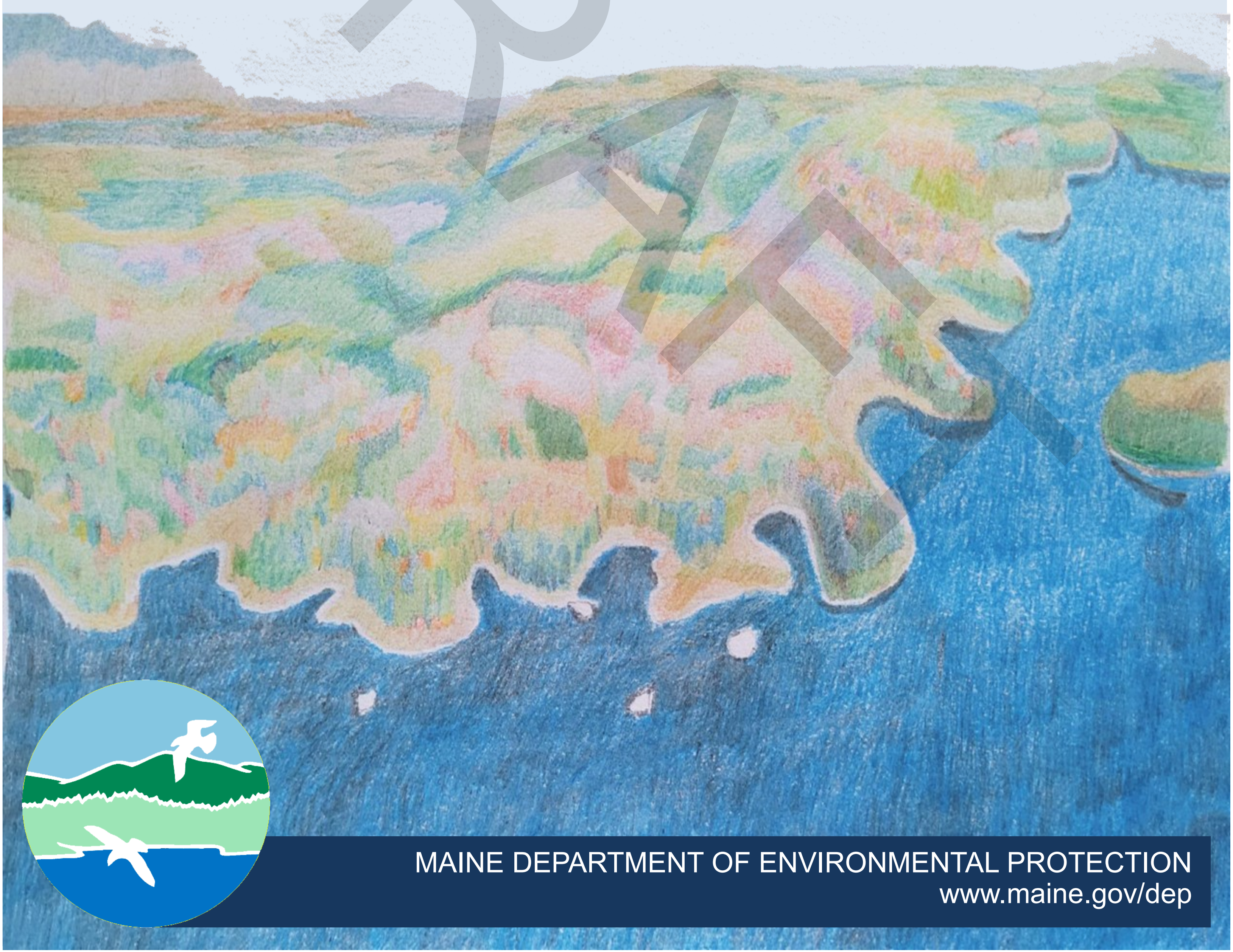
OUR SHORE

Guide to Nature-Based Shoreline Stabilization Options in Maine



MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION
www.maine.gov/dep

OUR SHORE

Guide to Nature-Based Shoreline Stabilization

This Document was prepared and compiled by
John Maclaine, Maine Department of Environmental Protection
Nathan Robbins, Maine Department of Environmental Protection
Claire Strevey, Maine Conservation Corps
Parker Gassett, Maine Climate Science Information Exchange, University of Maine
Gregory LeClair, PhD Candidate, University of Maine
Karina Cortijo-Robles, University of Maine

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Why Nature-based solutions are necessary

Erosion is a natural process. Over a geologic timeframe, nothing remains stable. Shorelines erode and change form, rivers meander, and bluffs fall. Historically, we have relied on engineered solutions and hardened shorelines when erosion poses a risk to property and safety. Unfortunately, traditional hardened stabilization structures like seawalls do not dissipate wind-driven wave energy, directing it sideways and down, leading to increased erosion down shore and lakebed scouring. This can reduce water clarity, increase algae growth, and harm or even eliminate critical nearshore aquatic habitat. The widespread use of materials like riprap to protect sites from wave erosion has negatively impacted many Maine species through loss of vegetation along the shoreline, erosion of nearshore habitats, and heat transfer.

OUR SHORE concept

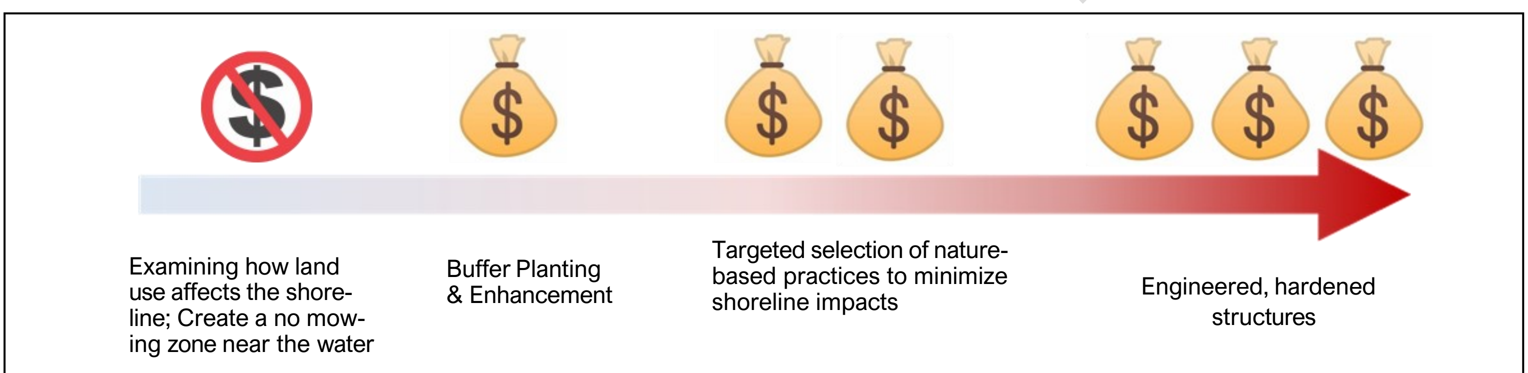
OUR SHORE is intended to provide a method of comparing options for shoreline stabilization so landowners, contractors, designers, and others can customize solutions for shoreline erosion in a manner that preserves or improves shoreline habitat and long-term resilience.

An ecological approach

By utilizing an ecological approach to shoreline stabilization, we can re-create a “living shoreline” using native plants and bioengineering techniques. Living shorelines prevent erosion and protect the banks from the impacts of flooding while maintaining a healthy aquatic habitat that supports recreation. Native plants stabilize the soil and filter run-off, preventing pollutants like phosphorus and nitrogen from entering lakes and coastal areas. They also provide habitat and food for terrestrial species, shade the lake to keep waters cooler for fish and other aquatic species, and enhance nearshore habitat.

Selecting the right tools

There are many common issues along lakeshores and coastal waterfronts that lead to erosive conditions which threaten the health of waterbodies and surrounding properties. Sometimes, it takes several Best Management Practices (BMPs) to address the compounded problems resulting from poor development along shorelands. Criteria for choosing appropriate shoreland BMPs or bioengineering solutions includes practices that cause minimal disturbance while providing maximum benefit. A combination of several techniques can often be used to ensure that the best practices chosen are suited to the specific site. The following page presents examples of common issues with armored shorelines along with three potential solutions for each problem.



"OUR SHORE"

Selecting appropriate tools and practices to stabilize shorelines using the least amount of intervention to become more resilient to erosion long term.

Design Goals & Objectives

O **Observe** and blend project with any unaltered shore near site

U **Use** native, natural, living, and biodegradable materials

R **Reach** conditions that function as a naturalized shore over time

Assess Sources of Instability & Erosion

S **Source & Severity of Erosion**

Assess the contributions of instability by source such as Surface water Flows, Groundwater, wave action/ toe erosion, and Ice.

H **Height & Slope Risk**

Assess contributions of height, slope, and soil conditions to instability risk

O **Overland Water and Land Use**

Assess how use of the site may affect stability

R **Revegetate/reconnect shoreline buffer**

Assess the existing shoreline vegetation and the contribution to stability, water quality, & shoreline habitat connectivity.

Tool Selec-

E **Erosion Control Selection Based on Site**

Select tools for stabilization based on the causes identified through assessment.

Costs and Performance

Photo: Paul Bernacki

Two of the most common questions when determining what shoreline stabilization practices to use are cost and performance. Direct comparisons between the cost of green infrastructure and gray approaches are difficult for many reasons, primarily due to low availability of data. Since riprap and walls have been the predominant choice for shoreline stabilization for many decades, data for these designs are often available, while data for natural or hybrid options are lacking. However, as more living shorelines are being installed, more information on the effectiveness is being gathered, and the increasing knowledge base is also reducing installation costs.

Other Environmental Impacts and Outcomes from Select Stabilization Tools

Outcomes	Metric	Root Wads	Biodegradable blankets (planted with vegetation)	Live Staking	Live Fascines	Brush Mattress	Living Wattles	Log Revetments	Log Jams (in-water)	Log Vanes & sills (in-water)
Residual Temporary Construction Damage	Comparative extent of construction disturbance	High	Low	Low	Low	Low	Moderate	High	High	Moderate
Bank Stability Short Term	Probability of remaining stable in comparative short term	Medium	Low	Low	High	Medium	Low	Medium	Low	High
Bank Stability Long Term	Probability of remaining stable in comparative long term	High	High	High	High	High	Medium	High	Medium	Low
Sediment Release	Amount of sediment movement from bank to water over time	Minimal	Moderate	Moderate	Low	Moderate	Moderate	Minimal	Moderate	High
Ability to self-heal	Whether the method can repair itself after receiving damage	Limited	High	High	High	High	High	Limited	Limited	No
Installation Costs		$$$	$	$	$$	$$	$	$$$	$$$$	$$

Outcomes	Metric	Coir Logs	Toe Logs	Vegetated Mechanically Stabilized Earth (MSE)	Log Cribs/Live Cribwalls	Riprap	Infilled/Vegetated Riprap	Green Gabions	Gabions
Residual Temporary Construction Damage	Comparative extent of construction disturbance	Low	High	High	High	High	High	High	High
Bank Stability Short Term	Probability of remaining stable in comparative short term	High	High	High	High	High	High	High	High
Bank Stability Long Term	Probability of remaining stable in comparative long term	High	Medium	High	High	High	High	High	High
Sediment Release	Amount of sediment movement from bank to water over time	Low	Moderate	Low	Moderate	Low	Moderate	Low	Low
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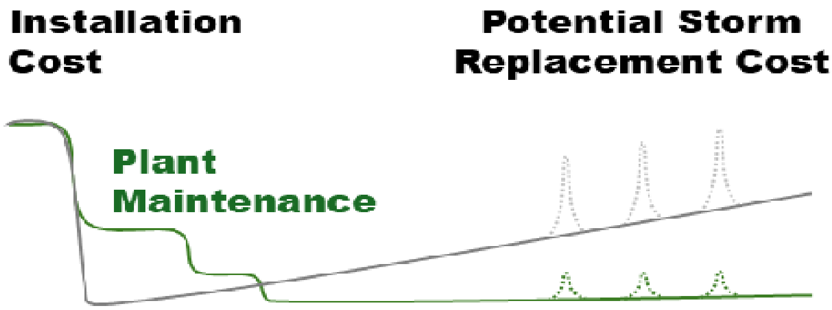
Installation Costs		$$	$	$$$$$	$$$	$$$$$	$$$$$	$$$$$	$$$$$



Green Infrastructure Effectiveness Database
https://coast.noaa.gov/digitalcoast/training/gi-database.html

What We Know

What we do know about cost and performance is that most calculations for return on investment, or life cycle cost, are determined based on a modeled performance period (e.g., fifty years), not actual. There are examples of green and of grey designs that have failed in 10 years or less. The aggregate, long-term cost of maintenance on each type of system is also understudied. There also is a lack of data on the negative costs of riprap, wall, or other grey options. As a result, there is substantial variation in cost estimation across different regions and designs.

What We Are Learning

What we are learning is that living shorelines grow stronger over time and can be more sustainable in the long run than seawalls or rip-rap revetments alone. Green infrastructure designs can adapt to changing environmental conditions and can be less prone to fail than rock revetments alone in storm events. Additionally, properties near green infrastructure may see an increase in value due to improved aesthetics and access to recreational activities.

Based on the information provided in NOAA's Green Infrastructure database, and case studies on NOAA's website it is evident that green infrastructure, including techniques such as living shorelines, can offer cost-effective solutions for coastal resilience compared to gray infrastructure. Green infrastructure, which encompasses natural and nature-based approaches, has been shown to not only reduce the impacts of flooding and erosion and require less long-term maintenance, but also provide additional social and economic benefits. In Maine, we are not yet able to offer an exact cost estimate across design types. However, we anticipate collecting this information over time, and currently recommend reaching out to practitioners for information on projecting materials and implementation expenses.

Photo Credit: Damon Yakovleff CCSWCD

OUR SHORE Key Principles

Minimize disturbance of as much soil as possible

Soil structure contains microscopic organisms, fine roots, fungi and other interconnected systems made over long time periods. Disturbing more soil than necessary or changing the way water flows across the soil can impact its stability. Keeping the soil structure as intact as possible helps with overall stability and healthy soils promote a balanced habitat.

Minimize removal of vegetation

A mixed stand of vegetation from herbaceous to trees provides a mix of roots with enormous holding ability. Erosion and instability increase when vegetation is lacking, and when development and lawns have encroached to the top of the bank.

Examine land use and overland flow contributions

Hardened shorelines have impacts on aquatic and terrestrial species and contribute to water quality issues. We can avoid these problems by addressing localized contributors to soil instability prior to reaching for engineered solutions.

Target the solutions at each of the contributing sources of erosion

Although it may seem simple to address shoreline erosion in a single action or project, the reasons for erosion can be complex and involve a number of contributing factors. By looking at each factor an overall plan can take shape that prevents unintended impacts to our water quality and resources.

Maintain, restore, and enhance shoreline habitat elements

When work is being done to the shoreline, it is important to consider a project's outcomes for maintaining a naturalized condition. A good stabilization project will also result in a natural transition from aquatic to land habitats and also provide continuity along the water's edge to ensure these important wildlife travel corridors are maintained.

Make it last

Riprap revetment, seawalls, and other hardened structures can increase erosion of shoreline habitat as well as neighboring properties through deflection. These solutions are not long term and require inevitable maintenance restoration. Riprap and walls may not be necessary at all if other erosion sources can be mitigated. If armoring does take place, using filter gravel instead of geotextiles allows the hardened shoreline to be infilled to introduce habitat and vegetative stabilization.

How to Use The OUR SHORE Guide

Through "O.U.R. S.H.O.R.E," individuals can **1. Assess sources of erosion**, **2. Identify appropriate design practices**, and **3. Navigate permit processes** to streamline installation of Nature-Based erosion control measures. This program caters to homeowners, contractors, resource managers, and community leaders, providing them with the necessary support for successful NBS implementation.

Design practices are identified based on the severity of risk and are not specific to the natural resource (lake, river, stream, sand dune, beach, bluff, etc.). Instead, the "O.U.R. S.H.O.R.E" approach was created from the understanding that these solutions have a proven track record in Maine, particularly along rivers, streams, and lakes, and there is an increasing number of successful applications of these solutions in Maine's estuaries and ocean coasts.

Results from using this guidance should not substitute professional consultation. Seeking expertise from a Professional Engineer, or qualified design professional, as well as biologist or other environmental professional who can support habitat design elements is highly recommended.

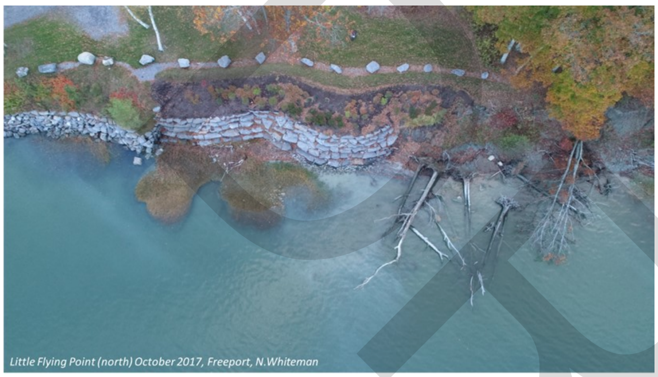
OUR SHORE RESOURCES

Guide to Shoreline Stabilization Options– This comprehensive guide provides orientation to why the OUR SHORE approach was developed and its key principles, as well as detailed information to become familiar with shoreline stabilization design practices. Included in the Guide are several companion documents such as the Assessment Checklist for Erosion, Common Materials in Nature-based Shoreline Stabilization, a Planting Guide, Case Studies, and more!

- **Assessment Checklist for Erosion**—The on-site checklist is used to assess the sources of instability and the severity of risk from those sources of instability at your site (sorted low to high risk). Based on the assessment findings, erosion control practices are identified (sorted low to high for ability to reduce risk). Contact Maine DEP if you are looking for assistance completing the Checklist.
- **Common Materials in Nature-based Shoreline Stabilization**-A short list of common materials to become more familiar with the field of nature-based shoreline stabilization.
- **Tools and Practices**–Descriptions and pictures of common design practices covered in the guidance.
- **Planting Guide**–The Planting Guide summarizes go-to planting guides for Maine landscapes recommended by experts who are designing and installing nature-based stabilization projects. A short list of inland and of coastal living shoreline plants is included.
- **Outcomes & Case Studies**–Example design solutions for different landscapes and case studies.
- **Training–**All of these materials as well as training opportunities for contractors, municipal officials, and community members can be found on the Maine Department of Environmental Protection website, https://www.maine.gov/dep/land/training/index.html.

The Problem with Riprapped Shorelines and Seawalls

Riprap has been used for many years to shield eroding shorelines from the influences of waves and weather. However, this technique has innate costs which have become clear over the past decade alongside the increase of armored shorelines. Covering the banks of waterbodies with rock is detrimental to surrounding ecosystems, eliminates habitat for native flora and fauna, and damages the very resources they were intended to protect. Riprap stone may still have a place in the design of erosion control projects. By understanding the consequences of traditional riprap installations, we can effectively incorporate stone into vegetative soil stabilization techniques.


Little Flying Point (north) October 2017, Freeport, N.Whiteman


Owl's Head, N.Whiteman

Consequences of Riprap

·Bare riprap stone inhibits growth of natural shoreline vegetation

·Riprap crushes habitat that is important to our native fish and wildlife species.

·Riprap is typically installed with a plastic geotextile fabric underneath which inhibits naturalization.

·Riprap redirects wave energy to neighboring non-armored shorelines and causes additional scour of bottom sediments.

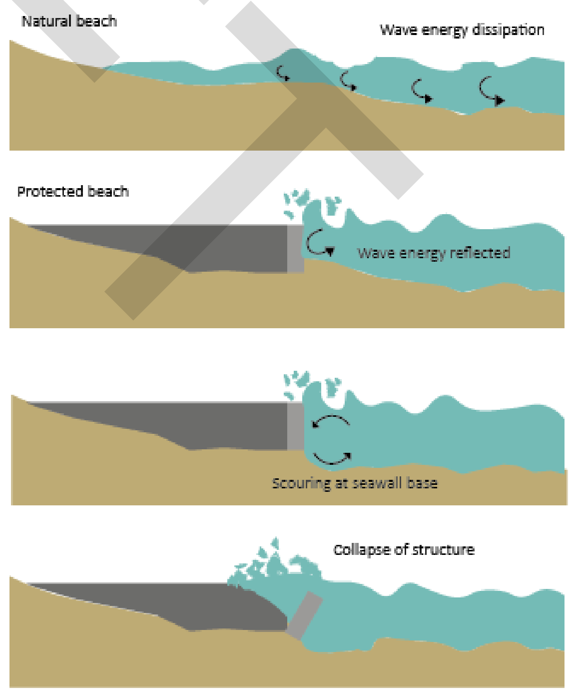
Consequences of Shoreline Walls

·Wave energy is deflected by shoreline walls. The energy moves downward and to the side leading to significant scour at the base and footing of the wall.

·Shoreline walls provide no interface between the water and land habitats

·Armored shorelines cause significant scour and alteration of nearshore habitats

·Shoreline walls frequently fail through a combination of undermining to the footer and inadequate drainage behind the wall.

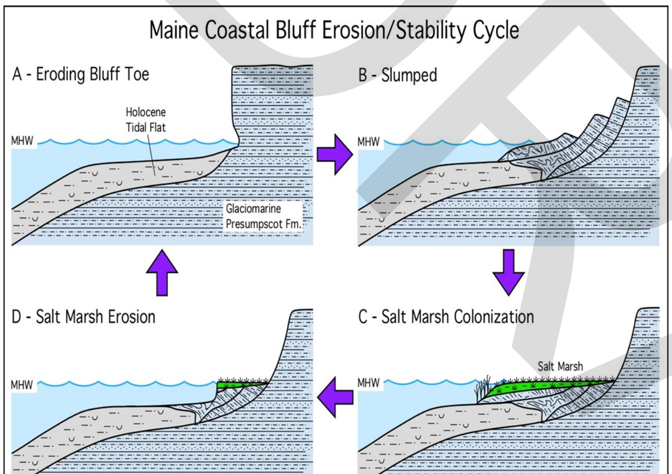


The Shoreline Erosion Process

Erosion occurs as the power of water and saturation overtake a soil particle's ability to stay connected to the soil particles surrounding it. Flowing water from overland can cause erosion in the form or raindrops, sheet erosion, rill erosion, and gully erosion. (*See page 17 for more information on soil structure)*

As wave action and saturation weaken and erode the base or toe of a bank, the weight and height of the soils become unsupported and can collapse, sliding or rotating into the water. This process results in a slope that is less steep and often contains vegetation that can easily regrow. The trees that fall into the resource can deflect flows and prevent further erosion of the slope. When slumps occur or trees fall in, the response to immediately remove them can make them more susceptible to continued erosion of the exposed soils.

Bank failure and stability cycles



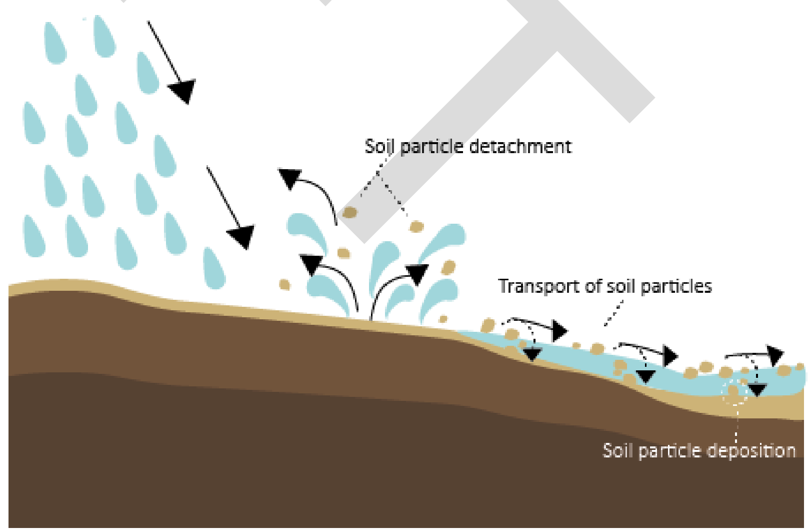
Belknap, 2012, after Kelley, Belknap, and Smith, 1987

Waves, weather, and time cause the toe of a coastal slope to gradually erode. The soil that rests above the eroded toe is now unsteady and slumps off the main body of the slope, down to the base, where is helps to stabilize the bluff. These slumps are repeated until the slope has reached a stable grade and the toe of the slope is rebuilt.

Erosion and Sedimentation

Erosion refers to the process of soil particles being detached from the soil structure and moved from their original location. Erosion can occur at a scale as small as a raindrop, or in large mass movements of soil or slides.

