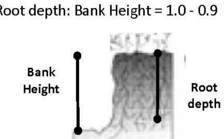
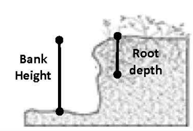
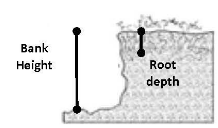
INSTABILITY ASSESSMENT RATING DATA SHEET

Location (Nearest Address or Coordinates) ______________________________

Name and Affiliation of Inspector: ______________________________

Date: ______________________________

Photo(s): ______________________________

	Category / Parameter / Measurement Method	Description of Bluff Condition			Rating
		Good (1)	Fair (2)	Poor (3)	(1, 2, or 3)
1	**Hydrology - Changes in Upland Runoff**	No recent alteration of upland area draining to study site. Drainage of bank has not been modified.	Minimal overland drainage changes upland from study site. Does not adversely affect hydrology or result in concentrated flow. No point discharge.	Surface drainage upland is discharging with an adverse affect to study site. Water is ponded above the bank. Seepage may be present.	
2	**Hydrology - Nature of Flow**	No apparent concentrated flow or channelized flow to study site from adjacent land use.	Some concentrated or channelized flow is directed to study site, causing point discharge. However, measures are in place to protect resources or discharge is limited.	Concentrated or channelized flow is heavy or results in a large point discharge observed at study site. No protection is in place.	
3	**Hydrology - Land Use**	Upland area is primarily native and undisturbed. Vegetated area is greater than 70% and is a mix of shrubs and trees. Trees larger than 12" diameter are at least 20 feet from top of bank.	Land development and/or active agricultural practices are occurring on less than 70% of the upland area. Vegetated area is between 20 and 70%. Trees larger than 12" diameter are between 5 and 20 feet from top of bank.	Upland is urban or primarily active agricultural practices (less than 30% is native or undisturbed). Vegetated area is less than 20%. Trees larger than 12" diameter are less than 5 feet from top of bank; tree roots may be exposed.	
4	**Hydrology - Distance to Roads**	No roads are on, or are within 20 feet of, the study site. No roads on or adjacent to site are proposed in 10 year plan.	No roads are on, or are within 20 feet of, the study site. No more than one major road on or adjacent are proposed in 10 year plan.	Roads are located on or adjacent to study site (less than 20 feet away) and/or multiple roads are proposed.	
5	**Hydrology - Seepage**	Upland runoff as a result of rainfall patterns, geology, and soils does not result in seepage in bank.	Upland runoff as a result of rainfall patterns, geology, and soils results in seepage in less than 10% of the bank area.	Upland runoff as a result of rainfall patterns, geology, and soils is creating seepage in more than 10% of the bank area.	
6	**Vegetation at Toe of Bluff** (strip = width of vegetation below highest annual tide line)	**Dense vegetation** >80% of contributing shoreline length has a strip >25 feet wide	**Average vegetation** 50 - 80% of contributing shoreline length has a strip >25 feet wide	**Low vegetation** <50% of contributing shoreline length has a strip >25 feet wide	
7	**Sediment Supply (Erosion)**	**Low soil erosion** Bank erosion shows no recent change or loss. Few runnels/gulleys are present on the bank face.	**Moderate soil erosion** Bank erosion is occurring: visual change and loss are observed. There are several runnels/gulleys on the bank face, all less than 6 inches deep.	**High soil erosion** Bank erosion is occurring with measurable change. There are numerous runnels/gulleys, or some that are more than 6 inches deep	
8	**Bank Slopes**	Slopes are between 3 and 8%. 	Slopes are between 8 and 20%. 	Slopes are 20% and greater or are undercut. 	
9	**Bank Height vs. High Tide Elevation**	High Tide Elevation is <u>at or near</u> Top of Bank 	High Tide Elevation is <u>1/3 below</u> the Top of Bank 	High Tide Elevation is <u>more than 1/3 below</u> the Top of Bank 	
10	**Soil & Geology**	Bedrock and boulders make up the bank. Or, cohesive soil types (sand/gravel mix) mixed evenly.	No bedrock or boulders, cohesive soils (sand/gravel mix) are dominant and mixed equally. Clay to very stony sandy loam.	Soils are non-cohesive and/or highly stratified. Sand/gravel mix with larger percentage of sand, sandy loam, silt,	
11	**Bank Surface Protection (%)** = a visual assessment of the amount of bank composed of root material. Also referred to as "Root Density" **Ratio of Root Depth: Bank Height**	Surface Protection = 80 - 100% Root depth: Bank Height = 1.0 - 0.9 	Surface Protection = 55 - 79% Root depth:Bank Height = 0.5 - 0.89 	Surface Protection= < 55% Root depth:Bank Height = < 0.5 	
12	**Biology / Landscape Connectivity**	Shoreline of study site, and the adjacent area, have native bank and vegetation materials. No rip-rap or hardened structures installed.	Shoreline of study site, and the adjacent area, have native vegetation and bank materials but are impaired by invasives and/or have rip-rap or hardened structure installed.	Shoreline of study site and.or the adjacent area are hardened by a concrete headwall, or rip-rap or other structure. Limited vegetation present.	
				Total Rating (sum column):	

Images included in this form are adapted from graphics developed by David Rosgen in 1993 and presented on March 25, 2001 in "A Practical Method of Computing Streambank Erosion Rate" at the Federal Interagency Sedimentation Conference in Reno, NV.

This Instability Rating Form was developed for the Maine Coastal Program/Maine Department of Agriculture, Conservation and Forestry by the Cumberland County Soil and Water Conservation District. This work was supported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Management Cooperative Agreement #NA14NOS4190047 pursuant to the Coastal Zone Management Act of 1972 as amended. For more information about the Maine Geological Survey, contact mgs@maine.gov or 207-287-2801. For more information about the MCP, visit www.mainecoastalprogram.org or contact 207-287-2351.

