StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Is Runoff and How Does It Cause Coastal Erosion?

Runoff is rainwater, snowmelt, and water from irrigation systems and other sources that does not soak into the ground or evaporate, but instead flows over the ground surface. Runoff causes erosion when water falling on and/or running across bare or sparsely vegetated areas dislodges soil and other sediments. When runoff flows over a coastal bank, dune, or beach, it can erode these landforms from above and exacerbate other coastal erosion problems.

Channels or gullies on the face of a bank or dune are a sign of a runoff problem. As shown in the photograph on the right, sediment carried by runoff is often deposited in a fan-shaped pile at the base of the slope. The channels and fan-shaped deposits are both indicators that runoff is eroding the bank. Similarly, runoff can erode soil from behind concrete seawalls and under rock revetments (i.e., shoreline stabilization structures constructed of sloping rock), causing them to slump or collapse. Indicators that runoff may be contributing to the failure of seawalls and revetments include channels in the bank above the structure or sinkholes behind the structure. If overland sources of runoff are not successfully managed, the effectiveness of other shoreline stabilization techniques can be compromised.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

Runoff has eroded a channel in this bank face, exacerbating the coastal erosion problem. Some of the eroded material has been deposited in a fan-shaped mound at the base of the bank. **(Photo: CZM)**

General Approaches to Runoff Control

Controlling runoff from upland sources helps reduce a significant cause of erosion on many beaches, dunes, and banks. Efforts to control runoff focus on reducing the quantity and velocity of water flowing across the land surface and changing the direction of flow as necessary to address specific erosion problems. Runoff control approaches include:

- Removing and reducing impervious surfaces (i.e., pavement, concrete, and other impermeable materials) and planting natural vegetation to help slow the flow of runoff and allow the water to naturally seep into the ground. For example, converting asphalt or concrete driveways to grass, crushed-shell, or other surfaces that allow water to soak into the ground is an excellent way to reduce impervious surfaces.
- Capturing runoff so that it can be infiltrated into the ground over a broad area or reused for irrigation.
- Redirecting the flow of water away from erosion-prone areas by regrading the ground surface, constructing a barrier of soil or other sediment (known as a berm), and removing landscaping elements that channel runoff.
- Maintaining the soil's natural capacity to absorb water by preventing saturation from lawn watering and other irrigation.

Runoff control techniques should address the specific patterns and sources of runoff on the site based on a comprehensive evaluation of site conditions. These conditions include the location and extent of impervious and vegetated surfaces, soil types, slope and elevations on the property, and sources and amounts of water coming from both on- and off-site. An experienced professional may need to be consulted for additional guidance regarding project design, and the local Conservation Commission should be contacted about permitting.

Several options are available for installing grass driveways, including this grass and paver system. As with all runoff control options, site conditions and potential impacts should be fully evaluated in project design. **(Photo: CZM)**

This lawn was regraded to slope inland, and a buffer of native shrubs was planted along the top of the bank to stabilize the area and direct runoff away from the bank. These measures reduced runoff flowing over the bank so that a bioengineering project with natural fiber blankets, coir rolls, and vegetation could be successfully installed. **(Photo: CZM)**

This figure demonstrates how a typical coastal property could be modified to reduce runoff and where appropriate runoff control techniques could be sited. **(Graphic: New England Environmental, Inc.)**

The following factors should be addressed to ensure that the runoff control options selected do not create unintended negative impacts:

- **Channelization of Runoff** - Improperly managing runoff can have negative impacts, particularly if the runoff is channelized or redirected onto adjacent properties where it inadvertently increases erosion and flooding issues or where it would impact sensitive environmental resources, such as salt marsh. To avoid these impacts, runoff control options should include components that redirect and spread the flow of water across a broad vegetated area or into a rain garden or vegetated swale (i.e., specially constructed depressions in the ground that are planted with vegetation).
- **Protected Species and Other Sensitive Resources** - If a project is proposed in or adjacent to nesting habitat for protected shorebird or turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts), project modifications may be required. For example, timing restrictions or other special conditions may be necessary to avoid digging up and destroying rare turtle nests. In addition, planting vegetation in open sandy areas may be prohibited because this habitat is needed for piping plovers and diamond-backed terrapin nesting. Additional information on protected species is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife. Project modifications may also be necessary in horseshoe crab spawning areas, and information is available from the Massachusetts Division of Marine Fisheries. Finally, projects must be designed to protect any nearby wetland resources, such as salt marsh and eelgrass beds.
- **Impermeable Soil Layers on Banks** - When there is an impermeable layer of soil (like clay) underlying permeable sediments in a coastal bank, water that infiltrates into the ground may flow along this impermeable layer toward the bank face. This concentration of water flow may exacerbate erosion where the water breaks out onto the bank face. The runoff control techniques described below may address this issue. However, it is not

always obvious that this situation exists and is exacerbating erosion on a bank. Therefore, professional assistance may be needed to identify the problem and determine the most appropriate techniques to address it.