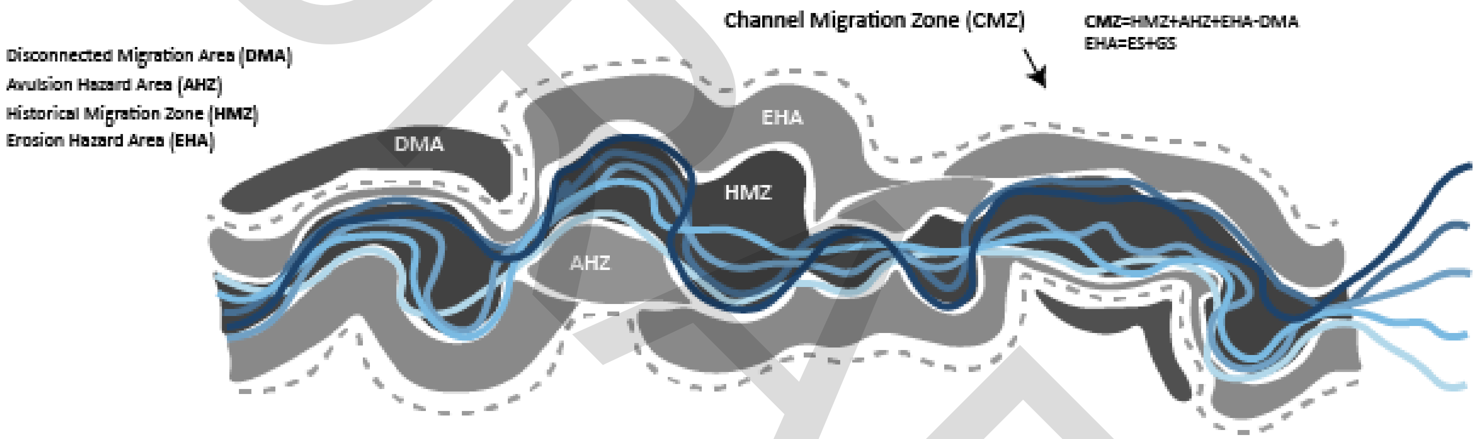
Sedimentation or deposition is the settling of soil particles out of the water. Water with higher velocity will be able to keep the particles in suspension longer. Larger and heavier particles will require a lot of energy keep moving, while small particles like silts and clays may require extremely calm conditions to settle out of the water.

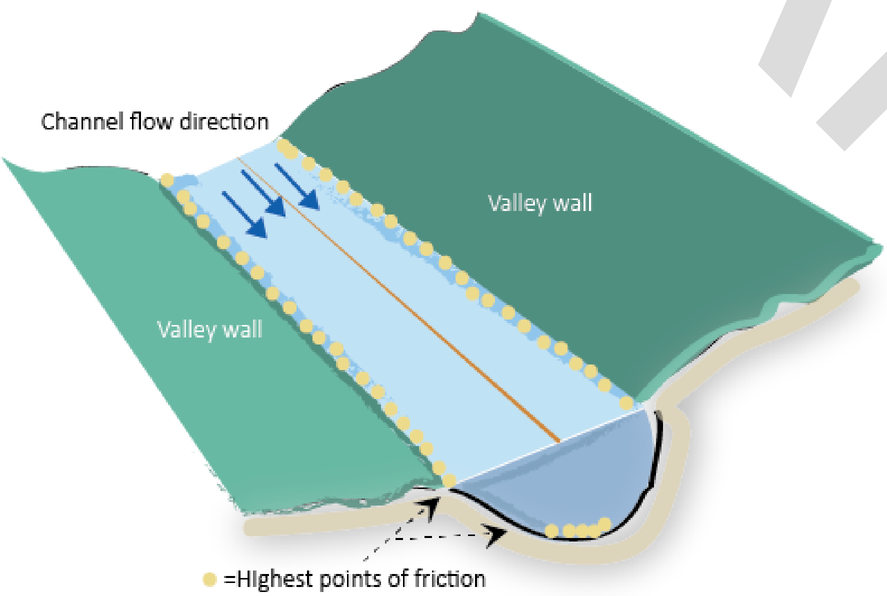


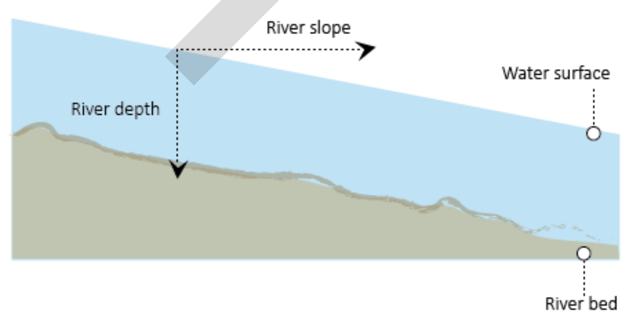
Erosion and Sedimentation in Rivers

The ability for a river or stream channel to erode depends on the localized watershed size and characteristics. Given the opportunity, river channels will migrate and move; forming deep bends and oxbows that can cut off sections of the river, creating oxbow lakes. Within streams and rivers, energy is concentrated within the deepest part of the channel (the thalweg). Deeper water has more energy than shallow water and when the river bends and moves, the water erodes the exposed banks. When rivers don't have the ability to move in natural ways, we've historically turned to armoring the bank, trying to shield the bank from the water—it can work, but often results in downstream erosion and other consequences.

An extremely effective method of shoreline stabilization in rivers and streams is biomimicry. By observing the ways channels move within natural systems and replicating those concepts, we can implement effective stabilization designs. Interventions such as chop and drop, weirs & deflectors, and strategically placed boulders have proved successful at modifying stream dynamics to benefit shoreline stability and fisheries habitat. *(See pages18 and19 for examples of the techniques listed*







Friction from the edges of the river banks and the bottom of the riverbed slow down the movement of water. This results in the highest points of velocity being in the middle and at the top of the river.

The larger the area of water (A) the greater the potential for a higher velocity (V) especially when there is a significant slope present.

Types of Erosion Along a Shoreline

Toe Erosion

https://www.maine.gov/dacf/mgs/hazards/chg/index.html

Toe erosion refers to the eroded or unvegetated sediment at the base of a bank along the water's edge. Toe erosion most commonly occurs from wave action hitting the shoreline or from scour along the edge of a river or stream bank. Other factors associated with toe erosion include ice scour/pushing, groundwater seepage, and saturation/draining of soils from water level fluctuations. Some toe erosion is common and may not be cause for any alarm by itself. This depends on the soil type, level of overall stability, rate of erosion, and presence of structures. When the toe erosion is low, protecting the toe should be enough to stop the erosion, but in more severe cases, the toe will need to be reestablished to support the slope weight in addition to protecting against further toe erosion.

Ice Erosion

Ice erosion affects the shoreline differently than wave action, but the results can be similar. When ice is able to "raft" into or onto the shoreline, the force is immense, sometimes forming ice berms along the shore. While strong toe protection may be necessary to redirect this ice mass, there are other strategies that can prevent ice damage. Many shoreline shrubs and several tree species are adapted to harsh winter conditions and can absorb some of the force of the moving ice. Branches will shear off, but the root systems will produce vigorous growth in spring. Logs, poles or other strategically placed materials can be used to help the ice slide up the bank with less friction on the underlying soil.

Surface Erosion

Surface Water plays a significant role in the overall stability of the shoreline embankment. As water flows across the land and crests the bank, the increase in velocity moves soil particles and increases the areas overall saturation levels. Surface water erosion can also be fed by wave spray, although dense vegetation does an excellent job of minimizing the effect by breaking up water droplets and diffusing the impact. During large weather events, sheet erosion can start to form more serious rills, even through the cover of grass. On longer or steeper slopes, this erosion may create channels and gullies along portions of the slope. These gullies leave the soil vulnerable to increased erosion from wave action and groundwater saturation.

Erosion from Surface Water and Wave Spray

Examples of Surface Erosion

Concentrated flows from land use are directed across a lawn to this shoreline

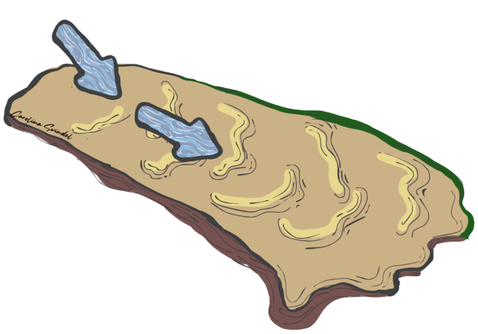
Sheet flows and foot traffic have exposed and started soil loss. Exposed roots used to be underground.

Compaction of soils through heavily travelled areas can decrease soil infiltration, increase overland flows, damage the mycelial network and concentrates water in a way that increases its force and erosive power.

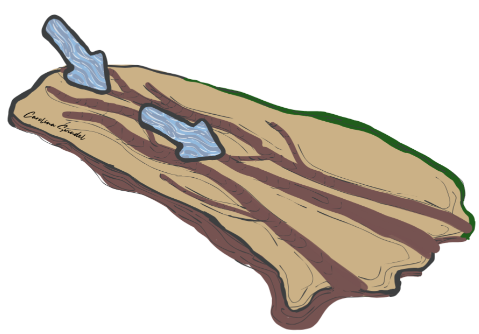
Concentrated flows have the power to erode soils and contribute to overall instability. Slowing surface water down and spreading it out can alleviate the chances of sediment disruption. When concentrated flows build enough energy or there is a rapid slope increase, a head cut can form and extend upwards rapidly.

Concentrated Flows have eroded into this vegetated slope

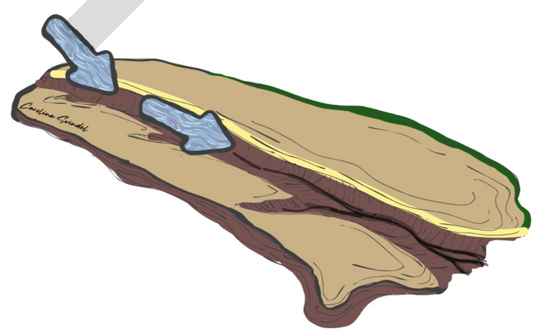
Diagrams of types of surface erosion



Sheet Erosion



Rill Erosion



Gully Erosion

Other Factors Influencing Stability

Groundwater & Saturation

Groundwater and **soil saturation** from fluctuating water levels (e.g. tidal areas), can contribute to bank instability in several ways. Saturated soils have reduced cohesion, meaning the soils do not "stick" to each other very well. This can lead to increased erosion rates from wave energy and makes slumps more likely. This is especially true when working with the less cohesive soil types and soil layer interactions.

Slope instability from landward groundwater may occur at the resource's edge or higher up the slope. Sometimes groundwater is trapped above an impermeable soil layer, creating flows which are especially hard to stabilize. Tools for addressing excess groundwater and saturation range from covering exposed soil with organic materials to improving the site's water drainage.

Groundwater instability and deflection from neighboring riprap Photo: P. Slovinsky, Maine Geological Survey

Height and slope

When assessing erosion risk, slope height and steepness are essential factors to consider, keeping in mind that other attributes such as vegetation and soil quality also play a role in the stability of the site. The grade of a slope is not always indicative of the risk of erosion, for instance a slope above 1:1 may be perfectly stable if the soils and vegetation are supportive. This is why it is important to look at all the forces that act upon a site during the assessment process.

The steeper and taller the slope, the greater the overall weight that must be supported from the bottom. Sometime this risk can be addressed with toe stones, other times, regrading or other measures may be necessary.

Angle of Repose

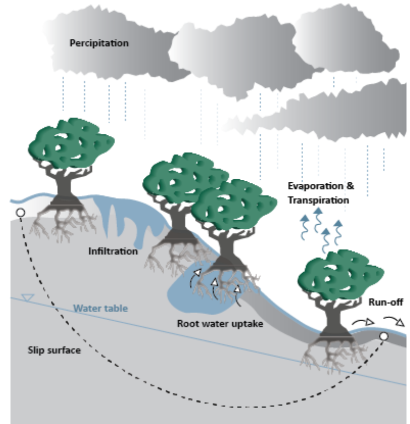
The angle of repose is the steepest angle that loose soil can remain stable. This angle is influenced by the particle size, shape, and moisture content of the soil. Coarse particles like sand and angular stone have steeper angles of repose compared to finer soils like silt. Soils with a high moisture content often have a lower angle of repose. This means that fine marine sediment will want to maintain a lower slope than sites with coarse soil types, gravels, or glacial till deposits.

NOTE: "Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information."

https://websoilsurvey.nrcs.usda.gov/app/

Rotational Failure Risk

With higher and steeper slopes, there is an increased risk of rotational failure within the bank. Rotational failure occurs when the toe of the slope slides out and up, while the upper embankment slides down. When addressing areas at high risk for erosion the involvement of a qualified engineer is highly recommended.



Factors influencing rotational failures

Tree Fall & Levering

When trees grow along shorelines, they often lean out over the water in order to gain more sunlight. A tree leaning over the water is not an immediate cause for concern, however when a tree gets extremely large, they can sometimes fall, tearing up portions of the shoreline in the process. If a tree has fallen, it may provide some stabilization to the immediate area and should be left alone when possible. When a tree needs to be removed along any shoreline, it should be cut above ground to keep the root mass intact and holding the soil in place. Hardwood trees will often resprout if cut while dormant, and therefore should be cut in the winter, when possible.

Tree has uprooted and fallen across a bank

Shallow Ledge, Bedrock, & Hard Pan Soils

Shallow ledge and hard pan soil layers are common in coastal Maine and can be tricky to work with. Water flows through permeable top layers of soil, but when it reaches a ledge or hardpan, it pools and flows, resulting in groundwater seeps, sliding, or faster erosion rates. Typically, toe stones or other toe treatments are anchored into the ledge with rebar and epoxy, or through shaping/fracturing the ledge into a supportive toe trench for anchoring.

Highly Erodible Soils and Bluffs

Certain soils (like sands) have poor cohesion and are susceptible to water or wind borne erosion . Special considerations should always be made for the soil type encountered at a specific site.

Research conducted by the U.S. Army Corps of Engineers has demonstrated that bioengineering projects can provide resistance to erosion comparable to hard armor. Soil bioengineering techniques have been found to withstand water velocities up to 12 feet per second (fps) for brush mattresses, 9.5 fps for coir rolls, and 10 fps for a log revetment with coir geotextile roll seeded with grass (see Table 1.1, Allen and Leech, 1997). Live stakes have a permissible velocity of up to 10 fps. Shear stress (the force exerted on the soil surface by flowing water) of up to 8 lb/ft2 can be sustained by live brush mattresses and vegetated coir rolls. This is equivalent to the resistance provided by 18" riprap, according to stability thresholds developed by the U.S. Army Corps of Engineers Waterways Experiment Station (Fischenich, 2001)

Nature’s Engineering Capabilities

Soil Structure

Our soils were formed during the last glacial period, about 12,000 years ago. Over time, those soils were colonized by plants, microbes, fungi, and other life. This process created a cohesive soil structure, meaning that the particles stick together and are harder to erode. Both bacteria and fungi secrete **polysaccharide mucilages**, which act as a glue, binding the soil particles together into water-stable soil aggregates.

When shoreline soils are disturbed, the soil structure is degraded. Particles become more easily eroded and it takes many years for the soil life to recover and rebuild its erosion resistance. When choosing strategies to address shoreline erosion, it is important to consider minimizing grading and other disturbances which will impact the existing stability of the slope and soil.

Shear Strength

Shear strength is the maximum force that can be exerted on a soil before movement occurs. The soil’s shear strength is determined by factors including particle size, particle shape, vegetation, saturation, and the bonding properties of particles. Water saturation decreases the overall soil cohesion and shear strength, which is one reason groundwater and toe saturation can lead to soil loss. Undisturbed soil structures have a higher shear strength than loose soil (e.g. tilled).

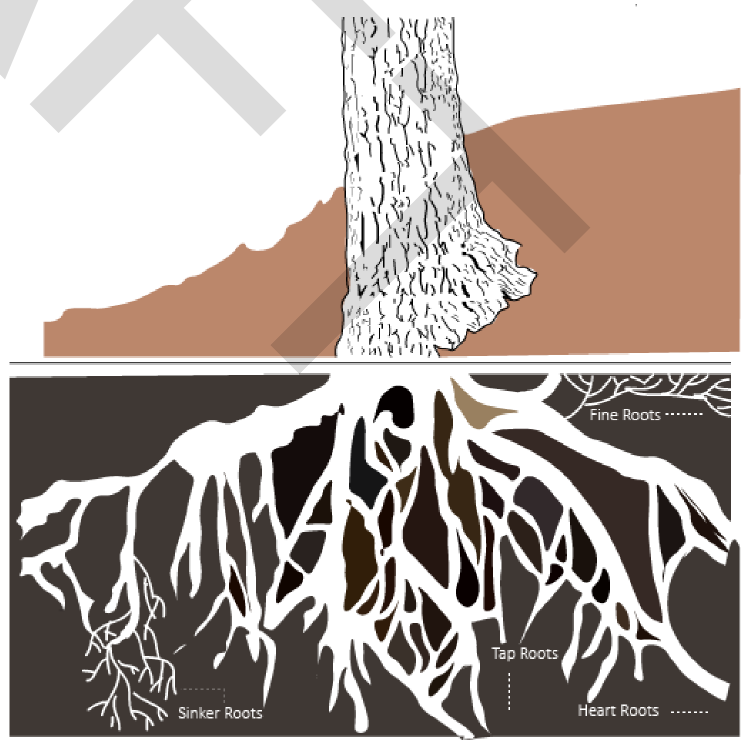
Comparative Sheer Strengths

TYPE OF MATERIAL	SHEAR STRENGTH (LB/FT²)
Rip-rap (boulder toe) with Live Stakes	6.10
Brush Mattress	6.10
Coarse Gravel with Live Stakes	5.08
12-inch Rock Rip-rap	4.00
Willow Brush Layer	2.84
Live Fascine	2.45
Live Stakes	2.26
Ideal Dense Sod	2.10
6-inch Rock Rip-rap	2.00
Grass and Legume Plot	1.40
1-inch Gravel	0.33

Source of data: “Planning Bioetechnical Streambank Protection.” US Dept. of Agriculture, Agroforestry Notes #24, March 2002

Buttressing & Arching

A wide variety shoreline root systems is essential to maximizing soil cohesion and holding strength. Herbaceous plants and the natural duff layer help to protect surface soil particles from erosion while the root systems of shrubs and trees reach between soil layers, adding strength against sliding. The roots of trees and shrubs can also arch together below ground level, increasing the soil’s ability to resist erosion. The deep roots of trees act as buttresses or piles in a slope, supporting the weight of soil above them and counteracting shear stresses.



Land Use Contributions to Instability

Everything flows downhill…especially water. If a hill is high enough, even a little bit of water can store quite a bit of potential energy. This is great if your intent is to provide drinking water for a town (that's why water storage tanks are always really tall), but perhaps it's not so great for developed shorelines. Steep slopes are typical in many of Maine's immediate shorelines, and water flowing down these slopes' transfers energy to loose soils – we call this erosion. Given enough volume, elevation change, and angle of slope, erosion can become quite severe. This is why paths to the water should meander through a well vegetated buffer.

Meandering helps to break up the flow path. But the quality of the buffer is important. Single shallow rooted plants (lawn grass), while better than bare soil, does not provide as much diversity of surface texture or complexity of rooting as a well-developed multi-species buffer with a natural intact duff layer. The more diverse the buffer the better.

Well vegetated shoreline

https://dec.vermont.gov/news/guidance-property-owners-help-protect-shorelands-vermont

Poorly vegetated shoreline

What's wrong with the lawn?

Lawns alone cannot provide sufficient protection from erosion on your shorefront lot by itself. While lawn grasses do protect against surface erosion, the lack of deep root structure doesn't support long-term stabilization. Lawns are best used as an overall landscape design, to provide open space for outdoor activities.

Almost all lawns contain non-native species which are ill-adapted to our climate conditions, requiring additional water and maintenance. Property owners can save time and money on maintenance while also increasing slope stability, protecting water quality and enhancing biodiversity by keeping lawn areas to a minimum and promoting native meadow conditions.

Photo: Pete Slovinsky, Maine Geological Survey

Contributions to bank erosion and instability can be varied, and addressing the root of the problem is often challenging. It is important to examine how the water flows across the property during rain events, especially towards areas where erosion has already begun. Even a shallow depression from compaction from walking can create a channelized, higher energy flow. Below are some easy ways to confront sources of erosion which originate on the land.

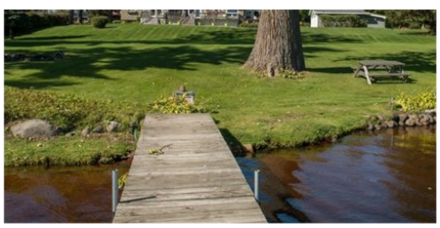
Shoreline Access Points

Constant foot traffic can prevent proper stabilization through compaction, footstep erosion, and prevention of plant growth. Consider defining a specific access point so the shoreline can recover. Always cover bare soil pathways with mulch and avoid laying them out in a straight line. A meandering pathway can limit surface erosion.

Impervious Surfaces

Capture, infiltrate, and divert flows to stable areas that can disperse and absorb running water. Think about how roof, driveway, and other impervious surface runoff can be slowed and redirected to minimize the impact to the soil.

Poorly-Vegetated Buffer



Lawn stretched to the edge of the bank causes instability due to lack of deep-rooted buttressing. Even a narrow buffer with some vegetation diversity and density will provide increased stabilization.

Excess Water

Other sources of water can create additional soil instability. Septic systems, for example, can contribute a significant amount of water into the ground if not properly maintained. Some septic systems weren’t designed for year-round use, others may be failing or undersized. Sprinkler systems also add extra water. Don’t forget to think about these or other potential sources of landward water.

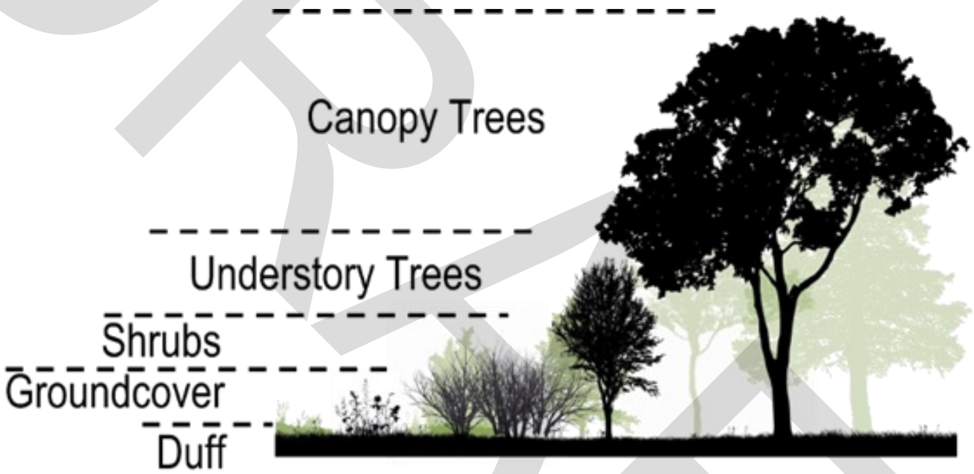
Maine DEP Guides to Reduce Stormwater Pollution & Runoff:

https://www.maine.gov/dep/land/watershed/materials.html

Shoreline Buffer Vegetation

Vegetated buffers protect water quality, provide important habitat, and are necessary for resilient, stable shorelines. Buffers help prevent erosion from overland flows and protect the shoreline from erosive wave action and ice. Vegetated buffers should not have straight channels through them; water flowing in a straight path increases energy and erosive power. Keep pathways and access points stable with good groundcover, mulch, and meandering to break up flows. Uneven ground surfaces, with hummocks and depressions, slow down runoff in natural systems, so that water can filter into the ground.

Elements of a Good Buffer



Trees: Whether evergreen or deciduous, break up the impact of rain and wind, provide shade and habitat, and are long lived. Leaf surfaces collect rain and allow for evaporation. The tree and shrub canopy intercepts raindrops and reduces their impact on the soil.

Shrubs: Including flowering or non-flowering species, also deflect wind, rain, and help stabilize the shore against wave erosion and are attractive to people and wildlife. Their medium-depth root systems help larger trees hold more soil in place.

Groundcovers: Such as vines, grasses, flowers and herbs, slow down surface water flow, and trap sediment and organic debris. Their shallow root systems hold the soil in place while protecting the ground surface from erosion.

Duff layer: An uneven soil surface (with hummocks and depressions) allows rain and snowmelt to puddle and infiltrate. The duff layer is made of accumulated leaves, pine needles, and other plant matter on the forest floor. This layer acts like a sponge, absorbs water, traps sediment, and prevents erosion. Duff is a host to microorganisms that break down plant material and recycle nutrients.

Shoreline Buffer Habitat

"Shoreland Habitat, sometimes called riparian habitat, is found adjacent to vernal pools, wetlands, streams, rivers, lakes, ponds, and coastal waters. More than 60 species of water-dependent birds, mammals, amphibians, and reptiles in Maine require shoreland areas for shelter or a critical part of their life cycle such as feeding or breeding. Shoreland habitat also provides other species access to drinking water and acts as a travel corridor as well as important core habitat. Up to 85 percent of Maine's vertebrate species use the shoreland zone at some time during their lives. Shoreland habitat also filters runoff from developed areas, helping to maintain clean water that fish, insects, and other aquatic species need."