Cumberland County Soil & Water Conservation District

maine Department of Agriculture Conservation & Forestry

Maine Coastal Program

Note: This checklist is for general planning purposes only and should not be the only resource used to determine hazard levels and potential risk.

Coastal Wetland and Coastal Flooding Checklist

Location: ____ Date: ____________________

	Question	Description of Hazard Level (rating)			Rating
		Low (1)	Moderate (2)	High (3)	(1, 2, or 3)
1	How far is the highest astronomical tide from your structure?	Over 75 feet	50 to 75 feet	50 feet or less	
2	How wide is the marsh (or beach if no marsh) in front of your property?	Over 30 feet	15 to 30 feet	No marsh or less than 15 feet of marsh	
3	How would you qualify the erosion of your marsh over the past decade?	Stable to accretive (0 feet per year or positive)	Erosive (0 to -1 foot per year)	Highly erosive (-1 foot per year or more)	
4	After big storms, does the marsh recover within a season or two?	Recovers in less than a season	Recovers in a season or two	No, it does not recover or takes more time	
5	Is your property located in the mapped coastal sand dune system?	Not in the mapped dune system	Back Dune (D2)	Front Dune (D1) or Erosion Hazard Area (EHA)	
6	If your structure is in the frontal dune or EHA, is the structure elevated?	3-feet or more above grade	Less than 3-feet above grade	Not elevated	
7	Is your structure located in a FEMA-designated flood zone?	X-zone or not in a flood zone	A-zone	V-zone, AO-Zone or Coastal A-Zone	
8	If your structure is in a flood zone, is your structure elevated?	More than 1-foot above the Base Flood Elevation (BFE)	1-foot above the Base Flood Elevation (BFE)	No	
9	In the past 2 decades, has your structure	No	Only once	Yes, more than once	
10	Is your structure bigger than 2,500	No	Don't know	Yes	
11	Is your structure built to current coastal construction standards?	Yes	Don't know	No	
12	Is your property fronted by a seawall or bulkhead of adequate elevation?	1-foot or more above the Base Flood Elevation (BFE)	At the Base Flood Elevation (BFE)	Below the Base Flood Elevation (BFE)	
13	If yes, does your seawall have a history of being damaged, needing repair?	No, it has not been damaged or needed repair	Once in the last 20 years	Multiple times over the last 20 years	
14	Is your structure located close to a tidal inlet or tidal channel?	Over 100 feet	Between 50 and 100 feet	Within 50 feet	
15	How do you plan to use your property?	Conservation property/easement	Secondary residence	Commercial property or primary residence	
				Total Hazard Rating:	

Total Hazard Rating	
15 - 22	Low
23 - 36	Moderate
37 - 45	High

Note: This checklist is for general planning purposes only and should not be the only resource used to determine hazard levels and potential risk.

Beach, Dune and Coastal Flooding Checklist

Location: ____ Date: ___________________

Question		Description of Hazard Level (rating)			Rating
		Low (1)	Moderate (2)	High (3)	(1, 2, or 3)
1	How far is the highest astronomical tide from your structure?	Over 75 feet	50 to 75 feet	50 feet or less	
2	How wide is the dry beach in front of your property?	50 feet or more	25 to 50 feet	25 feet or less	
3	Is your property fronted by a sand dune of adequate elevation?	1-foot or more above the Base Flood Elevation (BFE)	At the Base Flood Elevation (BFE)	No sand dune or it is below the Base Flood Elevation	
4	How would you qualify the erosion of your dune over the past decade?	Stable to accretive (0 feet per year or positive)	Erosive (0 to -2 foot per year)	Highly erosive (-2 foot per year or more)	
5	After big storms, does the dune recover within a season or two?	Recovers in less than a season	Recovers in a season or two	No, it does not recover or takes more time	
6	Is your property located in the mapped coastal sand dune system?	Not in the mapped dune system	Back Dune (D2)	Front Dune (D1) or Erosion Hazard Area (EHA)	
7	If your structure is in the frontal dune or EHA, is the structure elevated?	3-feet or more above grade	Less than 3-feet above grade	Not elevated	
8	Is your structure located in a FEMA-designated flood zone?	X-zone or not in a flood zone	A-zone	V-zone, AO-Zone or Coastal A-Zone	
9	If your structure is in a flood zone, is your structure elevated?	More than 1-foot above the Base Flood Elevation	1-foot above the Base Flood Elevation (BFE)	No	
10	In the past 2 decades, has your structure ever flooded?	No	Only once	Yes, more than once	
11	Is your structure bigger than 2,500 square feet?	No	Don't know	Yes	
12	Is your structure built to current coastal construction standards?	Yes	Don't know	No	
13	Is your property fronted by a seawall or bulkhead of adequate elevation?	1-foot or more above the Base Flood Elevation (BFE) or no seawall	At the Base Flood Elevation (BFE)	Below the Base Flood Elevation (BFE)	
14	If yes, does your seawall have a history of being damaged, needing repair?	No, it has not been damaged or needed repair	Once in the last 20 years	Multiple times over the last 20 years	
15	Is your structure located close to a tidal inlet or tidal channel?	Over 100 feet	Between 50 and 100 feet	Within 50 feet	
16	How do you plan to use your property?	Conservation property/easement	Secondary residence	Commercial property or primary residence	
				Total Hazard Rating:	

Total Hazard Rating	
16 - 24	Low
25 - 39	Moderate
40 - 48	High

Note: This checklist is for general planning purposes only and should not be the only resource used to determine hazard levels and potential risk.