Design Considerations for Common Runoff Control Techniques

The following section describes a variety of techniques that can be used to help control runoff erosion problems. Specific suggestions for proper design, construction, and implementation are listed for each technique.

Reduce Impervious Surfaces

Reducing the area covered by impervious surfaces slows overland flow and allows water to naturally seep into the ground. To reduce impervious cover:

- Construct driveways or patios with pea stone, gravel, crushed shells, or other pervious materials, rather than using impermeable pavement or concrete.
- Avoid the use of dense-graded aggregate, stone dust materials, and other products that prevent water from permeating into the ground on driveways, patios, or walkways. These products are designed to eliminate voids in the compacted surface, which causes these areas to become impervious.
- Minimize the footprints of proposed buildings and impervious surfaces as much as possible.

Additional Benefit - Improved Coastal Water Quality
Contaminants carried in runoff can significantly harm coastal water quality. Oils and greases washed from roadways and driveways and pesticides from lawns can introduce toxins to coastal waters. Bacteria in runoff can lead to closed shellfish beds and swimming areas. Nutrients from fertilizers, pet waste, or septic systems can lead to nuisance plant or algae growth, which can reduce oxygen supplies (leading to fish kills and odors) and shade out eelgrass beds. Runoff control techniques allow the runoff to seep into the ground where some contaminants may be filtered out by the soil or absorbed by plant roots, minimizing contamination of coastal waters.

Replace Lawns with Natural Plantings

Lawns exacerbate runoff issues because water readily runs over mowed grass and the soils under lawns tend to compact to create an impervious surface. Replacing lawn with longer grass, shrubs, and other vegetation can therefore significantly improve runoff problems. Where possible:

- Restrict the use of mowed lawns to areas needed for pathways and recreation.
- Avoid mowing the lawn right up to the edge of the dune, bank, beach, or marsh (which has the added advantage of keeping people back from the edge—foot traffic may exacerbate erosion).

Extensive irrigated lawns that slope seaward have exacerbated the erosion of this coastal bank. **(Photo: CZM)**

Plant Vegetated Buffers

Vegetated buffers are strips of high grasses, shrubs, and other plants (other than lawn). These buffers absorb runoff, slow its overland flow, and break the impact of raindrops or wave splash. The plant roots also bind the soils and help improve the stability of the area. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for additional information on using plants for coastal erosion control. To improve the success of runoff control projects:

- Plant vegetated buffers 5-10 feet in width landward of the top of the bank, dune, or beach to be protected.
- Plant salt-tolerant grasses with extensive root systems to provide more immediate erosion control. Though trees and shrubs may look more stable, grasses can grow more quickly and effectively stabilize large areas and require less maintenance to thrive.
- Plant native and salt-tolerant species that are adapted to local conditions and require less maintenance, watering, and pest control.
- Select appropriate species for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific instructions for watering, fertilizing, and general care and maintenance.
- Plant trees far enough back from the top of coastal banks to ensure that their weight does not contribute to bank instability.
- If trees on or near the bank are leaning, they may increase instability of the bank and may need to be pruned or removed.
- Do not place dead plant material, such as lawn clipping, brush, and discarded Christmas trees, on a bank or other coastal area. These dead plant materials limit the natural growth and establishment of plants and do not have roots that help bind soils together. Many municipal landfills accept yard waste for composting.
- Some of the most effective plants for vegetated buffers in coastal areas include beach plum, bayberry, Virginia or Carolina rose, arrowwood viburnum, sweet fern, and bearberry.

Fertilizer can cause nuisance plant or algae growth that can degrade water quality. The nitrogen in fertilizer is a particular problem in coastal waters. Consequently, the use of fertilizer on vegetated buffers, as in all coastal areas, should be limited as much as possible. When designed and maintained correctly, vegetated buffers actually filter out nitrogen and other contaminants from inland sources, helping to reduce coastal water contamination.