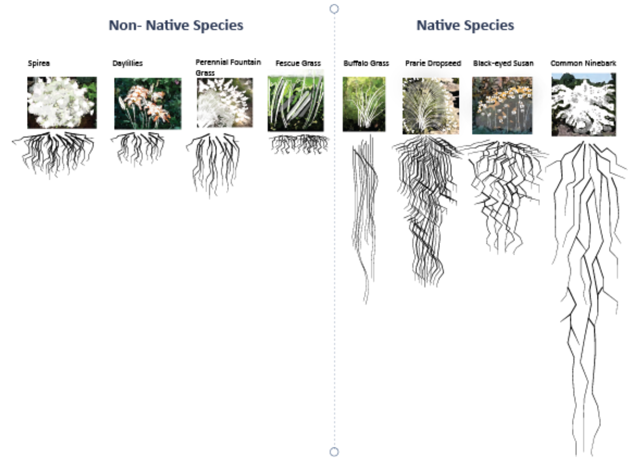
*excerpt from Maine Audubon's Guide: "Conserving Wildlife in Maine's Shoreland Habitats". More information can be found here: https://www.maine.gov/ifw/docs/MEAud-Conserving-Wildlife-Shoreland-Habitats.pdf

What makes good shoreline habitat?

Below follows a selection of specific habitat elements that can be incorporated into shoreline stabilization projects of all kinds.

- **Terrestrial & Aquatic Shade** — Fish and wildlife need shade to keep the ground and water cool and to provide places to escape predators.
- **Cover Diversity** — Fish and wildlife need different types of cover, for example overhanging trees, herbaceous plants, logs, leaves and duff.
- **Natural Vegetation Diversity**— A diversity of plant species give wildlife varied food sources, refuge, perching, and hiding spots.
- **Woody Material Inputs** —Decomposing wood feeds fungi and bacteria into the ground promoting soil health and enriching the surrounding environment. The promotion of trees and natural wood fibers in shoreline projects helps to prevent the surrounding waters from becoming nutrient starved.
- **Travel Corridor**—Animals need to be able to move along and adjacent to the shoreline. Dense cover and a traversable surface are essential to facilitating this migration.
- **Soil Health & Subsurface Habitat** —Minimizing disturbances to the soil structure goes a long way towards preserving the health of the shoreline soil system. To promote a healthy subsurface soil habitat, compaction, smothering, and other negative construction impacts to soil should be avoided.
- **Natural Sediment Transfer** — Erosion and sediment transfer is a natural process, and species including clams and turtles rely on erosion and sediment transfer to sustain healthy populations.

Native Plants

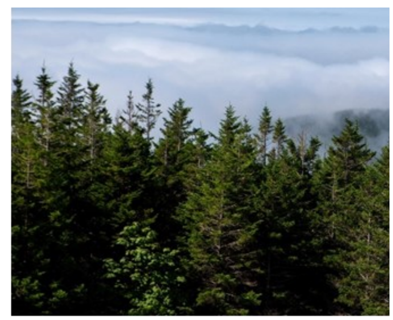


Native plants are vital to preserving Maine's unique landscape, biodiversity, and wildlife species. Native plants have evolved in tandem with many of our native fish and wildlife species, who rely on them for habitat, travel, cover, houses, and food. Non-native plants are often of little value to our native wildlife and pollinators and can sometimes turn into invasive species. Since seeds can travel far on water, special care to use only native plants along the shoreline will have lasting benefits.

Note: For a list of invasive aquatic and terrestrial plant species in Mine, see "Maine Natural Areas Program Invasive Plant Fact Sheets".


https://www.nps.gov/acad/learn/nature/plants.htm


https://www.nps.gov/acad/learn/nature/plants.htm


https://www.nps.gov/acad/learn/nature/plants.htm

Key Aspects to Native Plants

Minimal maintenance

- Require no attention once established
- Require no fertilizers as they are adapted to the natural soil conditions

Important to Native Fauna

- Shoreline vegetation is important for both fish and wildlife in Maine for cover, food and other habitat elements
- Certain native species are especially important host species and food sources for butterflies

Deeper roots system & resiliency

- Deeper root systems are important for increasing soil stability and tying together soil layers

- **Maine Natural Areas Program Publications -** https://www.maine.gov/dacf/mnap/publications/index.htm
- **Plants for the Maine Landscape -** University of Maine Cooperative Extension https://extension.umaine.edu/gardening/manual/plants-for-the-maine-landscape
- **Natural Landscapes of Maine** (Book) - https://www.maine.gov/dacf/mnap/publications/natural_landscapes_maine2018.pdf
- **Yard scaping Program**— https://www.maine.gov/dacf/php/pesticides/yardscaping/plants/index.htm
- **Maine Coastal Planting Guide:** https://static1.squarespace.com/static/5e4af21b92caed7f481a25b7/t/5ffe1e3d9bc50a541964d41f/1610489417767/Appendix+E-Planting+Guide.pdf
- **Inland Plant Selection Resources** https://www1.maine.gov/dep/land/watershed/buffer_plant_list.pdf
- **How to Find Native Plants -** Wild Seed Project https://wildseedproject.net/2022/02/navigating-the-nurseries-how-to-find-native-plants
- **Maine Native Plant Finder -** Maine Audubon https://mainenativeplants.org/

Invasive Plants

What is an invasive plant?

An invasive plant is defined as a plant that is not native to a particular ecosystem, whose introduction does or is likely to cause economic or environmental harm or harm to human health. There are currently approximately 2,100 plant species recorded from Maine. Approximately one third of those are not native. Of those plants that are not native, only a small fraction are considered invasive, but these have the potential to cause great harm to our landscape. Please visit our list of fact sheets to determine if a particular species is considered invasive in Maine, and our new invasive plant brochure for a general overview-including the do not sell list.

How do these plants reach our landscape?

In some cases, invasive species have been imported for ornamental and landscaping purposes. In other cases, invasive species are intentionally planted because they have strong root systems and can stabilize soil. Accidental introduction is also possible, with seeds sticking to boots, tires, and other plants. Aquatic invasives are easily transported on boats, float planes, and attached to their gear. Watercraft registration fees in Maine help fund the prevention and control of aquatic invasive plants and fish.

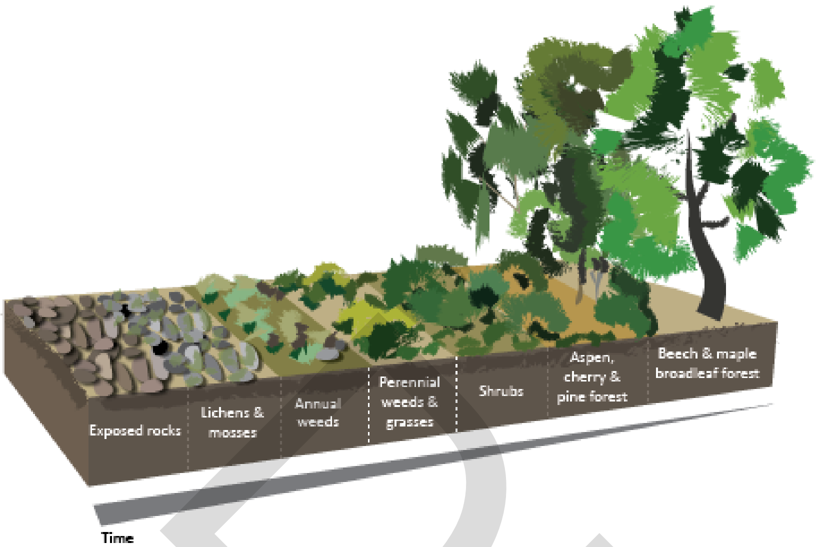
Why should you care?

Invasive plants are a direct threat to what we value about Maine's natural and working landscapes. The aggressive growth of invasive plants increases the costs of agriculture, can affect forest regeneration, threatens our recreational experiences, and potentially decrease property values. Species like Japanese barberry and multiflora rose can form thorny, impenetrable thickets in forests and agricultural fields. Aquatic invasives can choke waterways, making it difficult to boat or swim.

Invasive species are the second-greatest threat to global biodiversity after loss of habitat. Invading plants out compete native species by hogging sunlight, nutrients, and space. They change animal habitat by eliminating native foods, altering cover, and destroying nesting opportunities.

For information about Removing Invasives near water resources, see Section **R** of this guide

A Living Shoreline Takes Time



It took time to be this stable

Shoreline stabilizations that include vegetation or promote vegetation growth, get stronger over time. While structural solutions eventually lose their effectiveness and may require significant maintenance, ones that include robust vegetation will get stronger as the root networks grow, buttressing and creating a web of interweaving root systems, while branches and leaves break up wave spray and absorb energy. Soil structure, plant roots, and fungal networks in the soil take time to establish, so the more disturbance done to the soil to prepare a site, the longer it will take nature to heal. Biological activity within the soil also leads to the creation of natural "glues" that increase soil cohesion. Once the soil structure is disturbed or tilled, it erodes more easily.

Vegetation gets stronger over time

While it may seem that nature-based stabilizations are some how "soft" solutions, this doesn't speak to the strength of vegetative practices once established. The trick is to provide temporary protection so the plants can become established and take over as the primary stabilizers. The first few growing seasons of a nature-based stabilization are crucial to the overall success of a resilient shoreline. This may mean checking on plants and seeded areas, occasional watering, and looking for signs of soil movement. Once the additional vegetation is established, they can be left alone

Speed up the natural process

In ecology, there is a term called succession, which is the natural change in the structure of a biological community over time. Succession can be observed across the state as old pastures return to forests, beginning with poplars and birch but leading way to other long-lived forest giants. On shorelines, humans are jumpstarting succession by disturbing the existing environment at a much greater rate and scale than would occur in nature. This is a yet another reason to disturb as little as necessary, especially existing vegetated areas.

Nature's inclination is for surfaces to be vegetated. Even riprap will have sediment wash in over time, creating pockets for seeds to grow. Unfortunately, complete naturalization can take at least 25 years depending on the extent and scale of shoreline impact. The speed and success of naturalization can be improved with easy modifications to erosion control designs. For example, using long term biodegradable filter fabric or filter gravel instead of synthetic filter fabrics keeps nano plastics out of waterbodies and encourages root growth. Additionally, partially infilling riprap with soil and vegetation or planting dense & diverse vegetation above riprap gives the naturalization process a hand up.

Maintaining healthy soil for long term stability

Biological elements within the soil play an essential role in soil aggregation and formation of soil structure. The fungal other microorganisms in the soil create network of microscopic connections throughout the soil matrix. There is a connection between the fungal network in the soil and the plant roots as well, helping deliver nutrients throughout the forest. Soil organisms such as fungi and bacteria also secrete binding agents into the soil, helping create a more cohesive soil structure.

The movement of oxygen and other gases, as well as water and nutrients through the soil is necessary for deep roots systems. Most upland plants cannot manage the toxic conditions that arise in the soil when oxygen isn't present. Many wetland and shoreline plants have adaptations to help them compete in low oxygen environments such as wetlands. Compaction and smothering of soils with fill can cause impacts to the soil pore space and affect plant growth. Upland soils that are over-compacted can sometime be full of wetland plants because they can outcompete the other plants that can't handle low oxygen soil—these areas may appear to be wetlands, but often are not.

Self-healing systems

One of the huge benefits of integrating nature-based solutions into stabilization projects is their ability to grow stronger over time and to self-heal. A healthy ecosystem of plants will develop broader and stronger roots systems year after year, and when allowed to seed, spread, and reproduce naturally, the plants will colonize and find the locations best suited to their needs. Even riprap and walls can be retrofitted and adapted to provide living elements, allowing vegetation and roots to anchors and buttress the stone from movement and tie the slope's soils and covering together.

Failed bluff with slumping forming a protective toe. Brunswick, ME. Photo: P. Slovinsky, Maine Geological Survey

Natural sediment transfer

Maintaining a natural flow of sediment from the shoreline to the sea, and vice versa, is important for both healthy coastal habitats and erosion prevention . The deposition of sediment from land into the ocean creates habitats like eelgrass meadows, mudflats, beaches, spawning grounds, and wetlands . These vital environments dissipate wave energy from storms and support the fish, birds, and other animals that make Maine special: bivalves like clams and oysters, fish like cod and salmon, and birds like blue herons and sandpipers. The movement of sediment in coastal waters also helps protect coastlines from erosion by building natural barriers like dunes, sandbars, and marshes. Natural transfer of soil from terrestrial to marine or freshwater environments is so important, it is written into the Natural Resource Protection Act (Title 38, §480-D: Standards).

A completely natural shoreline will adjust best to its wave energy environment and sediment will flow accordingly. A seawall interferes with that land-sea connection and can cause losses in beach, wetland, and shallow nearshore habitat. Depletion of these habitats in front of walls can exacerbate erosion and allow bigger waves to reach the wall. The better a shoreline can fit into its surrounding environment, the better it is at adapting to dynamic natural conditions. When considering shoreline stabilization techniques, sediment transport should not be overlooked.

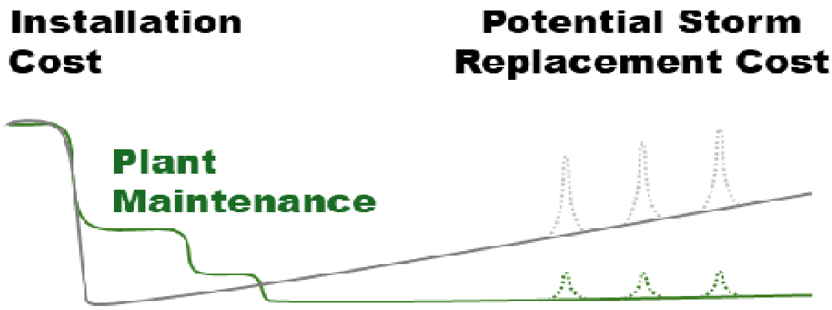
Costs and Performance

Two of the most common questions when determining what shoreline stabilization practices to use are cost and performance. Direct comparisons between the cost of green infrastructure and gray approaches are difficult for many reasons, primarily due to low availability of data. Since riprap and walls have been the predominant choice for shoreline stabilization for many decades, data for these designs are often available, while data for natural or hybrid options are lacking. However, as more living shorelines are being installed, more information on the effectiveness is being gathered, and the increasing knowledge base is also reducing installation costs.


Photo: Paul Bernacki

Other Environmental Impacts and Outcomes from Select Stabilization Tools

Outcomes	Metric	Root Wads	Biodegradable blankets (planted with vegetation)	Live Staking	Live Fascines	Brush Mattress	Living Wattles	Log Revetments	Log Jams (in-water)	Log Vanes & sills (in-water)	Coir Logs	Toe Logs	Vegetated Mechanically Stabilized Earth (MSE)	Log Cribs/Live Cribwalls	Riprap	Infilled/Vegetated Riprap	Green Gabions	Gabions
Residual Temporary Construction Damage	Comparative extent of construction disturbance	High	Low	Low	Low	Low	Moderate	High	High	Moderate	Low	High	High	High	High	High	High	High
Bank Stability Short Term	Probability of remaining stable in comparative short term	Medium	Low	Low	High	Medium	Low	Medium	Low	High	High	High	High	High	High	High	High	High
Bank Stability Long Term	Probability of remaining stable in comparative long term	High	High	High	High	High	Medium	High	Medium	Low	High	Medium	High	High	High	High	High	High
Sediment Release	Amount of sediment movement from bank to water over time	Minimal	Moderate	Moderate	Low	Moderate	Moderate	Minimal	Moderate	High	Low	Moderate	Low	Moderate	Low	Moderate	Low	Low
Ability to self-heal	Whether the method can repair itself after receiving damage	Limited	High	High	High	High	High	Limited	Limited	No	Limited	No	Limited	Limited	No	High	Limited	No
Installation Costs		$$$	$	$	$$	$$	$	$$$	$$$$	$$	$$	$	$$$$$	$$$	$$$$$	$$$$$	$$$$$	$$$$$



Green Infrastructure Effectiveness Database
https://coast.noaa.gov/digitalcoast/training/gi-database.html

What We Know

What we do know about cost and performance is that most calculations for return on investment, or life cycle cost, are determined based on a modeled performance period (e.g., fifty years), not actual. There are examples of green and of grey designs that have failed in 10 years or less. The aggregate, long-term cost of maintenance on each type of system is also understudied. There also is a lack of data on the negative costs of riprap, wall, or other grey options. As a result, there is substantial variation in cost estimation across different regions and designs.

What We Are Learning

What we are learning is that living shorelines grow stronger over time and can be more sustainable in the long run than seawalls or rip-rap revetments alone. Green infrastructure designs can adapt to changing environmental conditions and can be less prone to fail than rock revetments alone in storm events. Additionally, properties near green infrastructure may see an increase in value due to improved aesthetics and access to recreational activities.

Based on the information provided in NOAA's Green Infrastructure database, and case studies on NOAA's website it is evident that green infrastructure, including techniques such as living shorelines, can offer cost-effective solutions for coastal resilience compared to gray infrastructure. Green infrastructure, which encompasses natural and nature-based approaches, has been shown to not only reduce the impacts of flooding and erosion and require less long-term maintenance, but also provide additional social and economic benefits. In Maine, we are not yet able to offer an exact cost estimate across design types. However, we anticipate collecting this information over time, and currently recommend reaching out to practitioners for information on projecting materials and implementation expenses.

Photo Credit: Damon Yakovleff CCSWCD

Common Materials in Nature-based Shoreline Stabilization

Maine DEP Erosion Control Material & Erosion Control Mix Suppliers: [2020-esc-materials-mix-list.pdf (maine.gov)]

Maine DEP Erosion Control Field Guide for Contractors: https://www.maine.gov/dep/land/erosion/escbmps/_esc_bmp_field.pdf

Biodegradable Materials

- **Biodegradable Erosion Control Socks**

  Erosion Control socks of various sizes are available with biodegradable casing material. Plastic casing should be avoided unless it will be removed. Socks can be filled with various materials for different purposes, including erosion controls mix, crushed stone, oyster shells, or other mixes.

- **Coir Logs**

  Coir logs are specialized materials similar to erosion control socks that are entirely comprised of coconut coir. Variety of diameters and lengths available.

- **Natural Fiber Blankets & Filter Fabrics** (long-lived, fully biodegradable), **Burlap, Heavy Coir blankets**

  Various blanket-style products can be used for stabilization tools. Heavy coir can provide long term stabilization while still being biodegradable over time. Avoid nonbiodegradable materials in blankets or other permanently-placed items.

- **Temporary Erosion Control Blankets**

  Temporary erosion control blankets typically are more affordable but may not last as long as other materials such as coir. Where vegetation will establish fairly quickly or in seeding applications, temporary blankets can be valuable tools.

Wood & Tree Materials

- **Erosion Control Mix**

  (see [BMP Manual] for Specs)

- **Tree root wads**

  Tree root wads can be effective at slowing water's energy and managing water's energy. It is often placed as toe protection, in manufactured log jams, or as flow deflection in the resource. Typically spruce trees are uprooted and driven into the bank or otherwise anchored.

  NOTE: Permitting may vary by placement location

- **Logs & Posts, Anchored tree material**

  Untreated logs, posts and other large tree material can be utilized for project components such as anchoring piles, targeted chop and drop, and manufactured log jams.

Photo: Shana Hostetter, Parterre Ecological

Mulches & Organic Matter

- **Erosion Control Mix (permanent)** *(see BMP Manual for Specs)*
- **Fine erosion control mix, super humus**
- **Hay or straw mulch** *(for temporary erosion control/seed establishment)*
- **Natural duff, leaves, pine needles**
- **Other natural wood-based mulches**
- **Hydraulically applied mulches & biotic soil media**

  Hydroseed and variations have become popular and effective methods for growing vegetation fast and also improving soil health. Great acre must be taken when using hydraulically-applied products to avoid overspray. Fertilizers should be avoided unless directed by a soil test. **NOTE: Some towns limit the use of hydroseed and fertilizers near waterbodies**
- **Plant-based compost**

  Plant-based composts provide a safer alternative when necessary as a topsoil additive or top dressing. Animal waste composts can leach high concentrations of nutrients and negatively affect water quality near resources.

Stone, Soil & Aggregate materials

- **Riprap stone**

  Large angular or subangular stones that are chemically stable and comprised of a mix of stone sizes. Typically from blasted or crushed ledge.
- **Bank-run stone & Cobbles**

  Rounded or screened stones from excavation (tailings) Bank run stone is not recommended for slopes greater than 3:1 or areas with water energy that could roll the stones.
- **Crushed Stone**

  Small stone that is crushed to create an angular, well packing clean stone with no or very limited fine content
- **Pea Stone**

  Small gravel of manufactured or natural original that are less than 3/8 inches.
- **Oyster shells**

  Shells of oysters recycled and used as an aggregate for various stabilization tools. ***NOTE: Special considerations are required for oyster shell use in permitting.***
- **Coarse sand**

  Large particles of sand that provides good drainage and compaction properties.
- **Loam**

  A mix of mineral soil including all three textures: sand, silt and clay in nearly even amounts. Typically used for it's ability to grow vegetation effectively.
- **Mixed materials**

  Mixed materials may have several applications as riprap infill, sock filler material, or other mulch applications. Examples include:
  - **Infilled Riprap with soil, erosion control mix or variations for growing vegetation**
  - **Cobbles mixed with erosion control mix**

Non-biodegradable Materials

(see BMP Manual for Use & Specifications)

- **Gabions** (plastic or non-galvanizedmetal, to be vegetated) **and variations** e.g. marine mattresses)
- **Turf Reinforcement Mats (TRM)**
- **Cellular confinement systems**

S

Overland Erosion & Spray

Correcting land use contributions

Addressing run off from lawns and roofs, as well as wave spray flowing back down the slope is a good place to start. Before correcting water level erosion issues, it's important to take a look at the way the property use affects the volume, depth, and power of water that can move soil particles. In this section, we'll focus on how to slow surface water down and how to protect the soil from disturbance. Turn to Section "O" - Land Use Contributions for ways to reduce impacts to the bank from human use and habits.

Slope erosion control

Overland erosion from runoff and wave spray can be combatted by reducing the water's energy as well as dispersing water over a larger area of land. Water originating in the upland beyond the crest of the slope can often be diverted to more stable areas, infiltrated, or spread out away from unstable banks. Wave spray and any remaining overland runoff can be dealt with by protecting the soil from flowing water (e.g. Erosion Control Mix mulch*, brush layering, anchored fiber blankets) or by modifying the amount of water moving on the slope. Dense canopies of vegetation break up water droplets so that when the water hits the underlying duff layer, the soil structure remains intact.

Dense vegetation

Whether a site is being enhanced or regraded completely, the goal should be a robustly vegetated embankment that shields the soil from flowing surface water and promotes long term bank stability. The best way to accomplish this is through the use of vegetation, which requires protection and support until established.

Mulch

Mulches reduce water velocity, improve soil water retention, and protect soil from surface level disturbances. While mulches have an important role in erosion control functions, it's important to understand that the ultimate stabilization is done by the plant community. Mulches and other temporary/biodegradable soil covering methods are there to help achieve successful vegetation establishment.

Permanent mulch and duff

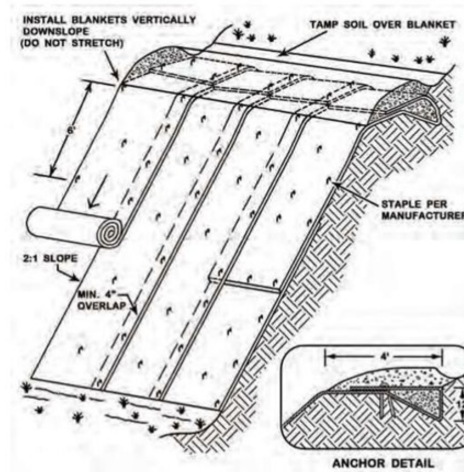
Erosion Control Mix (ECM) mulch applied to slopes less than 1.5:1 at a thickness of 4 inches can provide an effective replacement for the natural duff layer. Erosion Control Mix can be supplemented with stone less than 4 inches to bulk out the mix and provide greater holding power. ECM will be fairly slow to vegetate naturally and may be difficult for some seeds to establish in.

*__Caution__, ECM should never contain compost, unfortunately some mixes have been found to contain jumping worms. Check for invasives before applying ECM to a site. For more information see [Amynthas Worms in Maine : Maine DACF]

Biodegradable Soil Covering (Mulch options)

MULCH TYPE	Installation	Benefits	Limitations
Erosion Control Mix	2 inches for slopes flatter than 3:1, 4 inches for slopes greater than 3:1	Lower cost, most effective loose mulch for soil protection. Over time, it decomposes to rebuild duff layer. Locally available & good for protecting newly planted vegetation & conserving soil moisture. Some stone can be added for more staying power.	Use should be limited to slopes less than 45% provided the material is installed with complimentary practices such as water diversion. Not effective with very steep or long slopes (without slope interruption), or in concentrated flows. Natural growth of plants and seed in ECM areas will be slow.
"Fine" Erosion Control Mix	Can be used for pathways, rebuilding/ replacing a poor duff layer.	Finer material that is more effective than wood chips or bark mulch. Provides a cleaner "landscaped" look. Can be very effectively sued as a top dressing over tradition ECM in combination.	Not as strong as tradition erosion control mix. Can be washed away fore easily without the long fibers
Straw Mulch	2 bales (70-90 lbs.)/1000 sq.ft for over 75% coverage Twice that rate for overwinter stabilization	fairly inexpensive, tends to be much lower in potential for weed seeds in sensitive areas.	TEMPORARY. Cannot withstand wind, concentrated flows, or steep slopes. May need to be anchored.
Hay Mulch	Same as straw mulch	Inexpensive, locally available.	TEMPORARY. Cannot withstand wind, concentrated flows, or steep slopes. May need to be anchored. Hay can import weed and invasive seeds.
Hydraulic Mulches & Biotic soil media	Applied using specialized equipment. Various fibers mulches, tackifiers, seed mixes, and fertilizer can be combined for specialized application	Includes tackifier and other amendments that can make it very easy and quick to establish vegetation	Biggest concern with hydraulically applied products is overspray into the water or resource, since the fertilizer and other components may negatively affect water quality if over sprayed. *NOTE: Some towns restrict the use of certain fertilizers near waterbodies. Check with the local Code Officer before using this technique on a shoreline.*
Erosion Control Blankets (Fully biodegradable, Temporary)	Roll and staple according to manufacturer's specifications	Fully biodegradable heavy coir blankets and other long-lived natural fiber blankets can be used as long term erosion control for areas that might be slow to revegetated. They can also be used for encapsulated soil lifts and other various effectively. Used for protecting soil while vegetation grows to increase overall stability.	Ground must be smoothly-graded to install properly. This material cannot be coupled with reversion or slope roughening practices due to need for full soil contact. Wide variability in strength and useful life (from a few months to over a year) before it biodegrades.
Natural Fiber Blankets (including heavy coir, long term biodegradable	As soil covering, can be integrated with other practices and provide longer term protection. Must be secured via manufacturer's recommendations	Good soil protection capability and long term protection for slowly-revegetating areas, like shady conditions. Or higher energy water flows. Can be used in various methods including creating soil lifts and other material encapsulation.	Similar to Erosion Control Blankets.
Wood Chips/Bark Mulch	3 inches, only for flat areas, not on slopes	Inexpensive, locally available.	Does not tolerate water flows—it floats away easily. Should be used in limited applications.

Erosion control blankets



An erosion control blanket (or mat) is a pre-made blanket of consisting of biodegradable organic fiber sewn into a biodegradable mesh. The blankets are made with various materials but should not contain any plastic netting when used along shorelines. The blanket is a medium term, stronger covering but requires vegetation to take over the role of long-term stabilization.

Blankets come in different widths and are secured to the soil with staples or wooden anchors. The blanket should be installed with overlap between sections and with the blankets on the top of slope anchored in a trench. Organic mats can be made out of many different biodegradable fibers; however, coir blankets tend to last longer and are an excellent choice for on shoreline application. Blankets can be seeded underneath, layered into encapsulated lifts, or planted through by cutting small holes in the fabric.

Hydraulic mulches & hydroseed

Hydraulically applied mulch is a product applied to slopes to assist in erosion control and vegetative establishment. Hydroseed is a variation of hydraulically applied mulch that contains seed and often fertilizer. Traditional mixes contain water, a mulch (often cellulose fiber), a tackifier or glue agent, seed and additives such as fertilizer. Seed mixes can be customized and modern tackifiers and mulches are available that have high sheer strength and can withstand steeper slopes and higher flow velocities than old hydroseed mixes. There are also special mixes that can help encourage soil health by introducing important soil microbes and nutrients. Care should be taken with any hydraulically applied product to not overspray the product close to the water.

Surface roughening

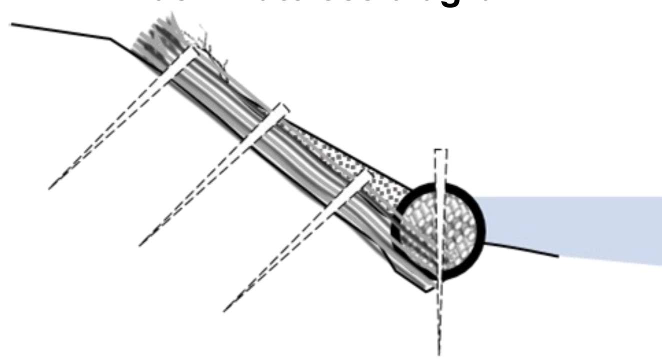
Surface roughening is a method that slows down flowing surface water to prevent rill formation and the movement of soil particles. Roughening can be done with woody mulch or a coarser soil material, but it can also include various grading and vegetation techniques such as slope interruption and brush mattresses. The concept is to break up the water's energy before it has enough power to move exposed soil at the surface.

A roughened slope covered with hydroseed

Brush mattresses

Brush mattresses use layers of untrimmed dormant plant cuttings to prevent erosion. The mattress is made of bundles of cuttings, tied together and then staked into the bank uniformly. The thick layer of live cuttings is covered by a layer of soil and compacted to prevent air pockets. When the cuttings grow, their roots extend into the soil, holding it in place.

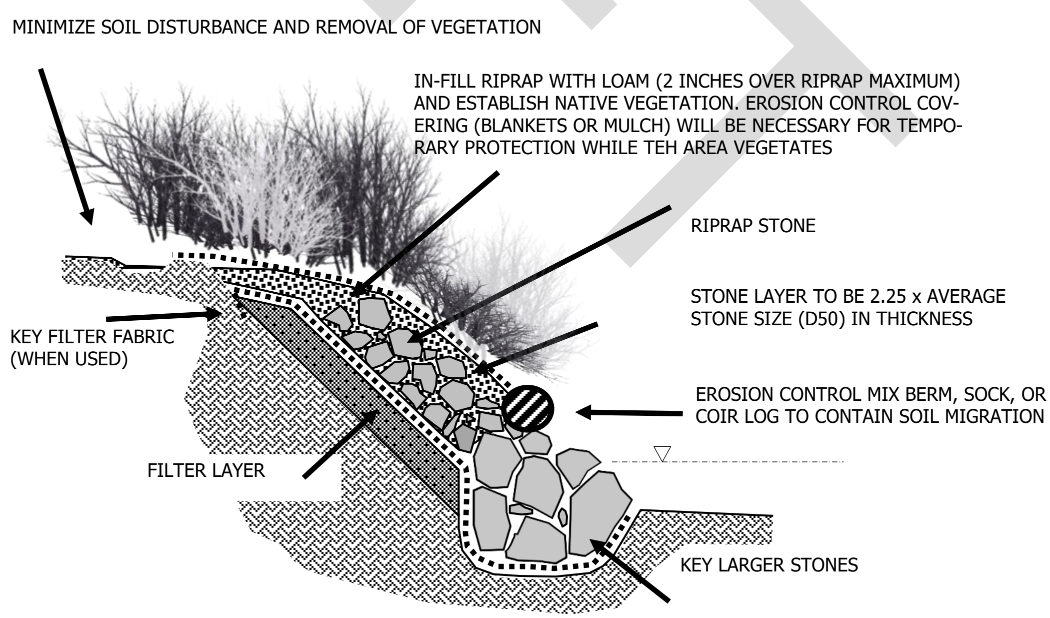
Brush mattress diagram



"Dirty riprap" & infilled riprap with vegetation **(see *** for variations)**

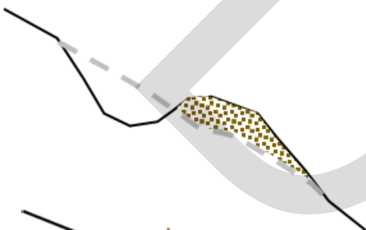
Riprap stone can be a useful for preventing bank erosion, and there are several methods to incorporate vegetation and habitat elements into the design. Adding vegetation to riprap stone speeds up the natural revegetation process and improves the overall strength of the project.

Instead of using bare riprap stone, a coarse gravel made of the riprap and other well graded materials that include some soil and/or erosion control mix (dirty riprap) can help provide a medium to more quickly establish vegetation. Similarly, well-graded riprap stone placement can have mulch, soil, or other media infilled between the riprap voids which provides a medium for natural vegetation.



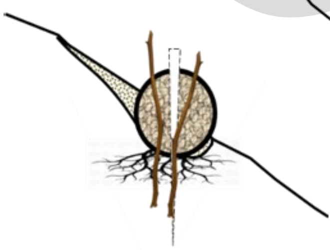
Slope Interruption

Slope interruption slows water flowing down the bank by installing features level across the slope. There are many ways to use this concept, but they all work in a similar way to help moderate water's power to erode. The basic concept is to avoid straight flows down the bank, and instead, continually turning that flow into a sheet or encouraging infiltration of water through the installation of simple devices kept level and following the elevation contour to capture and slow water.



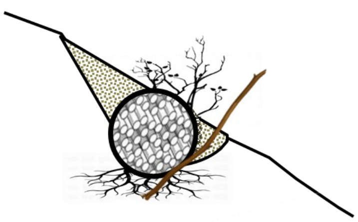
Swales & berms

Swales (depressions built into the ground) or berms (material filled on top of the ground can be effective at slowing water



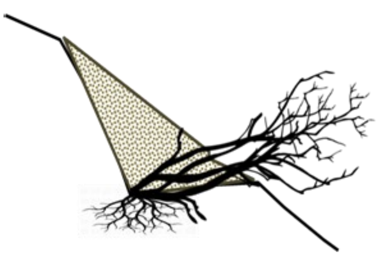
Coir logs & log sills

Staked coir logs and anchored log sills can be used as slope interruption with minimal disturbance of the underlying soils. Coir logs can also be seeded or used in conjunction with live staking.



Fascines

Fascines can be installed in a trench or filled behind in limited situations These fascines can be placed in a level trench so the fascine barely extends above ground so water will be captured in the stable living trench.



Dense contour live staking and living brush

You can apply the dense toe staking concept on the bank as well. Install live stakes in multiple rows approximately 1 inch apart. These should be roughly level and on-contour. See *** for more detailed information.

Living wattles

Living wattles are made of live stakes and live whips woven together into small fences. Wattle fences are not more than 6 inches in height and will need soil infilled behind to give each living branch something to root in to.

Groundwater and Soil Saturation

One overlooked contributor to instability is groundwater. Along shorelines, it is common in Maine for groundwater to seep out and become surface water lower in the watershed. Saturated soil has less shear strength and as a result, can be very hard to stabilize directly. In riprap designs, this is addressed by using geotextile filter fabric or crushed stone to encourage filtration without disturbing the soil.

Targeted stabilization

Small zones of groundwater instability and seeping can be targeted with stone stabilization. Using riprap or stone sparingly to address localized saturation instability minimizes impacts to the surrounding natural resources and is preferable to extensive slope armoring.

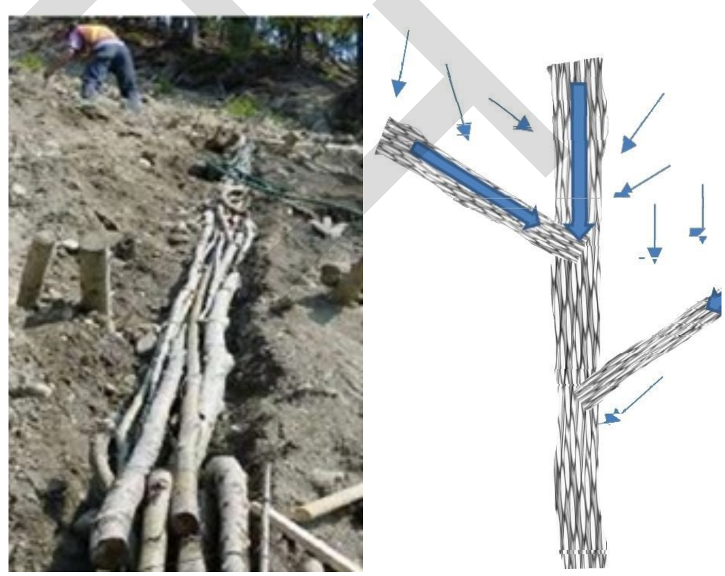
Groundwater interception & subsurface drainage

If groundwater is a major cause of instability, upslope interception can help to minimize the need or scope of direct bank stabilization. Upslope groundwater interception techniques direct sub surface water to infiltration sites where it can drain properly rather than seeping out of the bank. Concentrated flows have energy that should be dissipated before they reach eroding banks.

Living pole drains

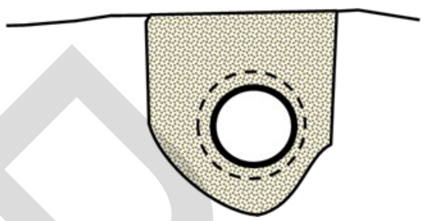
Bundles of live cuttings (often willow) are placed lengthwise on slopes that experience excess groundwater seepage or oversaturation due to poor soil. The bundled cuttings direct runoff to the base of the slope and once they take root, absorb excess subsurface water and filter sediments. Living pole drains are dormant poles placed in a trench to intercept groundwater and some surface flows. They can be left open but are often lightly covered to allow the voids to remain underground. The living poles will sprout roots and grown new stems while maintain the void space for water to move underground to another location.

Living pole drains diagrams



French drains

Small zones of groundwater instability and seeping can be targeted with stone stabilization. Using riprap or stone sparingly to address localized saturation instability minimizes impacts to the surrounding natural resources and is preferable to extensive slope armoring.



Note: Pipes concentrate moving water and can encourage erosion elsewhere. Additionally, a pipe may require additional permitting approval when discharged near or in to a protected resource.

Living brush layer toe

0623-2815-MTDC: Wilderness and Backcountry Site Restoration Guide

Brush layering is using living brush bundles in 3-6 ft lengths and burying the end sections into the bank with the branch ends facing out and building the atop it. Brush layering is typically used in conjunction with encapsulate soils lifts or other grading/filling work as the technique requires backfilling over the brush, which will require additional protection. Brush layers can also be installed under a riprap toe layer to provide additional wave/flow attenuation at the bank to reduce erosive forces and provides good habitat connection between the land and water.

NOTE: When groundwater is intercepted upslope of the embankment, that water will be directed somewhere else. Outlets for living pole drains and stone will likely be slow and cold, while drains using pipes may have more energy. Consider where these drains will outlet and whether additional energy reduction techniques may be necessary to prevent erosion somewhere else.

Filter Layers: Groundwater & Saturation

Filter design

A filter is a transitional layer of material placed between the underlying soil and the riprap or other erosion control treatments, typically composed of gravel, small stone, fabric, or living vegetation The filter prevents the movement of the fine soil particles through voids in the stone, provides more uniform settlement and allows of hydrostatic pressures within the soils to be relieved. A filter should be used whenever the riprap is placed where ground water, saturation, or significant subsurface drainage are present.

What does a filter layer do?

- Protects soil fines from movement of water through unvegetated riprap from wave action
- Allows groundwater and other water that may be present behind the riprap stone to drain away without losing fine soil particles through the stone

Synthetic nonwoven filter fabrics

Most filter fabrics used today are synthetic felt-like materials that have replaced the traditional granular filters used because they are readily available, easy to install, generally have good tensile strength and initial filtration. While there are benefits to such a permanent fabric installation and it serves the filter functions effectively, they do present potential problems and anecdotally have been tied to some riprap failures during severe storms if energetic water is able to get underneath the geotextile. Plastic-based geotextiles may also not be preferable in nature-based designs for other reasons.

Why synthetic geotextiles may not be the best option for nature-based designs

- Pores clog over time from biological action in the surrounding soils
- Can trap water behind the fabric when not properly keyed at the top and cause large riprap stones to roll or bounce off the shoreline
- Inhibits growth of vegetation and prevents roots of any vegetation growing in the riprap from connecting soil layers
- Potential contribution to microplastic pollution
- Bacterial activity within the soil or upon the filter can control the hydraulic responses of a fabric filter system

Long term biodegradable blankets

For stabilization projects with riprap stone and vegetation, long term biodegradable filter blankets may be considered. Materials such as coconut coir have a long life span and can last several years before breaking down. The filter fabric protects the underlying soil until the newly planted vegetation takes over that role once mature. It is recommended that sand be placed behind any filter fabric to extend the function and help prevent clogging the pores with fine sediments.

Filter gravel (granular filters)

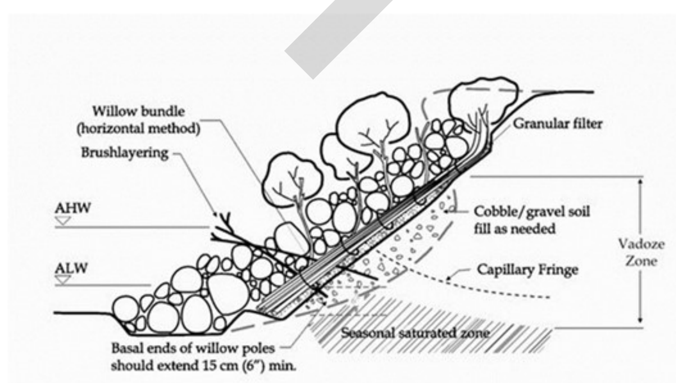
Typical riprap installations use granular filters as a transitional layer between the riprap and underlying soil. In some cases, further analysis of the granular filter layer may be warranted. Guidelines for granular filter design are found in HEC-11.

Example Granular Filter Gradation*

Sieve Size	% Passing
25 mm (1 in)	100
19 mm (3/4 in)	90-100
10 mm (3/8 in)	40-100
No. 4	25-40
No. 8	18-33
No. 30	5-15
No. 50	0-7
No. 200	0-3

Brush mattress (living filters)

While a brush mattress can be used as a standalone tool, it can also function as a filter layer behind stone. Living dormant poles and brush are arranged along the eroded or graded slope for maximum soil contact. Riprap stone can be placed on top of this living brush, resulting in a vegetated riprap stabilization with a living filter layer.



Source and Severity of Erosion

Toe Erosion

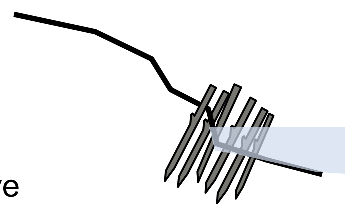
Erosion at the Base of the Bank

Depending on the severity of erosion, there are several techniques that can be used to protect exposed banks from the forces of wave and ice. The toe of a slope supports the weight of the soil above and behind it and is critical to the area's overall stability. By addressing signs of toe instability, more elaborate and costly shoreline projects can be avoided. Toe erosion can be slowed or corrected by diffusing oncoming water energy, increasing nearshore vegetation, sills, and through other methods of deflection. When working with extreme toe erosion or high-risk sites, it may be necessary to anchor the toe of the slope to prevent sliding and rotation of embankment soils. Embedded toe stones can be utilized as a standalone anchor instead of covering the entire bank with riprap.

Living Toe Protection

Dense toe live-staking

Dense toe live-staking is a technique where several rows of live-stakes are installed in tight bunches, typically about 1 inch apart. The live stakes grow into a mat of intertwined root systems which stabilizes the soil. This method creates extra roughness along the eroded toe and disperses oncoming wave action.



Living fascine toe protection

Fascines are long, cigar-shaped bundles of living brush held together by wire or twine. They can be installed in front of an eroding toe or packed within an eroding undercut to improve soil stability. Fascines should be staked in place with live stakes or untreated wood.

Living brush layer toe

Brush layering uses living brush bundles, of 3-6 ft in length, and buries the basal ends into the bank with rest of the branches protruding out. Brush layering is typically used in conjunction with grading/filling techniques as it requires backfilling over the layered levels of brush. Brush layers can also be installed beneath a riprap toe to reduce erosive forces and improve the habitat connection between land and water.

Biodegradable toe protection

Coir logs

Coir logs (coconut fiber logs) have been used successfully in many settings, one being as a long-lasting biodegradable toe protection. Coir logs last for several years, even when saturated, and are a great media for shoreline locations. Coir logs are pre-manufactured and can be seeded with native seeds to create living toe protection that will increase in strength over time. Coir logs can be placed in front of an eroding area or packed into an undercut bank. They are typically secured using hardwood stakes.

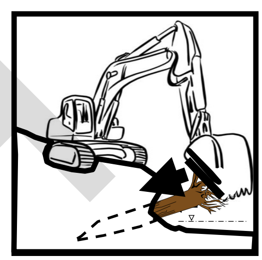
Natural media filled socks & bags

Natural media filled socks and bags can be used in a similar manner to coir logs in front of a toe or packed in an undercut. Biodegradable erosion control socks or bags filled with untreated woody material, cobbles, oyster shells, coarse gravel without fines, and other natural material mixes can be filled in-place or sometimes purchased in pre-made units. Socks and bags can also be made on-site by filling sock material, burlap bags, or creating a tube out of heavy coir fabric (similar to an encapsulated soil lift), rolled and stitched together using binding material. These socks also need to be secured using hardwood stakes or another appropriate method.

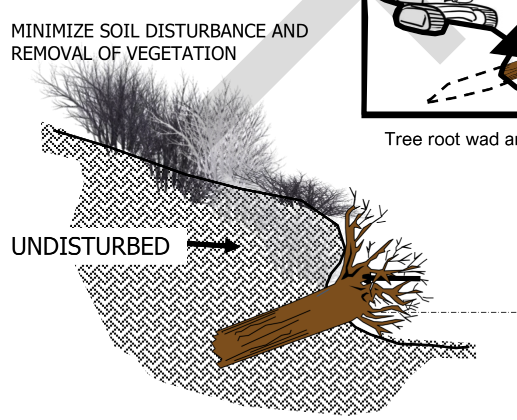
Anchored Woody Deposits

Root wad toe protection

The root wads from large trees (often hemlock) with a large section of trunk still attached can be buried or pushed into an embankment with the roots pointing out. Root wads at the toe of the bank provide significant wave protection and can even help sediment accumulate, reversing the erosion problem. This technique is different from root wad deflectors which are typically used in riverine systems (see appendix).



Tree root wad and trunk



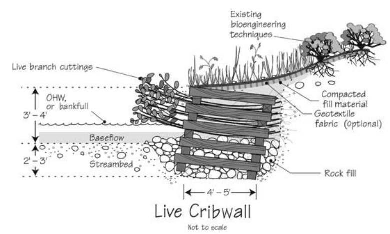
Log sill toe

A log sill is essentially the use of a log or fallen tree as a toe treatment. Logs can be placed into undercuts or anchored at the toe of the slope using appropriate anchoring techniques for the location. They can also be used as slope interruption or benching with minimal soil disturbance. Log toe sills can help to encourage vegetation establishment by preventing fine sediment from migrating beyond the toe of slope. Log sills typically consist of a single log placed in to or along the eroded area, however more engineered methods can be employed for energetic locations such as manufactured logs jams and living crib toes.

Owls Head, Maine.

Living crib toe

A living toe crib is a smaller version of a living crib wall, typically consisting of only one or two layers of stacked parallel logs which are attached to the embankment. Living crib toes are filled with gravel, stone, or soil, and are heavily vegetated (commonly brush layering and live staking) to provide a long-term stabilization. Living crib toes can be useful on steeply eroded areas where the toe support is lacking and there is a threat of entire slope failure, or where the slope can not be cut back to allow other techniques.



https://www.fs.usda.gov/t-d/pubs/htmlpubs/htm06232815/longdesc/fig3_68.htm

Manufactured log jam

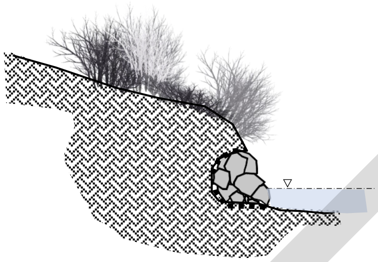
Manufactured log jams are man-made piles of interconnected trees placed along a bank or within a resource to mimic a natural log jam. These structures vary in size and location depending on the desired outcome. Some slow water along the bank to prevent erosion and provide habitat for fish and wildlife, while others modify river flows to improve habitat diversity. Manufactured log jams are typically tied together and held in place with supporting piles, anchors, cables, and other elements.

Ammonoosuc River in Starks, NH .Field Geology Services

Log Skids

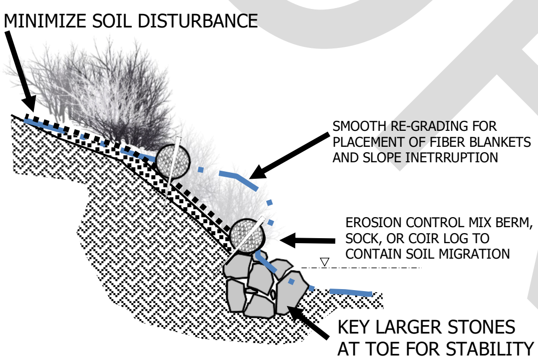
Log skids help to protect vegetation and soils from ice scour. In areas of ice action along the shoreline, anchored log skids placed up the bank with their bases anchored to prevent movement. The logs help the ice skid up the bank without ripping out newly planted vegetation. Many native shoreline shrub species are adapted to ice and will grow more vigorously if the stems are broken over winter while they are dormant. Log skids help protect the toe of the slope from direct ice pushing/heaving and can provide some bank protection as well. This practice can be combined with many other tools including brush mattresses, stone toe, fiber blankets, and slope interruption.