Install Vegetated Swales and Rain Gardens

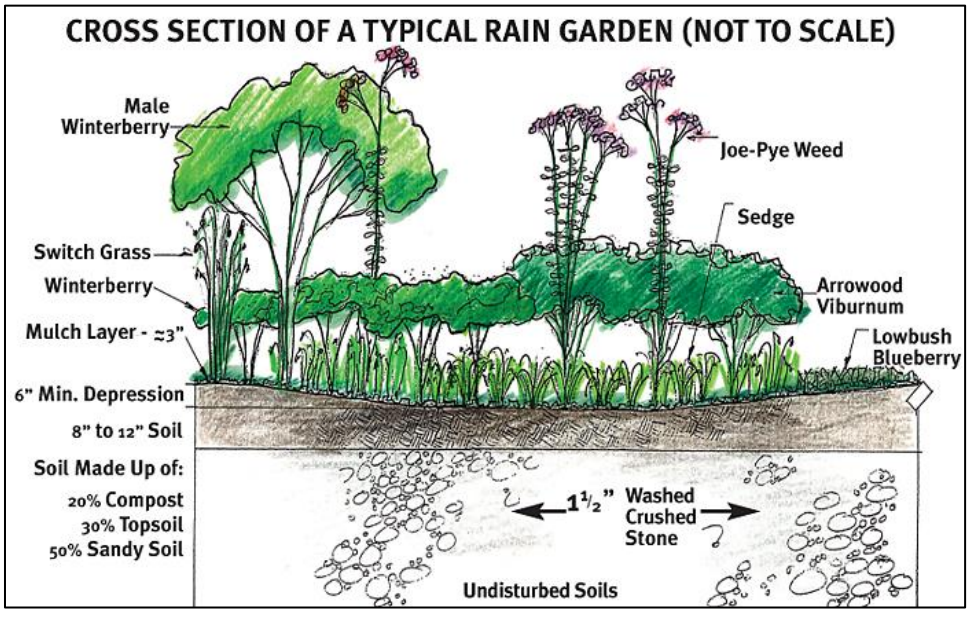
Vegetated swales are channel-like depressions in the ground used to slow, filter, and direct water to another location. Rain gardens are wider and flatter depressions that allow for the maximum collection and infiltration of water. Swales and rain gardens both use plants that tolerate both wet and dry conditions to ensure plant survival (swales often use grasses, while rain gardens are planted with a mix of grasses, perennials, shrubs, and trees).

A large rain garden. **(Photo: Massachusetts Bays National Estuary Program)**

To maximize effectiveness and prevent problems:

- Place swales/rain gardens downslope from a downspout, driveway, or other impervious surface in a relatively flat area (with less than a 5% slope), at least 50 feet away from septic systems, 100 feet away from wells, and 10 feet away from a dwelling foundation. Regrade the area if necessary to create an appropriate location for the swale/rain garden. Consult with your municipal board of health before installing a rain garden or swale near a septic system or well to make sure the proposed setback is sufficient.
- Locate vegetated swales/rain gardens as far away from the top of a bank as possible to reduce the amount of groundwater that may flow toward the bank face and potentially cause erosion.
- Determine the appropriate size of the swale/rain garden needed to effectively capture the runoff based on average yearly rainfall, soil infiltration rates, the size of the area that runoff is draining from, and impervious surface cover. Swales and rain gardens constructed in wetland resource areas will need to meet specifications contained in the *Massachusetts Stormwater Handbook* if a permit is required by the Conservation Commission.
- Plant a series of interconnected swales/rain gardens if one is too small to hold and infiltrate the amount of water flowing into it.
- If necessary, add amendments to clay or poorly drained soils to increase the infiltration capacity of the swale/rain garden. Some of the existing soil may need to be removed and replaced with a layer of gravel, planting soil mix, and mulch.
- To help prevent runoff from washing out the mulch or soil in large storm events, consider installing a temporary erosion-control blanket made of natural fibers over the swale/rain garden to stabilize the soil until the plants become established. (See *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks* for further information.) In addition, if concentrated flow is being introduced from a driveway, downspout, or other source, spread a layer of crushed stone across the entrance point where the water comes into the swale/rain garden to slow the speed of the flow.

As with vegetated buffers, select appropriate plants for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific planting and care instructions. (See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for other tips.)



Adapted illustration courtesy of Comprehensive Environmental, Inc.