Structural and Green-Gray Options



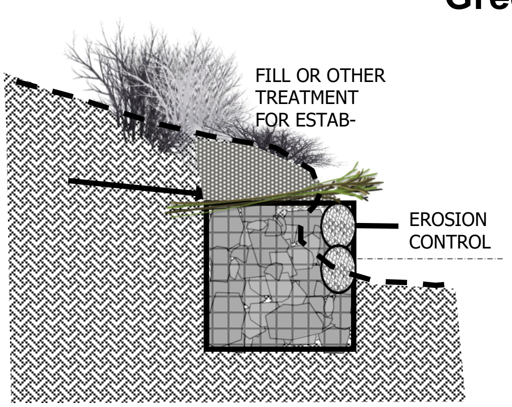
Stone packed undercut

Similar to other toe protection methods, riprap stone or large cobble can be packed into an undercut area if the bank above remains stable. Packing mixed size stones into the undercut area can be an effective was to prevent further undercutting and potential slumping of the bank as the soil weight becomes unsupported. Primarily addressing the undercut area prevents unnecessary grading or damage to the remainder of the embankment.



Anchored riprap toe protection

When the embankment is to be regraded or there is worry about rotation or slumping soil, trenched riprap toe protection can be employed similar to standard riprap designs, however it can be used with other vegetative methods without riprap on the bank.



Green gabion toe

Gabions are wire cages filled with stone material that are typically wired together to create a structure. Traditional gabion walls create hardscapes which discourage plant growth and diminish the available shoreline habitat. However, green gabions are a viable alternative method for extremely unstable toe areas. Green gabions are a variation of a gabion that uses additional media of fabric to allow the growth of vegetation. When used as toe protection, green gabions are entrenched at the base of graded slopes to provide support and protection in extreme environments.

In Resource and Flow Attenuation Tools

Some practices utilize a more indirect method of shoreline protection by altering the water's energy where it interacts with a shoreline. Since these techniques require work within a resource as opposed to adjacent to it, they typically fall under a higher level of permitting. That said, these in-resource actions can provide long term stabilization by preventing the bank form eroding in the first place, sometimes even allowing sediment to deposit where it had previous eroded.

Fringe wetlands & marshes

Aquatic vegetation can have an affect on the amount of wave energy that reaches the shore. Restoring fringe wetlands and marshes creates a buffer between erosive forces and the shoreline. Sometime logs or oyster shell sills may be necessary to help reestablish these habitats and help hold fine sediments in place.

Root wad deflectors

Root wad deflectors are a variation on root wad toe protection. The tree roots are placed into the flow of a river or stream, placed facing upstream to deflect the fastest moving water toward the center of the channel. This can be an effective treatment for erosion along the outer bend of a meandering river channel where the energy is directed at the outer bank in the bend.

Chop & drop

Ammonoosuc River in Stark, NH

Chop and drop is a forestry technique that improves stream habitat by adding woody material directly into the resource. The addition of wood to streams is encouraged by Maine fisheries biologists and mimics the natural forest and stream interactions. While not intended to prevent erosion, the technique can mimic the effects of fallen trees in strategic locations, buffering the shoreline and enriching the surrounding habitat.

Flow deflection: Veins, weirs, & groins

Veins, weirs, and groins are structures placed in flowing water to alter the direction and reduce the energy of the water. These techniques are primarily used in rivers and streams but can be seen in other environments as well. Veins weirs and groins aim to slow erosion by redirecting the flow away from the affected bank. They can also be used to help improve stream habitat for fish and other aquatic organisms. It is important to understand the desired response of the stream when attempting to conduct these types of projects to prevent unintended damage elsewhere.



Manufactured reefs & wave attenuation devices

Manufactured reefs have been used across the globe to improve aquatic habitat diversity and to attenuate wave energy before it breaks on shore. The materials used for wave attenuation structures and their habitat value ranges widely depending on the location and goals of the project. Examples include oyster reef structures, concrete wave attenuation structures/reef balls, floating wetlands, and in-resource woody deposits/log jams.


Atlaticfishhabitat.org

Sand dune sediment capture (Christmas trees)

Sediments in sand dune systems migrate easily from the action of water and wind. Providing roughness with the use of woody materials such as trees can naturally accumulate sand on land similarly to the way roughness can prevent erosion in water. One way that has been successful in Maine is the use of anchored, discarded Christmas tress. These trees are typically collected at a central point for installation. Note that since these trees are a waste product, there may be additional DEP permitting for the beneficial reuse of these materials.

Height & Slope Risk

When slopes experiencing instability or erosion become too steep, there can be increased risk of sliding or other slope failures. While stable slopes can persist at slopes greater than 1:1, slopes steeper than 1:1 tend to be much more difficult to stabilize. When steeper sites have a healthy buffer, mixes of mature vegetation, trees and otherwise don't show signs of soil movement, it may not be necessary to disturb this stable slope to complete a shoreline stabilization project. Once the slope is disturbed or graded, it requires much more vigilance, oversight, and maintenance to restabilize the area.

Regrading slopes inherently increases the erosion risk in the short term, so good temporary erosion control practices like mulch, blankets, and other protection of the soil is necessary. When working with nature to control erosion, it's important to recognize what is working on the site and make efforts to prevent unnecessary soil disturbance. For any element of a stabilization, minimization of disturbance and impact is key –only conduct these impacts when they are necessary.


Bank failure . Photo: Pete Slovinsky, Maine Geological Survey

Options for dealing with steep and high slopes

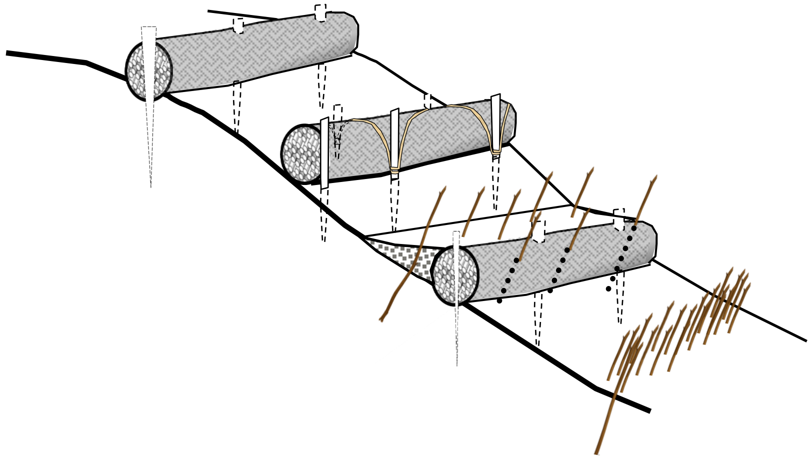
Slopes over 1:1, especially when subjected to toe erosion or other additive factors such as groundwater and overland flows, can be difficult to stabilize using only vegetation. When dealing with severe slopes, establishment of adequate toe treatment is important to be able to support the bank behind it as well as protect that bank from new to erosion. Sometimes dealing with just the toe will give enough protection to allow vegetative establishment, but sometimes additional slope modifications or treatments are necessary. Where possible, regrading the slope should be avoided, but where it is necessary for the stability of the rest of the bank, there are several ways to use nature-based tools to provide stabilization.

1. **Treat the toe & protect the slope (establish vegetation)**—while difficult, there are methods to vegetate steep, eroding areas. Various seeding, hydraulically-applied mulches, bioengineering, and live stake options have ben successful in certain locations.
2. **Rebuild the slope from the toe**— in rebuilding an embankment, there are some nature-based tools that can be utilized to help deal with steeper slopes, while still providing habitat
3. **Protect the toe and regrading the exiting slope back**— while slopes are traditionally graded smooth, other variations can be used to mimic more natural shoreline and habitat features, while increasing erosion resistance.

Techniques with no or minimal soil disturbance

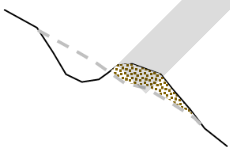
Slope Interruption Practices

While slope interruption practices are used for erosion protection of a slope with exposed soil, they can also be employed as a method to prevent unnecessary grading of a steeper slope, keeping the natural soil structure and roots in place to the maximum extent, allowing the slope to remain as is. Examples of slope interruption that can help add stability to s steep slope include coir logs with vegetation, contour fascines, wattles, and more. See the Slope Interruption Practices on Page *** for additional options.



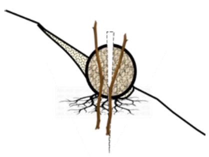
Slope interruption

Slope interruption is essentially slowing the water flow coming down the bank by installing features level across the slope. There are many ways to use this concept, but they all work in a similar way to help moderate water's power to erode. The basic concept is not allowing water to find a straight path down the bank; instead, continually turning that flow back into a sheet or encouraging infiltration of water through the installation of simple devices kept level and following the elevation contour to capture and slow water.



Swales & berms

Swales (depressions built into the ground) or berms (material filled on top of the ground can be effective at slowing water

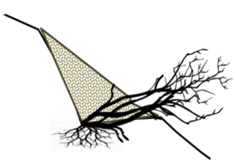


Coir logs & Log Sills

Staked coir logs and anchored log sills can be used as slope interruption with minimal disturbance of the underlying soils. Coir logs can also be seeded or used in conjunction with live staking

Fascines

Fascines can be installed in a trench or filled behind in limited situations These fascines can be placed in a level trench so the fascine barely extends above ground so water will be captured in the stable living trench.



Dense contour live staking and living brush

You can apply the dense toe staking concept on the bank as well, just install live stakes in multiple rows approximately 1 inch apart. These should be roughly level and on-contour. See *** for more detailed information.

Living Wattles (micro-terracing)

Dense live staking

Using live stakes in the eroded bank with very tight spacing (1-2 inches), covering all the eroded areas.

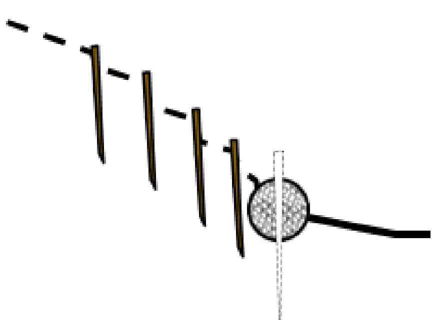
Pilings/vertical slope support

Pilings are logs or other materials driven vertically into the ground deeply to provide some support to the weight to the slope behind it. Pilings can be driven deeply into the soil where ledge is not close to the surface or where the method of installation could compromise other unstable soil conditions (e.g. vibration in marine sediments can cause liquefaction of soil). A log sill is sometimes placed behind the piling to create a small slope bench without overly disturbing the soils below. Pilings may also be used as part of other larger projects like manufacture log jams, slope benching, and wattles.

A living version of pilings using **live poles** can also be effective. And integrated with other live stake techniques like living wattles.

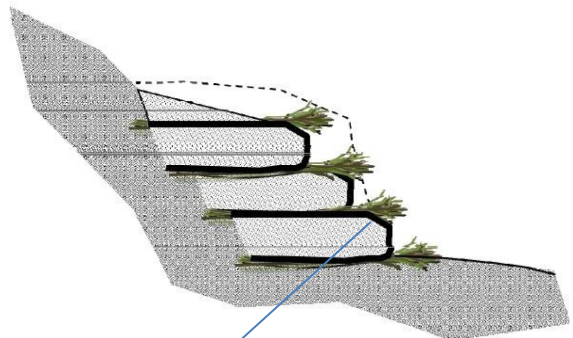
Living wattles

Living wattles are a live-staking variation where vertical stakes are placed 6-12 inches apart along a level contour on the slope. Long living whips or poles are then woven between the branches to create a short fence (less than 6 inch), similar to weaving a basket. Once complete, the wattles are filled behind to create small slope breaks (like terracing) that can be vegetated. The horizontal woven whips need contact with the soil behind them to successfully root back into the newly added soil. All the living material will grow and create a strong matrix of roots and stems. This can be done on a graded slope or added to unstable areas without pre-grading the area.



Encapsulated soil lifts

Lifts of soil material contained within heavy fiber blankets such as heavy coir. Soil lifts are created by laying the fabric on the bare ground, filling the landward side with 12-14” of soil material, and folding the fabric back over that soil and anchoring with wooden stakes. The process is repeated going up the slope, each lift is set back to create a protected soil envelope for vegetation to link together. This practice is commonly joined with brush layering and seeding.



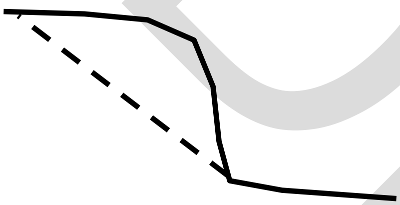
Brush layering

This variation on live staking uses bundles of live cuttings and untrimmed brush placed between lifts of soil to stabilize the bank and provide protection from wave spray and high water flows. The cuttings are set into the bank and layered with soil to create a the desired slope angle.

Regrading over-steepened Slopes

Surface roughening & reversion

Surface roughening refers to creating a rougher surface on the bank to help slow down water. This is most often done in the form of tracking (for large slopes), reversion, loosening soil, adding a rough covering (Erosion Control Mix), or slope interruption practices, but the concept can be expanded when trying to further mimic the natural landscape elements along a shoreline. Reversion is a light soil grading that does not disturb the soil structure but allows the existing seeds and roots to remain in the soil and resprout to more quickly revegetate.

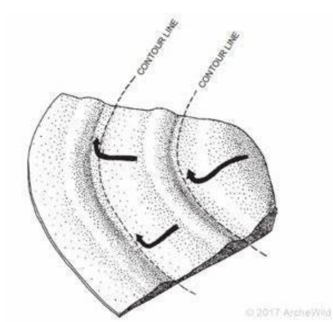


Cutting back slope - smooth grading

Slopes are commonly regraded back when they exceed a 1:1 slope. Smooth regrading is used for areas where fiber blankets will be placed for erosion control, where filter fabrics or other filter layers may be installed, or for maintaining sheet flow across the slope. These slopes will have smooth, consistent soil grade. When blankets aren't used, basic surface roughening or tracking can help slow water down as a temporary erosion control addition.

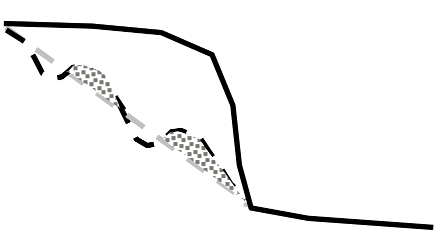
Benching/terracing

Benching and terracing are similar practices where the slope can be eased in small sections to better allow plants to grow, and water to infiltrate. Since benching and terracing can create more vertical faces that might be problematic for wildlife movement, these benched areas should be of minimal height and always be incorporated with dense vegetation.



Contour Swales

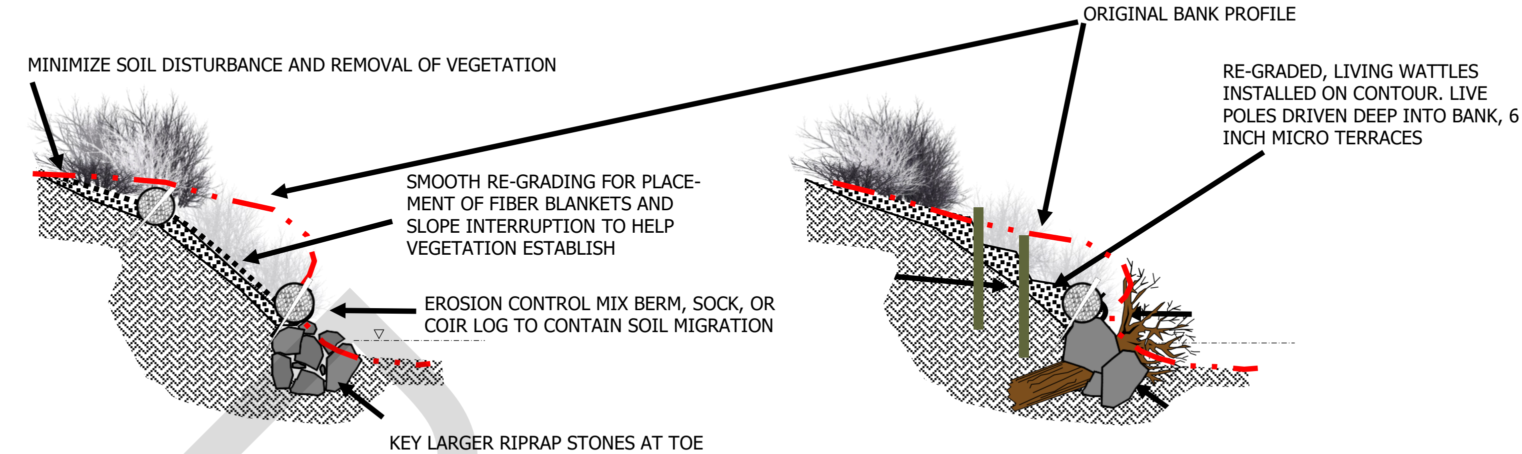
Contour swales are similar to benching where small swales are installed across the slope to capture and infiltrate flows coming down the embankment. More on this technique can be found in the "Slope Interruption" section.



Pit and Mound Grading

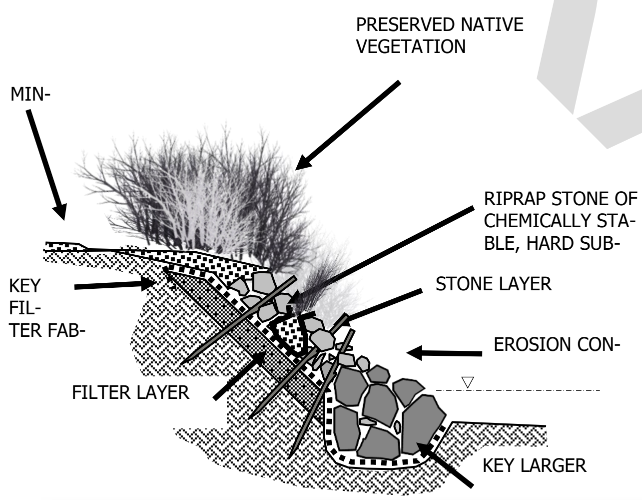
This technique involves either matching the irregular topography of the surrounding untouched areas, or digging small pits across the slope in an alternating pattern that doesn't allow water to find a pathway down the slope. Each pit can collect water and seeds that can help create better growing conditions for diverse vegetation.

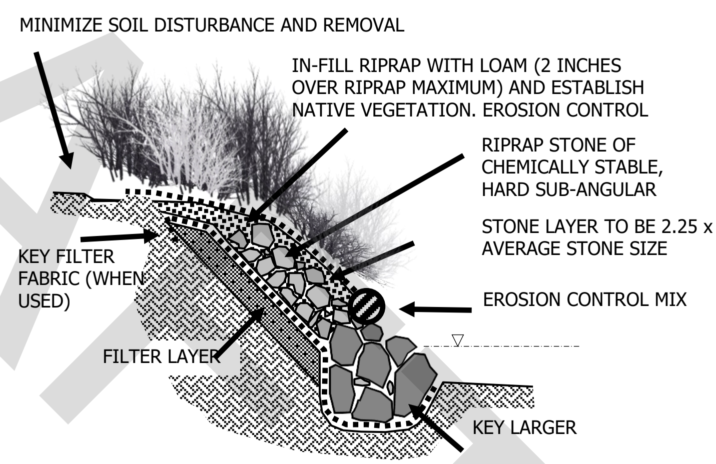
Riprap slopes with habitat considerations

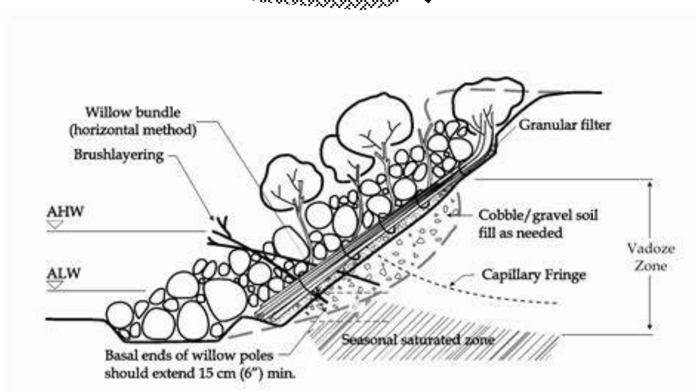


Two variations of toe protection shown two grading options. LEFT: Anchored riprap toe with smooth regrading, erosion control blanket (heavy coir) seeded underneath with native seeds, could easily be live-staked or planted in to, slope interruption. RIGHT: Anchored root wad toe protection with riprap wedged between with living wattles with less than 6 inches of soil infilled behind. Any bare soil must be protected with mulch or blankets while seed establishes. This grading method can also be easily live staked or planted with more mature vegetation to speed up the process.

Live-staked riprap



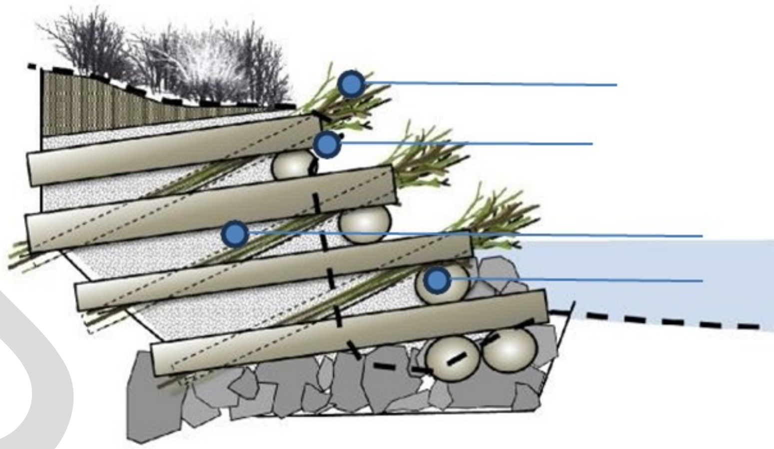




Riprap over Brush Mattress

Living Crib Walls

An option for higher energy sites. Sets of large logs are placed into the bank of a slope and layered in a grid pattern parallel to the water and tying back in to the slope. This type of living structure creates a cribwork that can be filled with coarse gravel or other stone and soil mixes to provide a media for live cuttings and **brush layers** to grow and strengthen the integrity of the slope while being protected by more structural elements. This practice may best be used in high energy flows or where wave action can be more severe and the bank cannot be cut back easily or there are structures that may prevent other re-grading options.



Sunday River in Newry, ME . Field Geology Services

Joint Planting Notes

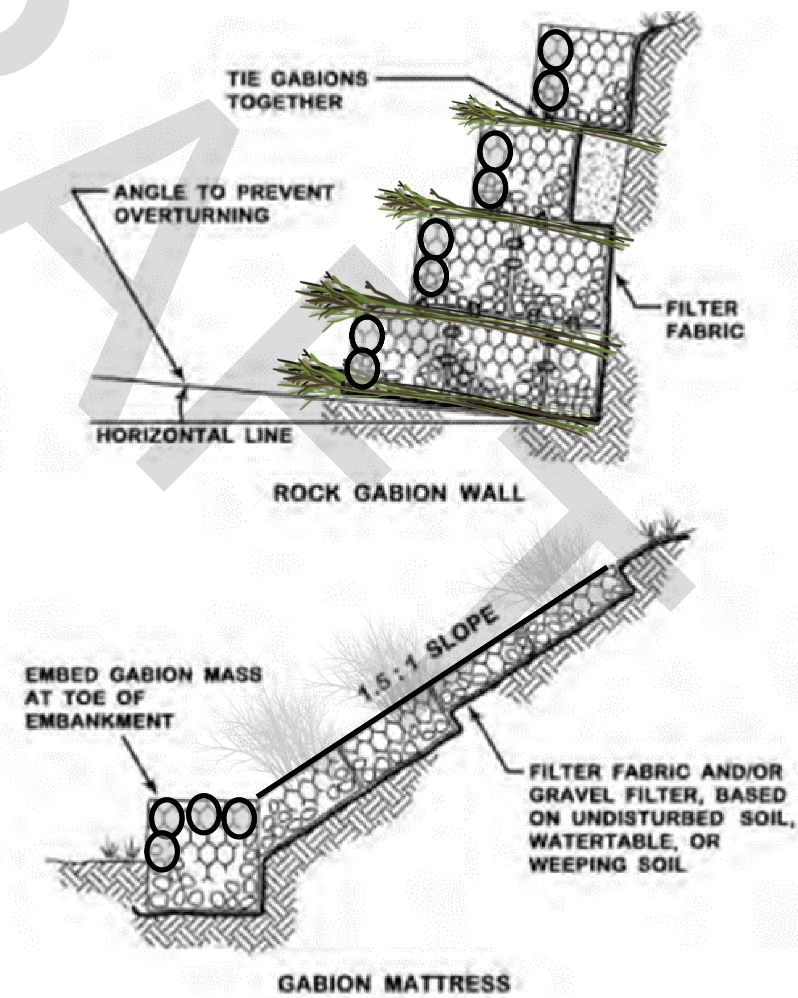
Living Crib Walls are composed of large logs set into a trench dug below the natural stream bed. The logs are set at an angle into the slope and are covered with more logs running perpendicular to create a grid. The quadrants are filled with rock up until the normal riverbed height and pinned together with rebar. Live stakes lie on top of the rock fill with their basal ends touching the back of the bank. The cuttings are covered with backfill and compacted. The process is

Green Gabions Walls & Mattresses

Gabions are wire baskets filled with stone, linked together, and stepped upon each other to support and protect steep or high energy slopes as a form of wall. Additionally, they can be used in the form of a single row for toe protection, or laid flat on a graded slope similar to riprap revetments, all using smaller stone. While they are historically not a habitat-friendly practices, installation and materials can be modified to improve the habitat value. During construction, soil can be packed behind the stone baskets and live stakes added so that they protrude from the front of the baskets. The soil and cuttings improve the strength of the gabions, and provide opportunity for habitat growth. While this may be more disruptive to the shoreline/water interface and habitat when installed as a wall, alternative layouts can also minimize this impact.

Several methods exist to vegetated gabions including using coir logs, socks, natural fiber materials wrapped or installed into the wire mesh. Combined with stone gradations that trap sediments or soil elements, create favorable growing conditions. Green gabions can be combined with seeding, live stakes, live brush, and overhanging vegetation from a dense upland buffer

Green gabions are likely best use for very steeply eroded areas where the slope cannot be cut back and where native soils and energy levels make vegetating the area unlikely by itself.



O Overland Contributions from Land Use

Additional guidance for these land use conservation practices, including info sheets, guides, and manuals can be found at:

https://www.maine.gov/dep/land/watershed/materials.html

Prevention – Look Up!

Prevention is always the best tool we have. While we may not be able to change all the forces that shorelines are subjected to, the way the land directly adjacent to the shoreline is used and maintained has an impact on the slope stability. Sometimes all it takes is a few small behavioral changes to turn around a developing erosion issue. Before embarking on a major alteration to the shoreline, the first step should be examining and minimizing as many contributions from the use of the land as possible.

Yard maintenance/Lawns and Gardens

- Refrain from raking or removing organic duff or vegetation away
- Refrain from yard waste or lawn clippings over the bank (clippings and extra material can smother growing plants if layered too thickly)
- Plant only native vegetation
- Don't treat the shoreline like a managed garden
- Cover bare soils with erosion control mulch
- Minimize or reduce lawn area and maintained areas near the bank
- Limit mowing frequency near the shore or set mower height higher

Accessways/Pathways

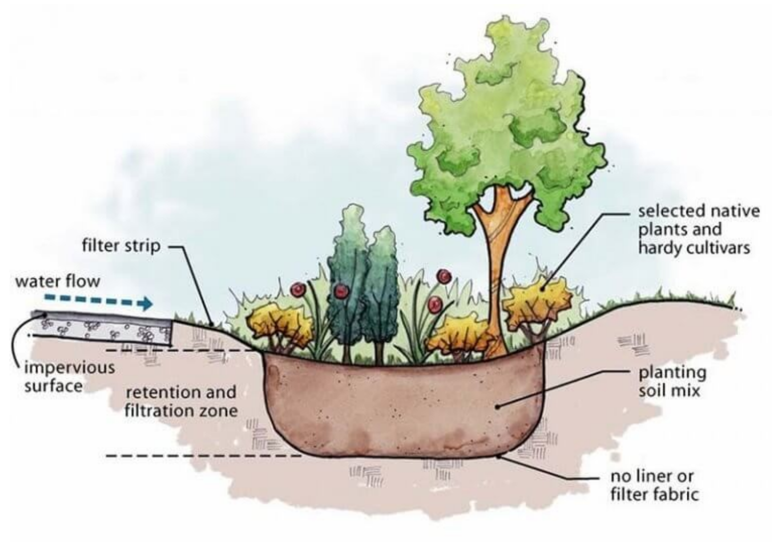
Properly designed pathways direct foot traffic, absorb water, reduce the rate of flow, and protect soil. Pathways can also reduce the potential for erosion and minimize the amount of pollutants flowing from your property into local

Ideally, paths should be no more than 3-4 feet wide. The walking surface should be covered with 3-4 inches of material such as Erosion Control Mix, pine needles, bark mulch, crushed stone, wood chips, or other material. This will define the path, guide foot traffic, and reduce soil erosion. Paths should be meandering around larger vegetation and provide opportunities for runoff to disperse into adjacent vegetation. Check on these accessway practices:

- Define and stabilize pathways
- Limit access to more stable areas of shoreline
- Cover pathways with mulch
- Make pathways meander
- Use infiltration steps in steeper areas
- Don't store docks on the shoreline or bank, as it disturbs vegetation growth

Houses & Roof Runoff

- **Dissipate concentrated water energy**—water leaving roofs, gutters, and drains will have some energy when they first leave the confined channel or pipe. Directing any channelized surface water flows toward the embankment may lead to overland erosion problems if not managed.



- For direct roof runoff, erosion and energy dissipation could be as simple as installing **dripline trenches** under the eaves, while houses with gutter downspouts may need additional energy dissipation. When located properly away from unstable shoreline areas, **rain gardens** (depressions for capturing overland water that use wetland and water-loving plants along with infiltration to absorb water and energy.

Septic Systems & Other Water Sources

- Regular maintenance of septic systems is not only good for human health and water quality. The amount of water contributions from subsurface wastewater systems can add up, especially if they are used contrary to their seasonal design.
- Other water-using activities like sprinkler systems should also be carefully monitored for leaks and runoff.

Driveways, Patios, & Other impervious surfaces

Water coming off of driveways, parking areas and other impervious surfaces can contribute high volumes of overland water flows toward a bank very quickly.

- Prevent/divert flows using water bars, infiltration swales, rain gardens
- Minimize impervious surface area, especially near the top of the bank
- Break up flows with buffer vegetation & duff
- Use "permeable" pavers and grid materials that allow for vegetation to grow beneath driving/parking surfaces

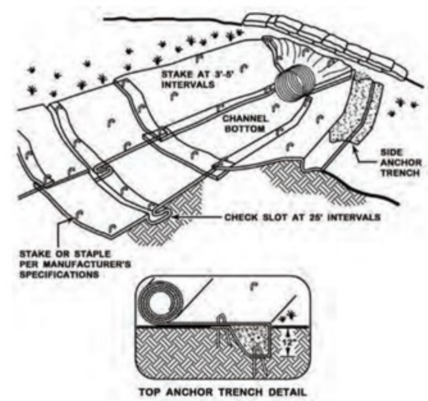
(NOTE: despite being more permeable to stormwater, many kinds of porous pavers and combinations may still be considered structures or impervious surfaces, depending on the regulation and jurisdiction. While they can be a better option than completely impervious surfaces, they often need special base preparation and may require maintenance to continue to function properly. They should be located away from shoreline areas and embankments, when used.)

Erosion control in stormwater ditches

Water that is allowed to concentrate will have power to erode soil. When determining sources of erosion, you may find areas where water can concentrate and flow down the bank from the upland. Water from roadways and other impervious surfaces should be spread out where possible, but often there are ditches or other stormwater drainage features to content with. Because of the increased risk of erosion, it is best practice for any constructed ditch to be vegetated, or protected with a mix of vegetation and riprap in steeper areas and larger watersheds. While the ditch is not a protected resource, the stormwater can be a source of shoreline erosion where (and how) it flows into the resource. The riprap in ditches can also can add heat to stormwater runoff, which can indirectly impact water quality of our resources. Below are some additional nature-based stabilization methods for stormwater ditches and outlets:

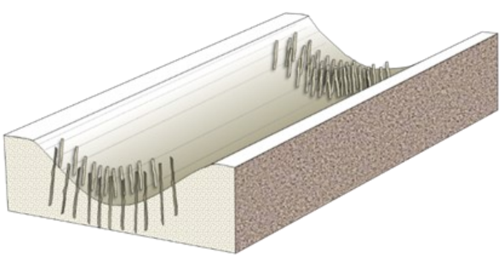
Temporary Erosion Control Blankets

Any stormwater channels/ditches should be vegetated when possible. To help vegetate the soil in these difficult flow areas, the use of fiber blankets and a variety of similar biodegradable mats can be used to protect the soil and seed while germination occurs. There area wide variety of strengths and materials available for these blankets, to the extend possible, use of blankets that are fully biodegradable and do no contain plastic element is recommended. The fine plastic netting from some blankets can entangle wildlife, end up in waterways, or even just remain in the soil for decades.



Turf Reinforcement Mats & grids

Turf Reinforcement mats (TRM) and grid products are typically extremely stong plastic-based products that are placed similarly to biodegradable blankets, used as slope stabilization within the soil, or sometimes as encapsulated soil lifts. These materials bind with the plant roots and stems across the site, essentially using the strength of all the roots across the slope. These materials allow for vegetated surfaces to be maintained in steep slopes and erosive channels. TRMs can be a useful tool when necessary; however, there is concern over the use of persistent plastic materials along sensitive resources. Where possible other biodegradable/natural methods should be considered first.



Living Check dams

Living check dams are velocity-reducing structures similar to the common stone check dam used in road ditches. This is a variation of dense live-staking where multiple rows of live stakes are installed close together in succession to slow channelized water.

Vegetated stone/riprap channel

In moderately sloped stormwater ditches where a geotextile filter fabric is not used, riprap or other stone can be placed over newly-graded channels that has been seeded. Provided the stone is not too thick, the seed will sprout between the stones and help lock the channel lining together, while providing some shading and cooling to the stone. This can be useful where there is concern of thermal dams or heated water entering streams, which can be harmful to fish and aquatic life, especially during stressful summer months.

Maintaining natural hydrology

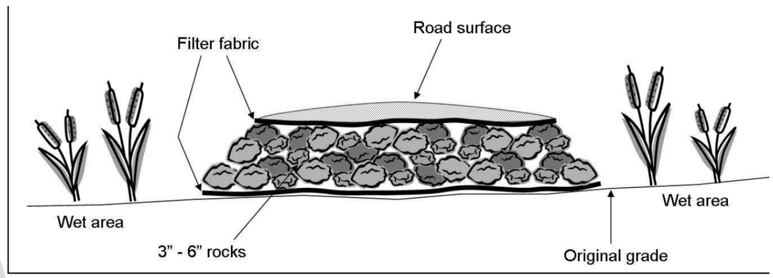
In an undisturbed forest, stormwater rarely has a chance to form channels, most precipitation is intercepted by the canopy, absorbed by the duff and soil & vegetation, or is unable to run-off due to topography. This helps the water reach resources without causing erosion, underground: slow and cold.

Wherever possible, ditches should not directly discharge to resources as concentrated flow. The flow should be released as sheet flow to the extent possible over a wider area to promote infiltration and prevent the water from having enough force to erode the soil.

Ditch Turnouts

Ditches can be turned out in to forested areas (if done regularly in a ditch, there is no change in surface hydrology), so the water volume is split into sections and absorbed, reducing the need for a direct outlet to the resource.

Passing water naturally with rock sandwiches



Rock sandwiches consists of stones “sandwiched” between two layers of filter fabric, allowing water to pass freely through the spaces between the rocks, and therefore from one side of the road to the other. Rock sandwiches are typically used to allow groundwater flows or wetlands to maintain water flow under a round without concentrating it. They should not be used solely for regular surface runoff since winter ice can build-up and cause vehicular safety problems. This is not a concern for groundwater however, since it has latent heat which prevents freezing. These types of crossings keep water in the ground as much as possible and prevent concentration of flows like culverts would without disrupting the natural hydrology of the soils.

Outlets for runoff

Rain Gardens

Rain gardens are attractive and functional landscaped areas that are designed to capture and filter stormwater from roofs, driveways, and other hard surfaces. They collect water in bowl shaped, vegetated areas, and allow it to slowly soak into the ground. Rain gardens for single-family homes will typically range from 150 to 300 square feet, but even a smaller one will help reduce water pollution problems. For more concentrated flows, a stone energy dissipator can be installed just above the garden to slow the water and trap sediments.

Settling basins & plunge pools

When channelized stormwater flow enters a resource, it can bring pollutants like soil and hydrocarbons, as well as causing shoreline stability issues. Whenever possible, water from channels should be “turned out” into surrounding buffer areas to infiltrate. When working with turnouts or other outlets to resource areas, an energy dissipator like a level spreader, stone apron or settling basin can help infiltrate and slow down water before reaching the resource. Give that spread out water as much vegetated space as possible before entering the resource.

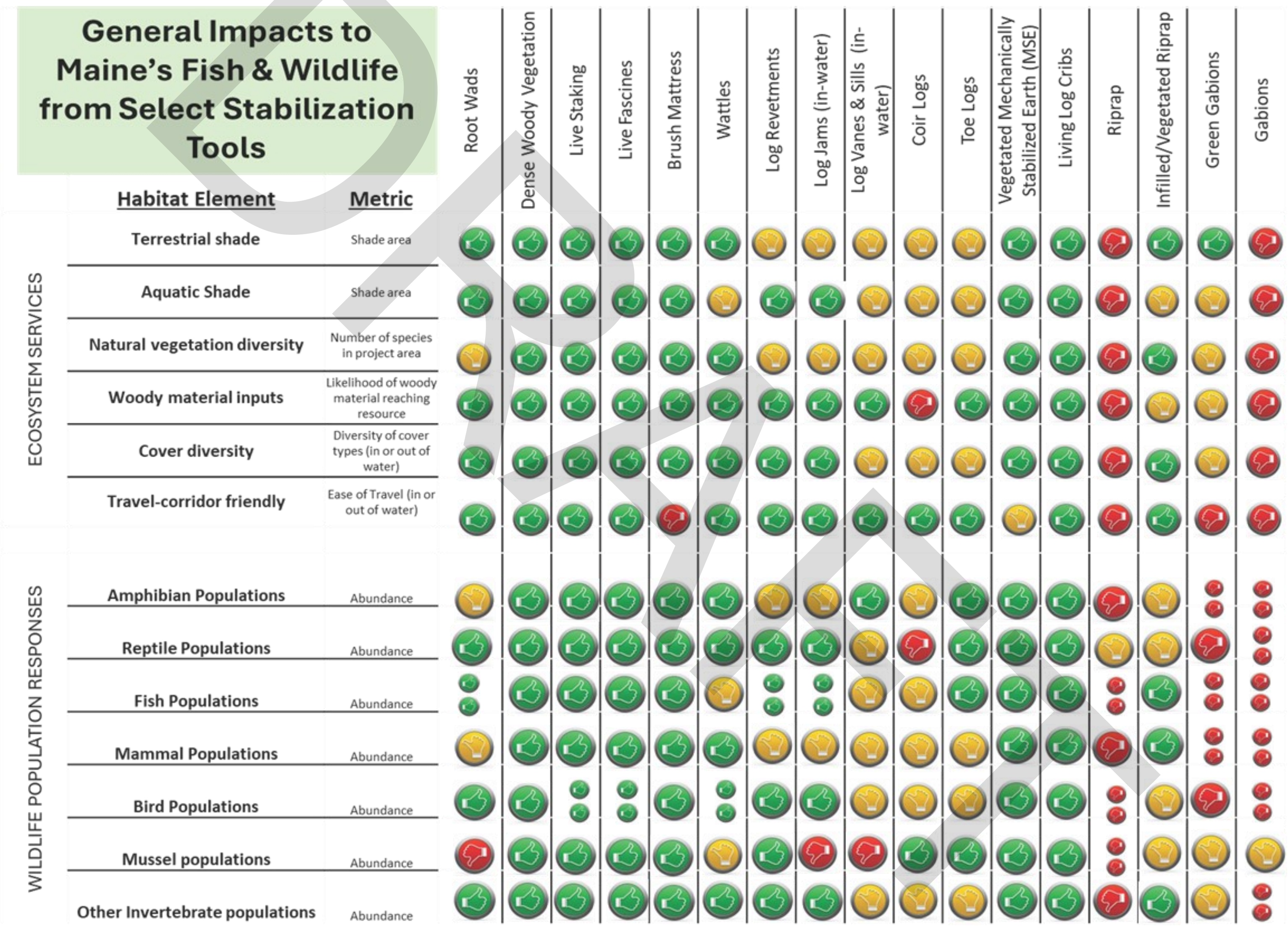
Level Spreaders & swales

A level spreader is a discharge outlet to disperse or spread runoff flows thinly (as sheet flow) across the slope and over a buffer to promote infiltration and to prevent channelization. The lip of the level spreader should be installed as level as possible to ensure a uniform distribution of flow and should blend smoothly into the downstream receiving area. This practice should not be used where an upgradient drainage area is greater than 10 acres; where the discharge is within 25 feet from a stream, or if the discharge crosses into an adjoining property. Stone can be used to create a level spreader with the advantage that the top of the spreader does not need to be level as any water flowing through the voids between the rocks will sheet flow out of the spreader. Level spreaders should be constructed on undisturbed soil.

R

Re-vegetate & Re-connect

As part of any shoreline stabilization project, the direct impacts on resource need to be minimized, but often there are indirect impacts to the resource the shoreline and nearshore habitat, and it's important to try to maintain of enhance these habitat elements as part of a stabilization project to further minimize these secondary impacts to habitat.



Beyond destruction of habitat, riprap changes other dynamics of the area, including thermal and nutrient dynamics. Many invasives seem to thrive in riprap dominated areas. Additionally, the lack of energy absorption by riprap causes energy to increase elsewhere in the system, resulting in greater needs for more riprap. Riprap is likely to affect many state/federally listed species and species of concern, including Wood Turtles, mussels, Brook Trout, and Bank Swallows. Terrestrial species may also see disruptions, e.g., loss of travel corridors (New England Cottontail).

Habitat Elements to Consider for Maine Fish and Wildlife

Insects & Pollinators

Insects and other pollinators require many different habitat elements depending on their type and life stage. There are many species of insects such as dragonflies that transition from water to land as they grow, so adequate connection between the land and water is important, as is diverse and overhanging vegetation. A wide variety of food sources is crucial for pollinator survival and dead stem materials can provide shelter and overwintering locations. Many butterfly and moth species are also linked to certain "host plants" like willows but need a mix of vegetation throughout their life cycle.

Aquatic Invertebrates

Aquatic invertebrates, clams, and mussels have differing habitat needs. Clams and mudflat health in coastal areas relies on natural sediment inputs. Water quality is also important to many aquatic filter feeders, so a healthy, vegetated shoreline can help regulate temperature and filter overland flows.

Fish

Maine fish benefit from increased cover from features like undercut banks and fallen logs or trees. Overhanging vegetation shades the water, and plays a role in promoting cooler water temperatures. Woody debris support healthy stream habitats by providing food and shelter for aquatic insects which species such as Maine's native Eastern brook trout depend on.

Amphibians

Amphibians need access to land and water, so a good transition from land to water is beneficial. Having a healthy amount of woody debris and vegetation in water bodies gives amphibians places to attach their egg sacks to. Additionally, vegetative shade cover, a healthy duff layer, and traversable surface into the upland will help amphibian movements.

Snakes

Reptiles require both open spaces to bask in and pockets of protected cover. Snakes have been known to benefit from basking on surfaces with sun exposure, for example, vegetated mats, root wads, and fascine bundles.

Turtles

In streams and rivers, logjams and woody debris are important habitat features for Wood, Blanding's, and Spotted Turtles. Since some turtle species burrow into eroding banks for nesting, maintaining natural soil and maintaining portions of eroding banks for burrowing and nesting habitat. A traversable surface supports turtle basking and movement along the shoreline and between land and water.

Birds

Perching points, berry and seed-bearing plants, insects, and thick, diverse vegetation are all important for many Maine songbirds using shorelines. Diversity of vegetation, including dead vegetation such as snags, can help provide nesting and food throughout the year. Many shorebirds and waterfowl require a thick vegetative buffer from human activities. Wading birds in particular need well vegetated shorelines to provide sufficient cover and space for nesting.

Mammals

Dense shrubs and saplings (like those grown from live stakes) may become great habitat for New England Cottontail and other small mammals that travel under vegetation and cover to escape predators. Wide openings along the shore restricts the movements of some mammals. Species such as deer and raccoons regularly use the water and surrounding upland, and require good connections along the shore and between land and water.

Preserving and Promoting Shoreline Habitat

As part of a stabilization project, preserving and restoring lost habitat in the design can speed up the time to naturalization and be incorporated into nearly any design to benefit our fish and wildlife species. Here are some basic habitat elements and considerations when altering shorelines.

Terrestrial & aquatic shade

The project should strive to provide 75-100% shade cover of the affected shoreland over time. Shade cover is important for keeping soils cool, maintaining soil moisture, providing overhead protection from predators for wildlife, among other benefits. This can only be accomplished with sufficient numbers of plants and close enough spacing so the crowns of the plants touch or overlap as the site matures. This can be done by preserving existing canopy and vegetation, enhancing various heights of plants (and root systems), combining seeding with more mature plants, including multiple species and plant forms (e.g. herbaceous/perennials/vines, woody shrub, small tree, large tree). Where appropriate, species and planting locations can be selected to provide nearshore aquatic shade with overhanging vegetation at maturity.

Cover diversity

A shoreline should have diverse cover that mimic nearby natural systems in form and plant community. Look around at the surrounding untouched areas for inspiration. Plant in non-linear and clumping arrangements, leave sticks or add snags or logs where practical—these are important features that increase habitat value for many species. Exposed soils should be covered with vegetation or non-erosive materials such as mulch. Where soil is bare, erosion control mix can be used as effective duff replacement.

Natural vegetation diversity

Dense native shoreline vegetation is key to the health of a wide range of fauna. Mixed vegetation provides food, shelter, perching, protection, shade and other benefits to our fish and wildlife. It is very important to have sufficient diversity between species and to source the plants as locally as possible. Aside from the above ground habitat, these multiple layers of plant forms to provide varied root interactions with undisturbed soil structure, adding strength to

Chop and drop project in White Mountains of NH

Woody material inputs

According to many Maine biologists, our resources are severely wood-starved. This is a critical input for in-water habitat diversity, sediment accumulation, and many aquatic macroinvertebrates. The use of woody material within or on the shoreline to mimic or preserve natural stabilization processes is encouraged and can be used very effectively with minimal alteration. In nature, fallen trees can provide a place for sediment accumulation and protection by breaking up water's energy to erode. Practices such as root wad toe protection mimic this natural process

Travel corridor

Shorelines provide an important travel corridor for the vast majority of species in Maine. From streams to lakes, to coastal areas, these immediate shoreline areas are the highways of wildlife movement . Continuous vegetation cover along the shore provides this function for prey animals that tend to dislike being in the open such as small mammals.

Soil health and subsurface habitat

Equally important to use as a travel corridor is a traversable surface for all sizes of animals or macroinvertebrates. This can be accomplished by having the soil surface designed to match the surrounding terrain and surface covering, while encouraging or enhancing the local natural community of vegetation.

Natural sediment transfer

In certain systems, the ecosystem is supported by the erosion of the shoreline. Adjacent to mud flats, the stabilization of bluffs can starve the mudflats of sediment, affecting clams and other creatures that live there. As sea levels rise, it's also important that natural sediment is able to

Enhancing & Establishing Buffer and Bank Vegetation

Vegetated buffers along our shores can be enhanced by increasing the variety and quantity of vegetation. Increased bank stability, resilience, nutrient removal, and water filtration are benefits of increasing vegetative cover withing several hundred feet of our water resources. In addition, buffers can enhance privacy, filter noise and wind, and attract birds, butterflies and other wildlife.

Natural growth

Increase growth indirectly by limiting mowing, pruning, raking of duff, and through thoughtful land use. Buffers will naturally revert over time and is a very cost effective option to increase buffer and bank stability.

Seeding

Enhancing shoreline resilience and habitat can be achieve by seeding disturbed areas with a native seed mix composed of species adapted to the site's conditions. However, the seeds will require time and attention for establish. To protect the soil and seeds from erosion, temporary mulches or natural fiber blankets should be used. Hand seeding is preferred, but other seeding options may be available. Seeds can be harvested locally or can often be purchased as native seed mixes.

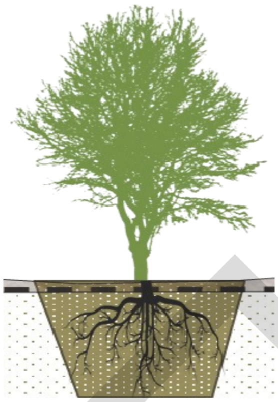
Live stakes & bioengineering

Live stakes are dormant woody shrub and tree cuttings that root quickly once planted in moist to wet soils along the banks of streams, lakes, and coastal areas. Live stakes make a good, low-cost source of plant materials for stabilizing banks and restoring shoreland and bank vegetation. Since it may take two or more growing seasons for the plantings to become well established. Live stakes should be installed in conjunction with erosion control measures such as mulching.

NOTE: Although cuttings develop into new plants, they are genetically identical to the plant the cutting was taken from, therefore, it is recommended that cuttings from several individual "mother" plants be included when many live stakes are used. Stakes can be used in many ways, such as contour planting, living fences/wattles, living check dams, fascines, brush mattresses, pole drains and other bioengineering techniques, making it an important resource in

Living Fascines

Variations on the live stake concept include living **brush, living poles, whips, fascines, and wattles**.



Planting potted nursery and bare root plants

Some native plants are available for purchase at local nurseries. ******This method of planting requires disturbance of the shoreline area, so Maine DEP and local Shoreland Zoning permits may be necessary. Additional mulch stabilization may also be needed to stabilize the remaining disturbed or bare soil.*

Transplanting wild plants

You can save money by transplanting native plants into your buffer area. Keep in mind, however, that mortality rates of transplants is relatively high. Here are some general transplanting guidelines:

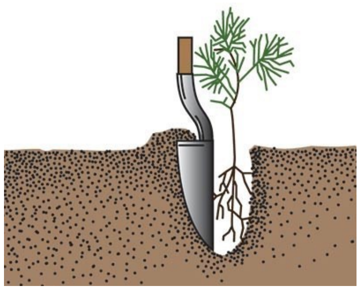
NOTE: Make sure to ask for landowner permission before harvesting and do not take too many plants from any one area. ***Do not remove plants next to protected resources.***

- Transplant in the early spring or late fall when the plants are dormant. This reduces trauma to their root systems.
- Choose sturdy-looking plants. Dig up the root ball as much as possible (extend your digging area at least to the width of the plant's branches.)
- Once your transplant has been replanted, water frequently until well established.

Shoreline planting to minimize soil disturbance

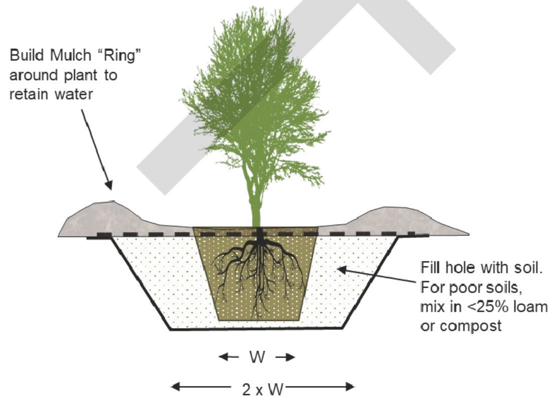
Keeping soil in structure plays a big role in maintaining soil stability. The existing microbes, cohesion, root networks, and fungal mycelia can be harmed by wholesale bank disturbance. Certain practices like seeding and live staking are optimal because they do not harm soil structure when installing. For living vegetation and larger potted plants, more disturbance may be required. Here are some planting methods that can help minimize disturbance.

Slit planting is a method of planting live stakes, living brush, bare root shrubs and trees that minimizes the disturbance of soil structure. The method involves creating a vertical slit in the soil with a shovel, then pushing the shovel forwards to create space for planting. Make sure it's deep enough for the tree roots. Keep the slit open with your spade and place your tree inside with the roots or live stake below ground level. Remove the shovel and push the soil back around the plant.



Bulb auger planting is an easy method to install plant plugs (small potted seedlings) that also minimizes disturbance to surrounding roots and soil life. Select a drill-mounted bulb auger of the same or slightly larger diameter than the plugs. Start the drill and lightly push the plant auger into the ground, letting it cut its way through the soil until you reach the desired depth. Pull out the plant auger, place the plant in the hole, and backfill with soil. Press firmly for good contact.

Potted plants require more soil disturbance to ensure a good head start. Dig a hole twice as wide as the pot and at least as deep. Center the root ball in the hole and fill with the original soil or amended soil as necessary. Be sure the pot has good firm soil contact without air pockets. Water in and mulch to prevent drying. A small mulch ring can be built to help hold water near the plant.



Planting vegetation into riprap

Riprap can be planted in multiple ways to enhance its holding power and to provide habitat benefits which are lost with straight rock. The success of vegetated riprap depends on the vegetation being able to bind and buttress the soils underneath. For this reason, using geotextiles is not recommended as they stifle root growth which inhibits long term resiliency.

Live stakes can be planted in riprap fairly easily, and can even be planted through geotextiles although granular filters will make this much easier.

Seeding into riprap is successful as long as seed growth is not impeded with synthetic filter fabric and there a media to grow in between the stones. Both seed and live-staked vegetation can be easily installed in riprap after it is infilled with soil and erosion control mulch.

Living brush can be installed anywhere the stems will have good soil contact and moisture such as under the toe stones of riprap within encapsulated soil lifts, and beneath riprap as a filter layer. When used as a filter under riprap, the vegetation will grow up through the rock and enhance the combined strength of the project.

Planting pockets and planting shelves by installing pockets of soil or benches of lush vegetation among the stone, some of the negative impacts of riprap can be mitigated. Planting pockets and shelves speed up the naturalization of riprap and create space for seeds to colonize. To be successful, roots must be able to access the soil below the stone, so non-biodegradable fabrics may need to be cut or an alternative filter layer can be used.

Edge of two stabilization projects. One with extended riprap and fabric (foreground) installed 1 year earlier than background that was graded and vegetated

Maintenance of Planted Native Vegetation

Photo: Shana Hostetter, Parterre Ecological

Year 1

Deep, weekly watering is a must during the first year of planting. Most plants that die in the first season do so because of inadequate watering. Make sure that the water reaches the depth of the root ball. The "ring" around the plant helps the water sink into the ground instead of running off. In coastal areas seed weed can function as an effective mulch.

After one year

After the first year, you should only need to water if there is a lack of normal rainfall. Once the plants are well established, you can let the planted area naturalize. The "duff" layer of leaves and pine needles will serve as natural mulch. Fertilizer can harm newly developing roots, and summer or fall applications can prevent shrubs and trees from hardening off in time for winter. Shrubs and trees should only be fertilized in early spring, and only after a soil test has been performed.

Photo: Cumberland County Soil & Water Conservation District

Photo: Shana Hostetter, Parterre Ecological

Removing Invasive Plants

The Suppression and Eradication of invasive plant species requires careful research, persistence, and patience. Tools used to combat invasive plants range from manual removal to concentrated chemical application. It is important to begin with the less severe techniques first, such as hand pulling and brush cutting, before scaling up to harsher treatments.

Examples of Invasives Removal Techniques

Removal with Planting Method

Root systems provide stabilization, regardless of whether they are roots from an invasive, native, or ornamental species. When removing invasive species, or any species from an area at risk from erosion, it's almost always best to keep the existing roots in the ground. Removing the roots can cause further erosion and instability. Depending on the species being removed and the severity of erosion, a combination of cutting the plant at the base, just above the ground, followed by herbicide stem injection, may serve to both keep soils stabilized while giving the best possible chance of killing the invasive plant at the same time. Planting desired native species in the same area, in between the invasive plants, and following the cutting and herbicide treatment, can help establish vegetation for the long-term stabilization of the area. Using herbicides in close proximity to a water resource (lake, river, stream, coastal wetland, etc.) requires a licensed applicator. https://www.maine.gov/dacf/php/pesticides/index.shtml

Manual Removal

With shallow rooted plants (such as honeysuckle), and small plants or patches, physical removal can be accomplished easily on shorelines provided soil is covered and kept away from the water. Manual removal of larger shrubs can be accomplished using a **weed wrench** or a **hand winch**, which are used to uproot small shrubs by utilizing leverage and mechanical advantage. This is and effective method for removal of honeysuckle.

Smothering

Smothering invasive plants with temporary tarps or other coverings to block light can be effective treatment for some species. Along shorelines, care should be taken to divert upland water and ensure the treated area cannot erode. It can take several months to adequately smother some invasives.

Herbicide Treatment

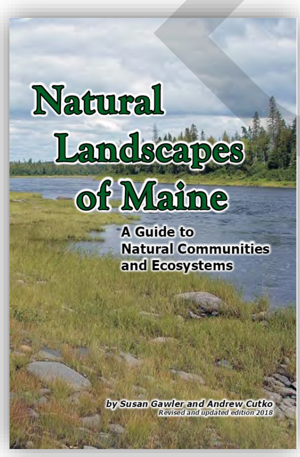
Targeted herbicide treatments such as stem injection may be effective for difficult-to-remove species like Japanese knotweed. While herbicides may be necessary for treatment of some invasives, it should always be the last option, especially around water resources. Herbicides around water should be applied by a licensed professional. Broadcast spraying of herbicides should never be performed near the water.

Planting Guide Summary

Selecting appropriate plants for a living shoreline is essential to long-term performance of the design and to restore habitat to natural conditions. This summary provides available planting guides for Maine landscapes, go-to sources recommended by experts who are designing and installing stabilization projects using nature-based practices, and a short list of coastal living shoreline plants.

Natural Landscapes of Maine: A Guide to Natural Communities and Ecosystems (Book)

https://www.maine.gov/dacf/mnap/publications/



An essential part of the OUR SHORE approach is to maintain, restore, and enhance shoreline habitat elements. The Maine Natural Areas Program maintains descriptions of natural communities and ecosystems that illustrate what property owners and contractors should aim to achieve with their designs. The publication includes detailed descriptions, maps, and photographs that serve as a valuable tool for understanding the rich biodiversity and environmental heritage of Maine's natural areas.

Maine Coastal Planting Guide

https://www.cumberlandswcd.org/documents-1/coastal-bluffs

This guide offers insights on selecting and cultivating plants that thrive in coastal conditions, such as salt spray, sandy soil, and strong winds, making it a valuable resource for coastal property owners, landscapers, and conservationists looking to establish resilient and visually appealing landscapes along the Maine coast. With tips on plant selection, maintenance, and design considerations specific to coastal settings, this planting guide serves as a practical tool for enhancing the ecological and aesthetic value of coastal areas in Maine.

Coastal Living Shoreline Plants

Low Marsh

- *Juncus gerardii*- saltmarsh rush
- *Spartina alterniflora*- smooth cordgrass

High Marsh

- *Spartina patens*- saltmeadow cordgrass
- *Distichlis spicata*- seashore saltgrass

Herbaceous Perennials

- *Solidago sempervirens*- seaside goldenrod
- *Symphyotrichum novae-angliae*– New England aster
- Symphyotrichum novi-belgii– New York aster

Trees & Shrubs

- *Acer rubra*- red maple
- *Amelanchier arborea*- serviceberry
- *Swida sericea*- red osier dogwood

Inland Living Shoreline Plants

Herbaceous Perennials

- *Solidago canadensis*– Canada goldenrod
- *Symphyotrichum novae-angliae*– New England aster
- *Symphyotrichum novi-belgii*– New York aster
- *Rudbeckia laciniata*—Black-eyed susan

Trees & Shrubs

- *Myrica gale*- Sweetgale
- *Vaccinium angustifolium*- Lowbush blueberry
- *Acer rubra*- red maple
- *Cephalanthus occidentalis*—Buttonbush
- *Amelanchier arborea*- serviceberry
- *Diervilla lonicera*- bush honeysuckle

PLANT SELECTION

Northeast plant list for benefitting pollinators, Xerces Society
https://xerces.org/pollinator-conservation/pollinator-friendly-plant-lists

A selection of plants specifically tailored to support and attract pollinators such as bees and butterflies. The plant list offers valuable guidance for those looking to enhance biodiversity and promote pollinator conservation.

Plants for the Maine Landscape, University of Maine Cooperative Extension
https://extension.umaine.edu/gardening/manual/plants-for-the-maine-landscape

A reference guide for selecting and cultivating ornamental plants, trees, shrubs, and perennials that thrive in Maine's climate, soil types, and growing seasons. This resource practical guidance on plant selection, care, and maintenance to create vibrant, resilient landscapes.

Yardscaping Program Maine Department of Agriculture, Conservation & Forestry
https://www.maine.gov/dacf/php/pesticides/yardscaping/plants/index.htm

The Yardscaping Program provides guidance on plant selection, soil health, water conservation, and integrated pest management strategies—together these techniques promote sustainable landscaping, reduce pesticide use, and encourage the cultivation of native plants to support local ecosystems.

Inland Plant Selection Resources, Maine Department of Environmental Protection
https://www1.maine.gov/dep/land/watershed/buffer_plant_list.pdf

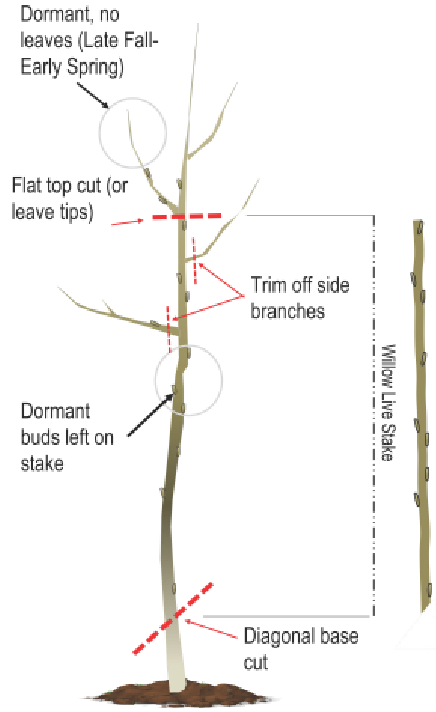
A comprehensive plant list tailored for inland areas, focusing on buffers and watershed management. This resource serves as a guide for selecting plant species suitable for enhancing water quality, preventing erosion, and promoting biodiversity in inland landscapes.

FINDING PLANTS

How to Find Native Plants, Wild Seed Project
https://wildseedproject.net/2022/02/navigating-the-nurseries-how-tofind-native-plants
This resource offers practical guidance on sourcing native plant species through nurseries, emphasizing the importance of incorporating native plants into landscaping projects to support biodiversity and ecosystem health. This resource provides valuable insights on navigating nurseries and plant suppliers to locate native species appropriate for different regions, helping individuals make informed choices that benefit local wildlife and pollinators.

Maine Native Plant Finder, Maine Audubon
https://mainenativeplants.org/
This online resource allows users to explore and discover native plant species suitable for various gardening and landscaping projects in Maine. This tool provides information on native plants based on specific criteria such as plant type, sun exposure, soil moisture, and wildlife value, making it easy for individuals to select plants that are well-adapted to Maine's unique environmental conditions.

Live Staking Dormant Trees & Shrubs



Vegetation from live staking

Live stakes are woody shrub cuttings that root once planted along the banks of streams, lakes, and other resources. Live stakes make a good, low-cost source of plant materials for stabilizing banks and restoring shoreland (riparian) vegetation. Live stakes are also used away from resources using bioengineering techniques for slope stabilization, erosion control, carbon sequestration, and for living fencing and structures.

Some of the best native species to use for live stakes are Pussy willows and other native willows, American elder, red osier dogwood, and grey dogwood. These shrubs have strong root systems to stabilize banks, are naturally found along lakes and streams, and can grow from cuttings without much assistance. Live stakes, like other plants, should be planted in areas with suitable soils, moisture and sunlight.

For more information on plant identification visit the website www.plants.USDA.gov

Timing of collection & installation

For best results, live stakes should be harvested and planted while the plant is dormant in late October until the ground is frozen, or in the spring before plants start to leaf-out. Stakes can be installed while the ground is still workable in Fall, installed immediately after harvest in early spring, or stored for use later in the growing season. The northern part of the state should aim for spring plantings because the frost heaves plants that are not established.

If stakes are properly-installed while dormant, with good soil contact, you can expect 50-80% success on average, depending on species. Some native willow species will also root after

Harvesting wild live stakes

Live stakes can be collected from wild healthy, established, mature plants. Be sure that permission is granted by property owners before gathering cuttings of a healthy parent plant. Collection from many individuals will increase genetic diversity of these future clones.

When gathering live stakes, make sure the thick end of the branches are at least ½ inch in diameter. At the base, cut on the diagonal to make a point. This will help you know which end goes into the ground when the time comes to install the stake. Removal all the side branches and make a straight cut at the top end of the branch about 12-18 inches from the base.

Generally stakes should be 12-18 inches long, although longer cuttings can also be used. Keep in mind that the more of the plant is exposed to the air, the quicker it may dry out. Examples of longer cuttings include use in living brush mattresses and living fences/structures

Local nurseries may carry live stakes for purchase but advance notice is generally required. Live stakes are also available for purchased online. Just ensure that the plant species are native to Maine.

Basic installation of live stakes

1. The site should be prepared before planting the live stakes. Invasive and competing vegetation should be cut back avoiding the use of herbicides to protect water quality. Information on invasive species can be found at www.mainenaturalareas.org/docs/program_activities.
2. Push (or use a rubber mallet) to carefully drive the pointed end of each live stake into the soil. If the stake doesn't go into the ground easily, use a metal rod (rebar) to first create a hole the length of the stake. Live Stake length should be 1-3 feet; ¾ of Stake length will be buried ¼ Stake length exposed (including a few buds) sticking out of the ground. Ensure good soil contact between soil and stake.
3. If the stake will be shaded by surrounding vegetation, use longer stakes and leave one foot sticking above the ground. If a willow stake, in particular, gets too much shade, it will drop its new leaves and die. The side branches, or whips, that were snipped off during the collection process will grow nicely if they are planted in very moist areas at the edges of streams and wetlands. Push them into the ground as far as they will go without breaking.
4. Live stakes can be placed as far as 1-3 feet apart or in dense, close formations for some techniques. See live stake installation variations below.

NOTE: In conjunction with live staking, cover bare soil with erosion control mulch (ECM) or annual grasses and hay mulch to hold the soil and help prevent weed establishment until the stakes are established.

The rooting process can be accelerated by wounding or scratching away some of the bark that will be in the ground when installed. Additionally, commercially available rooting hormones can be applied prior to installation to speed up the rooting process and increase success rates. Before planting, the cuttings can be placed in a bucket of water and left in a cool, dark area for several days which will help keep them

Slope stabilization using live stakes of dogwood & willow with coir blanket, slope interruption to control temporary erosion. Following construction and 1st growing season.

Storing live stakes for later use

To increase the survival rate of the stakes, it is best to plant within 24 hours of collection. Stakes can be stored in a cool, dark place for several weeks if the stakes are kept damp by wrapping them in wet burlap sacks or soaking them in buckets of water. Stakes will die if they are allowed to dry out or may experience significant shock if planted once leaves begin to develop. If the stakes are being planted on a hot day, make sure to store them in the shade.

Refrigeration- Stakes can be stored for longer periods using refrigeration. Stakes kept moist and refrigerated will remain dormant and can be used for projects well into the growing season. For large installations involving many stakes, on-site refrigeration may be an option to prevent stake mortality.

Potting lives takes for later planting- Live stakes can be planted in nursery pots with potting soil to establish new plants that can be installed later in the growing season. These cuttings can be placed at high density, approximately 1 inch apart in the pots or separated individually. The most critical time for survival of live stakes is when leaves begin forming (leaves emerge before roots begin developing). Leaves will lose valuable water from the plant during this time, so tending the stakes early on can increase survival. Split plants from the pots prior to planting in small planting holes

Maintenance of installed live stakes

If live stakes are planted while dormant, shoots (leaves and small branches) should be seen in spring. If live stakes are planted during the growing season, it may take a full year or two to see results. To increase

Timing for Living Shorelines and Associated Activities

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Growing Season																								
Winter Erosion Control Practices																								
Live stake collection																								
Live stake installation	*	*	*	*	*																			*
Dormant Bare root planting					*																			*
Dormant seeding																								
Permanent seeding																								
Non-dormant potted plants																								
Inland in-water work window																								

*when ground is not frozen

Bioengineering and Live Stake Variations

Live poles

Live poles are long (typically >6 feet), slender poles with diameters typically less than 1 inch at the base. These poles can be woven into wattles, fascines, or other living structures. Live poles typically have their side branches removed to a single straight stem.

Live posts

Live posts are large diameter (over 2 inch) posts cut from mature live stake species, typically balsam poplar and willows. The can be used as a live post piling, driving them deep into the ground or using them along the ground such as in living cribs or sills.

Living brush

Living brush is a variation that uses untrimmed dormant branches and twigs that can be bundled together for installation as brush layering and to create fascines.

Living fascines

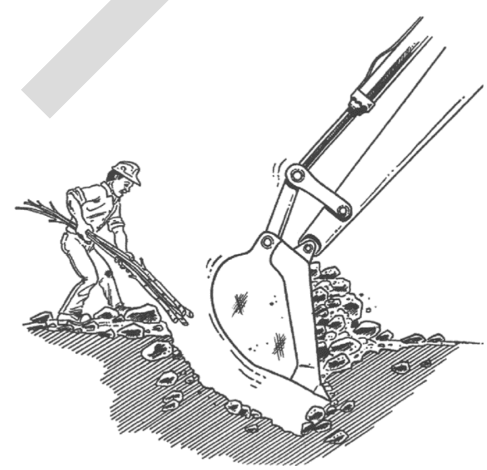
Living fascines are long, cigar-shaped bundles of living brush or poles, bound by wire or strong twine. These bundles can be made in different lengths and diameters, depending on the use. Good soil contact must be maintained for good rooting and growth to occur. A mix of species within a fascine is also recommended.

Living wattles

Wattles are woven structures consisting of upright live stakes installed in a line approximately 6-12 inches apart. Then long live poles are woven between the uprights similar to basket weaving. Once completed, soil is typically filled behind to allow rooting to occur. Wattles are typically less than 6 inches in height.

Live-staking where there is ice action or high water flows

In areas of high flows or ice action, live poles can be installed extremely deep into sand bars or slopes and placed at an angle away from the direction of ice or water flow. This will allow the water or ice to slide over the cuttings. Since most plants with live staking ability are adapted to these environments, they may get sheared off, but roots will remain and vigorous send out new shoots the following growing season.



Maine Native Species for Live-Staking & Bioengineering

While many species can be propagated from cuttings, most require significant assistance and ideal conditions to form new roots and become self-sufficient. Many of Maine's native shrub species can be propagated by dormant cuttings, but survival is generally low and additions such as rooting hormones may be required. While it is possible to root many deciduous shrubs and trees, certain ones like willows have excellent ability to form new roots.. You can expect 50-80% survival of live stake generally, but this can be increased with some simple maintenance and plant care in the first growing season. The #1 reason for failure of live stakes is that they dry out before being able to root. The higher percentage of the stake exposed to the air and sun will increase drying and leave emergence before roots will result in a net loss of more moisture.

Pussy willow

Salix discolor

Pussy willow is a common and easily identifiable shrub on Maine's landscape. Pussy willow is a short-lived, fast-growing, native tree or large shrub with a rounded crown. In early spring, the silky, furry catkins open before the leaves appear to

Missouri River willow

Salix eriocephala

The Missouri river willow is a shrub 7 to 13 feet tall, native to Eastern to Central North America. The flower catkins appear in April at the same time or slightly before the leaves and are pollinated by many insects especially bees and flies. Missouri river willow tolerates strong winds but not seaside conditions, and does not like too much shade.

American Elderberry

Sambucus canadensis

American elderberry is an easy to grow live stake that provides great visual and wildlife habitat. It tolerates a wide variety of wet to dry soils but prefers rich, moist, slightly acidic soil in sun to partial shade. In summer, small white flowers are borne in dense clusters. Flowers are followed by purple-black fruits

Redosier Dogwood

Cornus sericea

Red-osier dogwood matures at 7 to 9 foot as a multi-stem shrub. Besides attractive, red stems in the winter, red-osier dogwood has yellowish-white flowers that appear in late May to early June, and bluish-white fruit in late summer. Fall foliage color is reddish-purple.

Gray Dogwood

Cornus racemosa

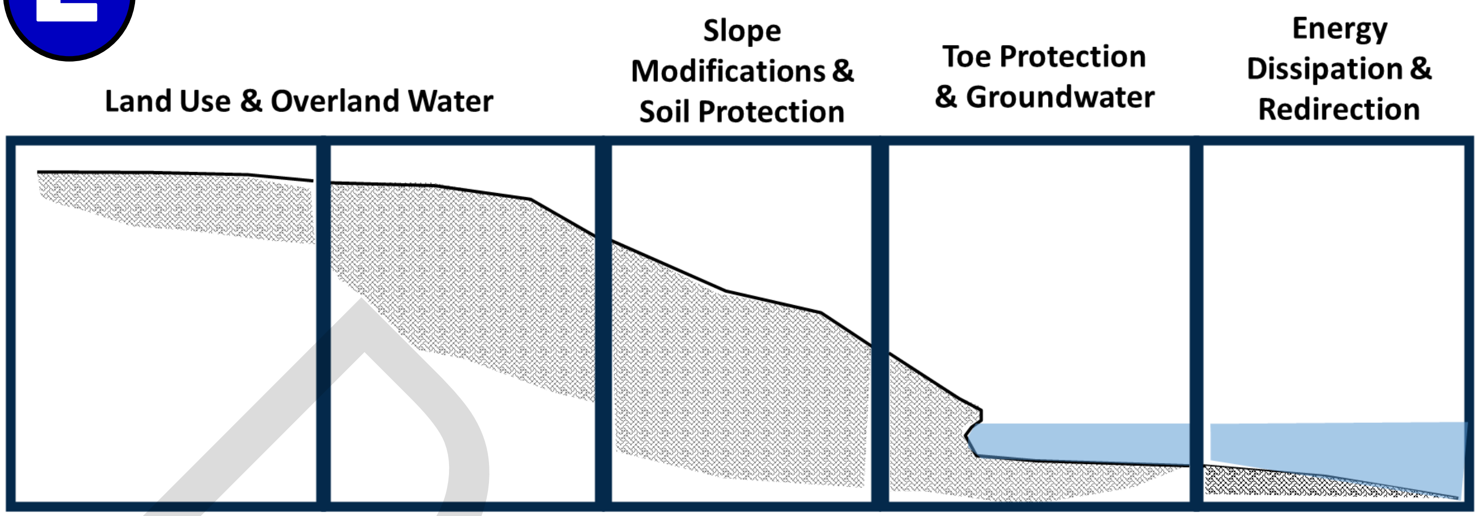
Gray dogwood is useful as a low-growing shrub which provides summer food and some cover for small animals and birds. It is a thickly branched, slow growing dogwood seldom more than 6 feet high at maturity. Gray dogwood is not well adapted to coastal conditions.

White meadowsweet

Spirea alba

Meadowsweet is a small woody shrub that can be found in many moist areas, shorelines, and fields across Maine. In mid-summer has spires of tiny white flowers. Well adapted to coastal environments.

Name	Size	Sun
Buttonbush *Cephalanthus occidentalis*	Shrub, 6-8 feet tall	full sun to partial shade in moist to wet soils, some salt tolerance
Silky Dogwood *Cornus amomum*	Shrub, 6-9 feet tall	Prefers partial sun, some salt toler-ance
Gray Dogwood *Cornus racemosa*	Shrub, up to 6 feet tall	Full sun, Partial Shade, moderate salt tolerance
Redosier Dogwood *Cornus sericea*	Shrub, 6-9 feet tall	Full Sun, Partial Sun, Shade
Balsam poplar *Populus balsamifera*	Tree, 50-70 feet	full or part **sun**
Bebb willow *Salix bebbiana*	Shrub, up to 10 feet tall	Part sun
Pussy willow *Salix discolor*	Shrub or small tree, 10-15 feet tall	full to partial sun, moderate salt tolerance
Missouri River willow *Salix eriocephala*	Shrub, 7-13 feet tall	Full sun
Prairie willow *Salix humilis*	Shrub, up to 4 feet tall	full to partial sun, tolerant of dry conditions
Shining willow *Salix lucida*	Shrub or tree, 12-20 feet, fast growing	Part sun
Black willow *Salix nigra*	Tree,70-80 feet can be pruned to maintain shrub form	full to partial sun, moderate salt tolerance
Meadowsweet *Spirea alba & S. tomentosa*	Shrub, 3-4 feet	Full sun, part shade, moderate salt tolerance
American Elderberry	Shrub, 5-10 feet	Full sun, part shade, some salt tolerance
Red Elderberry *Sambucus racemosa*	Shrub, 8-15 feet	Full sun, part shade
Ninebark *Physocarpus opulifolius*	Shrub, 3-9 feet	full sun, light shade, some salt tol-erance



Riprap toe with live stakes or living brush

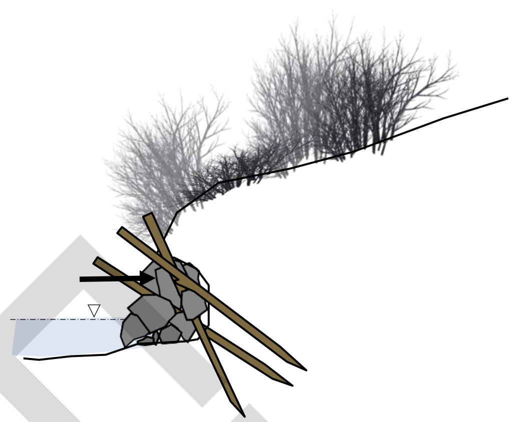
In this example, the slope was regraded with riprap placed at the toe for protection and support, while preserving as much natural vegetation and soil structure as possible. The disturbed slope will be more vulnerable to erosion, long term biodegradable soil protection such as erosion control blankets or erosion control mix will help provide temporary protection while the site re-vegetates.

S — Riprap-packed in to undercut area to support undisturbed bank above, with live stakes installed through into soil behind. The vegetation will break up energy and help hold stones in place once established. This can also be accompanied by a filter layer.

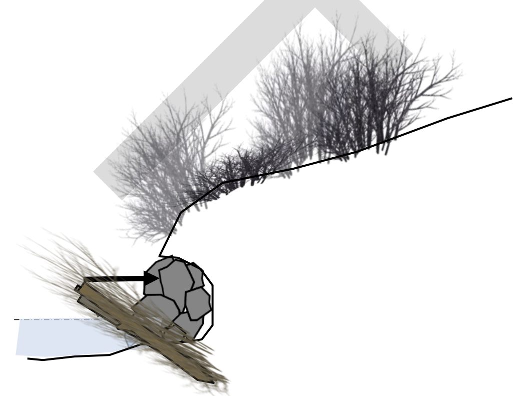
H — No regrading or removal of vegetation.

O — Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, and other flow interception techniques.

R — No vegetation was removed and vegetation is added to help provide habitat and prevent stones from moving. Shoreline vegetation could also be enhanced with additional planting or seeding.



Riprap packed into undercut area with live stakes installed through the stone.



Variation showing living brush installed under the stone in the undercut bank. This can also be used with anchored stone riprap.

In some locations where toe erosion or groundwater creates an over-steepened slope, minimizing hard armoring up the slope can be accomplished with or without regrading and slope erosion control methods. Here are five examples of riprap toe variations that do not involve bank armoring.

Riprap toe with regrading

In this example, the slope was regraded with riprap placed at the toe for protection and support, while preserving as much natural vegetation and soil structure as possible. The disturbed slope will be more vulnerable to erosion, long term biodegradable soil protection such as erosion control blankets or erosion control mix will help provide temporary protection while the site re-vegetates.

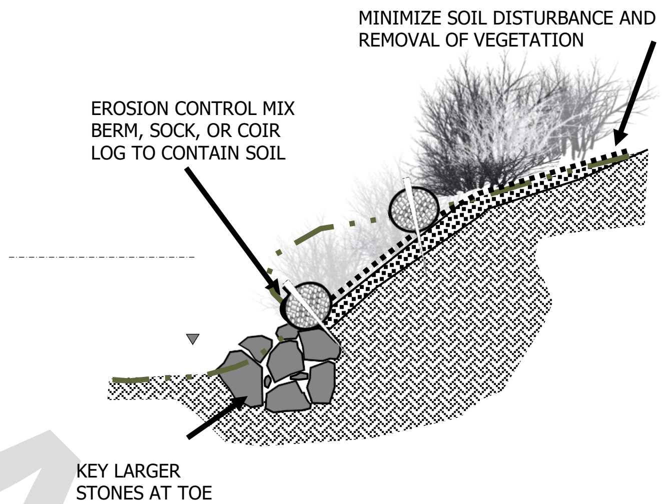
S — Riprap toe for protection and slope support.

Erosion control mulch and coir logs (slope interruption) for overland flows and spray.

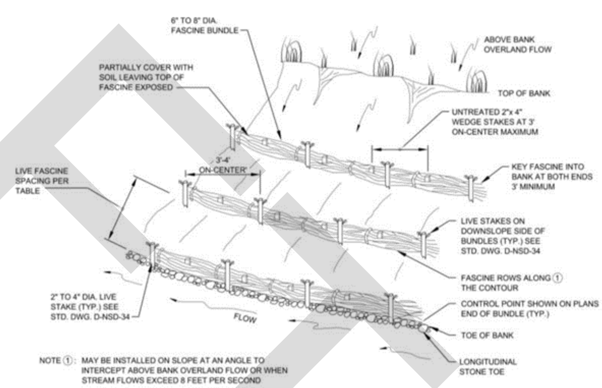
H — Over-steepened slope has been regraded, slope interruption installed to slow water.

O — Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, flow diversions and other flow interception, or rain gardens.

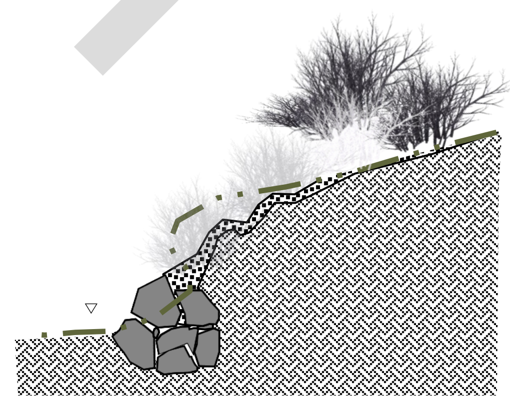
R — This slope's permanent erosion control will be robust vegetation. Any method could be utilized or combined in this scenario such as seeding, live-staking, fascines, potted plants, etc.



This variation shows a stone toe with regrading and installation of living fascines installed along the slope's contour. Fascines can be installed in trenches or filled with soil above to create vegetated micro-terracing



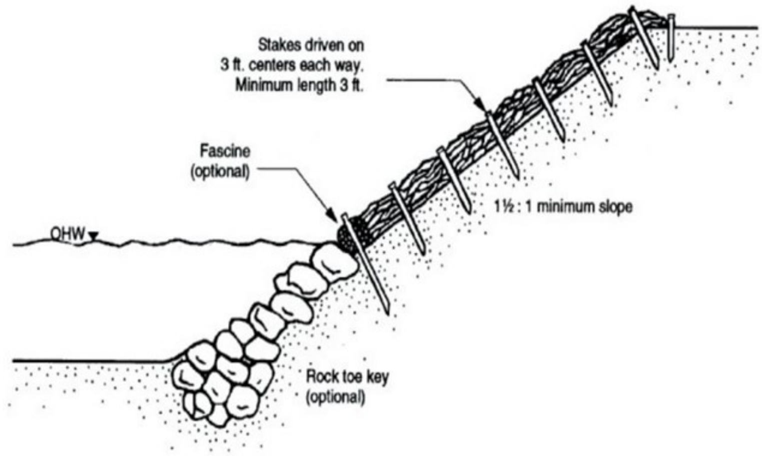
This variation shows a grading method involving contour swales or irregular topography rather than smooth, linear grading to slow water energy flowing down the bank through roughness and microtopography



Riprap toe with re-grading and brush mattress slope protection

A simple combination of riprap toe stones, with grading and a brush mattress can provide significant protection. Upon installation and anchoring, the living brush will provide a level of temporary erosion control for the slope while and will increase as the roots form and plants establish.

This variation shows a similar riprap toe and re-graded slope, however, a living brush mattress is used above the stone to create a densely vegetated slope covering once established. NOTE: Live stakes and similar practices such as brush mattresses should be installed when the plant material is dormant, in late fall, winter, or early spring



Riprap over living brush mattress

By using a living brush mattress as a filter layer under riprap stone, an incredibly strong protection can be created. Once the living material begins to sprout, it will emerge from the voids in the stone, buttressing all the stones and anchoring them to the soil through the mattress underneath. Riprap should not be so deep as to prevent the new growth accessing the light. If the vegetation gets sheared in winter, it will easily regrow since the roots and some portion are protected below the stone.

S

Riprap toe for protection and slope support.

Brush mattress for filter layer and slope erosion control.

Buttressing and armor protection from stone/vegetation combination.

H

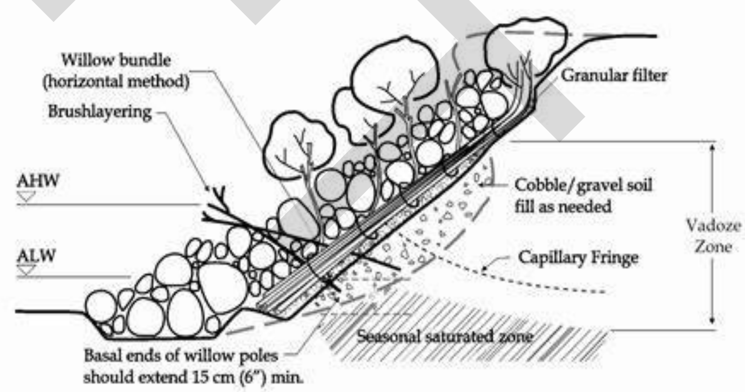
Over-steepened slope has been regraded, living filter layer and stone protection integrated.

O

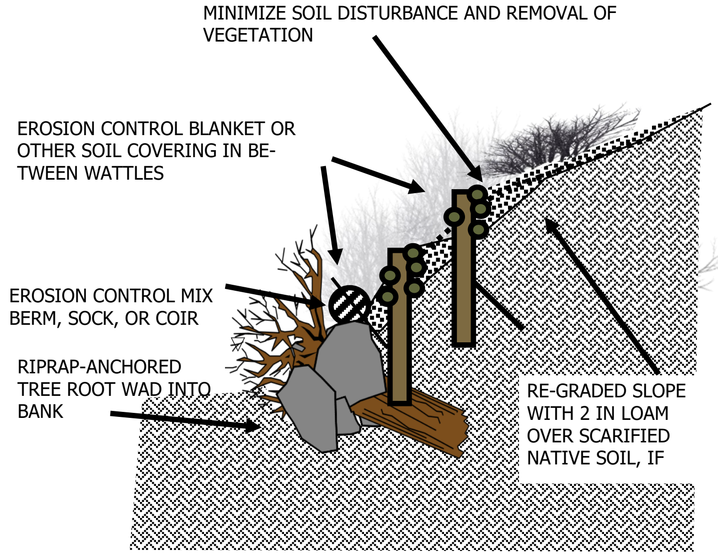
Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, flow diversions and other flow interception, or rain gardens.

R

This slope's permanent erosion control will be mixed stone and robust vegetation growing through the stones that will help hold it in place against high energy, encourage sedimentation within the voids, and create dense vegetation and habitat benefits.



Riprap and root wad toe with regrading, live posts, & live wattle benching



S — Riprap and anchored root wads for toe protection and slope support, root wads may help allow sediment accumulation.

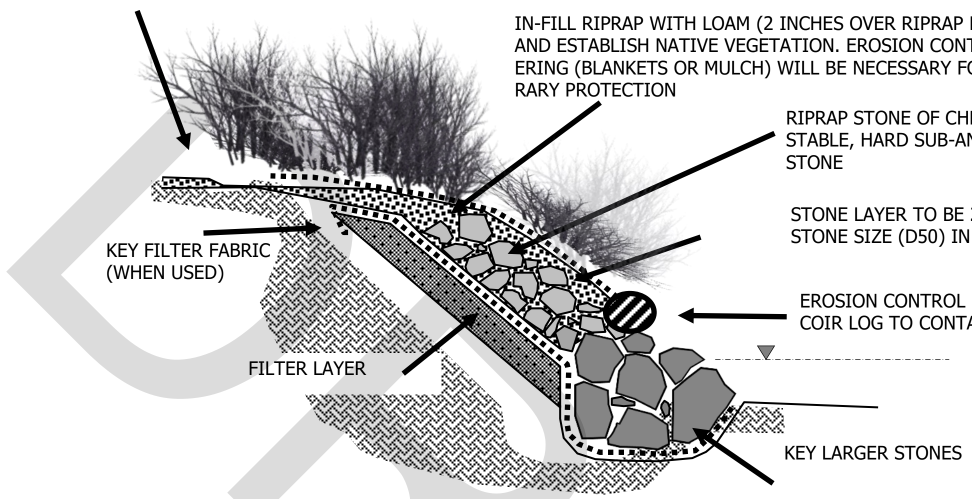
H — Over-steepened slope has been minimally graded, with living wattle fences (anchored with thicker, living posts) installed to create small micro-terraces. These can be made through cut and fill slopes, or placed on grade and filled behind with soil. All living material must have soil contact.

O — Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, flow diversions and other flow interception, or rain gardens.

R — This slope's permanent erosion control will be robust vegetation. The toe can also be supplemented with live stake plantings.

Infilled riprap slope

In this example,



S

Riprap toe for protection and slope support (large clean stone).

Riprap slope for erosion covering that is infilled with a soil media or mix, ECM, or similar material that will settle in to the voids below the stone, or mix soil media with riprap prior to placement. A separation of stone, erosion control mix or coir logs may be necessary to contain the loose soil until vegetation can establish completely.

A granular filter gravel or long term biodegradable filter fabric is placed behind the riprap to allow groundwater and trapped water to escape, while not inhibiting root growth for deep stabilization.

H

Over-steepened slope has been regraded, slope interruption installed to slow water.

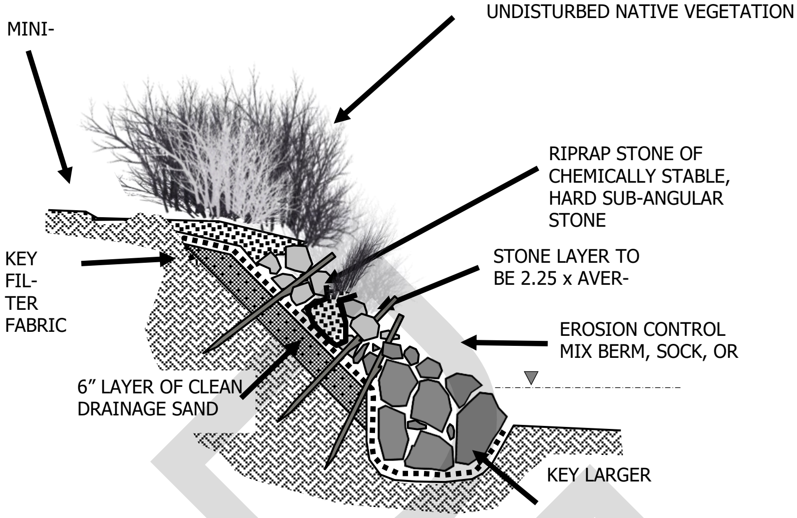
O

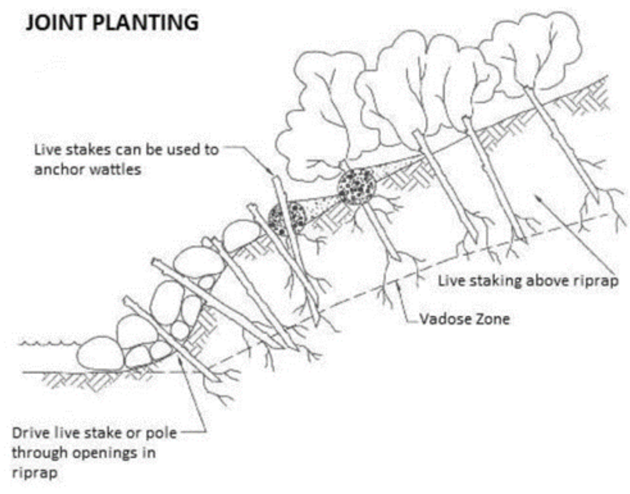
Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, flow diversions and other flow interception, or rain gardens.

R

This slope's permanent erosion control will be robust vegetation. Any method could be utilized or combined in this scenario such as seeding, live-staking, fascines, potted plants, etc. NOTE: A temporary covering of the bare soil will be necessary on the slope until permanent vegetative stabilization occurs.

Riprap with live stakes and planting pockets





S

Riprap toe for protection and slope support (large clean stone).

Riprap slope for erosion covering that is fitted with joint planting of live stakes and planting pockets for nursery stock.

A granular filter gravel or long term biodegradable filter fabric is placed behind the riprap to allow groundwater and trapped water to escape, while not inhibiting root growth for deep stabilization.

H

Over-steepened slope has been regraded, slope interruption installed to slow water.

O

Land Use Contributions identified and fixed above the bank (e.g. reducing lawn area, stabilizing access points, flow diversions and other flow interception, or rain gardens.

R

This slope's permanent erosion control will be robust vegetation. For planting pockets, it is important to create an area where minimal soil movement can occur within the riprap voids. This can be accomplished using smaller aggregate gradations in the area to be planted to fill in the spaces in the immediate area, or use of granular filters or biodegradable filter fabrics. By choosing plants with strong, deep root systems for these pockets, they can help act as buttresses and provide organic inputs and shading. Live stakes must extend into the soil behind.

Living crib wall with root wad deflectors

This example combines flow attenuation using root wad deflectors that add roughness within the flow of a river or stream to move the highest power away from the outer bank's toe. To further limit disturbance of the area, a living crib wall was installed to support the over -steepened slope behind it, while taking advantage of the existing soil structure and vegetation. While vertical structures on shorelines are not preferred, for some situations where the bank can not be cut back or access would cause additional damage, a thoughtfully considered living crib wall can provide many habitat benefits.

S

Over steepened slopes supported by living cribs in highly eroded areas in a river.

Tree root wad deflectors for flow attenuation projecting beyond the eroded areas to help break up water energy and allowing sediment accumulation and natural vegetation growth.

H

Over-steepened slope not regraded—a log crib structure installed and vegetated while retaining the existing vegetation, natural seed bank and soil structure in tact.

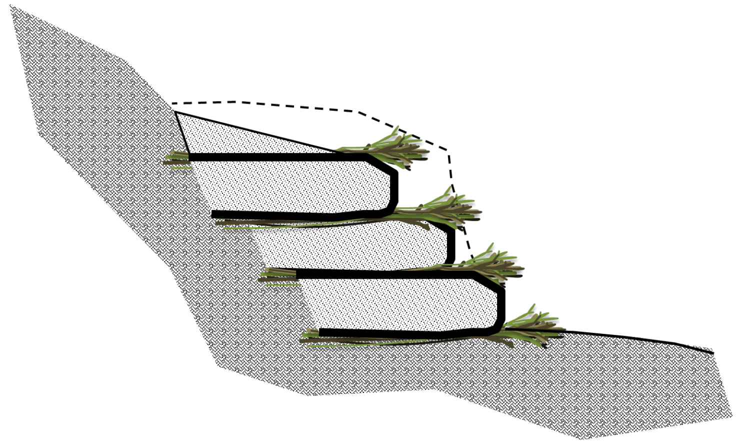
O

Correction of any land use contributions to overland flows.

R

This slope's permanent erosion control will be robust vegetation that can be accomplished somewhat naturally through the reduction in water power interacting with the bank.

Engineered woody wave attenuation devices and encapsulated soi lifts



S

Anchored woody structures installed in the nearshore are used to help break wave action based on many factors such as wind/wave direction and intensity. These woody structures help protect the bank that is protected with encapsulated soil lifts. Given the sandy nature of this site, the material erodes very easily, making planting or establishing seed very difficult without multiple tools.

H

Over-steepened slope has been wrapped by heavy coir fabric in soil lifts that are anchored into the bank.

O

Land Use Contributions identified and fixed above the bank . Since the site is open to the public, erosion from uncontrolled foot traffic is a significant factor. Additional practices to help define appropriate access points is incorporated.

R

This slope's permanent erosion control will be robust vegetation. With soil lifts, seeding, live stakes and brush layering are the most common companion techniques.

Marsh toe with log sills

S Log sills were anchored below the high tide line to create a sill that can trap fine sediments from migrating out of the bank and create conditions for fringe marsh vegetation in lower energy marine environments. This broke up energy and provided some indirect toe stability through roughness. Additionally, an encapsulated tube made of heavy coir fabric was filled with cobbles and erosion control mix in-situ and packed into undercut areas with maximum soil contact. This will help protect the toes and provide a good growing media.

H No regrading necessary, practices include additional planting, slope interruption.

O Lawn area has been reduced near banks and flows are directed to more stable portions of the site.

R The encapsulated toe media, marsh plantings, shoreline plantings, and retaining the natural soil structure provides exceptional habitat and soil health benefits.

Encapsulated oyster shell toe protection and log skids

S Oyster shell bags help protect the toe of this eroding marsh while the log skids can help protect the area from ice and debris directly hitting the bank.

H No regrading necessary.

O Land use is not a major direct source here, but other human activity such as boat wakes can still be considered

R Over time, the upper portions of the oyster shell media may become colonized by plants; however, the shells may also contribute buffering against ocean acidification and host habitat to other important shoreline and marine life

Nature-based Permitting Guide

- Municipal Shoreland Zoning
- Maine DEP/ NRPA
- Land Use Planning Commission
- Army Corps of Engineers

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Specialized practices by Resource Type

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Rivers and Streams

Resources and Guidance for nature-based designs in and around rivers and streams:

- Guidance for Stream Restoration (usda.gov)
- engr.colostate.edu/~bbledsoe/CIVE413/Practical_Streambank_Bioengineering_Guide.pdf
- 31800.pdf (usda.gov)
- STREAM RESTORATION, A NATURAL CHANNEL DESIGN HANDBOOK (epa.gov)

PLACEHOLDER

Coastal Wetlands, Bluffs, & Sand Dunes

Resources and Guidance for nature-based designs in and around **COASTAL WETLANDS**

SAND DUNE RESOURCES