Regrade Site to Direct Water Away from the Shoreline

Regrading the area landward of a bank, dune, or beach can ensure that runoff flows away from the shoreline. With this technique:

- Grade the site to slope toward vegetated swales or rain gardens. As mentioned above, swales/rain gardens should be placed well away from the top of a bank.
- To prevent basement flooding, do not direct the water toward a dwelling.
- To prevent erosion of the regraded area, consider covering exposed soils with a temporary erosion-control blanket and successfully plant the area as soon as possible. See the *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*.
- Avoid regrading work during heavy rains when exposed soils are more vulnerable to erosion.
- Avoid making slopes too steep, which will accelerate the flow of runoff and may cause additional erosion problems. Consult a professional for site-specific assistance in determining the appropriate slope.

Construct a Vegetated Berm

A berm (i.e., a mound of soil or other sediment built as a barrier) can be used as a "speed bump" to slow the flow of runoff. It is important to:

- Strategically construct vegetated berms to address specific runoff problems. For example, place a berm landward of the top of a coastal bank to redirect runoff away from the shoreline, or use a berm as a barrier to block or redirect runoff from roads, other properties, and other offsite sources.
- Determine the height and overall shape of the berm based on site conditions, such as soil characteristics, existing vegetation, site slope, and volume of water flowing toward the berm. The steeper the slope of the site, the faster the water will be flowing, requiring a higher berm to redirect the flow. As for shape, a berm is generally more stable when its base is twice the width of its height.
- Select sediments to construct the berm based on the amount of runoff. For average water flow, a mix of sediments (such as well-drained soil and sand) provides an effective physical barrier while also allowing for infiltration. For higher water flow, coarser materials (such as sand and gravel) provide greater flow-through and infiltration (to avoid the pooling of water behind the berm).
- Cover the berm with a layer of topsoil and plant/seed the area to stabilize the soil (see *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*).
- Consider using a short-term natural fiber blanket to stabilize the berm while the plants get established (see *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*).

Capture Roof Runoff

Significant quantities of rainwater and snowmelt run into roof downspouts. This water can be directed into a rain barrel, where it can be stored for reuse as irrigation water, or into a system designed to immediately infiltrate the water into the ground, such as a drywell or a French drain. When using these techniques:

- Place rain barrels below downspouts (55 gallon drums are the most common size for rain barrels). Cut the downspout to fit directly into the rain barrel. Special adaptations can be used, such as a spigot to attach hoses to reuse the water or an overflow hose to direct any overflow away from the foundation. Rain barrels should have a screen and cover to keep out mosquitoes, leaves, and debris.

- Design the drywells/French drains to channel water away from foundations. For sites directly adjacent to banks, French drains are generally preferred over drywells because they disperse the water infiltration, which helps ensure that the water successfully seeps into the ground and does not flow toward the bank face.
- Base the storage capacity of the drywell/French drain on the quantity of roof runoff, as well as on the depth of the water table. The bottom of the drywell/French drain should be at least two feet (but preferably four feet) above the seasonal high groundwater level.
- Drywells need to be at least 10 feet from building foundations, 50 feet from vegetated wetlands or tops of coastal banks, 50 feet from any component of a septic system, and 100 feet from wells.

Avoid or Reduce Watering of Lawns and Plants

Watering less keeps soils from becoming saturated, allowing them to more effectively soak up rainwater and other runoff. To water less:

- For the first year, if necessary, use a temporary irrigation system (such as drip tubing on a timer) while newly planted vegetation becomes established (see the planting instructions for specific watering requirements). Once the plants are established, watering is only required during extreme drought.
- When nature does not provide enough water to keep a lawn green and growing, allow it to go dormant. Though it may appear dead, this dormant state allows grass to preserve the vital parts of the plant during times of heat and low moisture and revive with the first saturation.
- Avoid cutting grass too short (generally no shorter than 2 inches). Taller grass has a deeper and more extensive root system, which enables the lawn to better withstand heat and drought.
- Plant less lawn grass and more drought-tolerant grasses and vegetation.

Slow the Flow of Water

By allowing water to spread out and flow over a wider vegetated surface, infiltration will increase, erosive forces will decrease, and runoff will be reduced. Specifically:

- Reduce the use of walls, solid fencing, curbs, etc., that concentrate runoff and create channels and gullies.
- Design discharge points for downspouts or other conduits of water to avoid causing scour, gullies, erosion, or alteration to vegetation. Place splash blocks or level spreaders (structures designed to uniformly distribute concentrated flow over a large area), or small amounts of gravel, at these discharge points to minimize erosion.
- Eliminate curbs or small retaining walls for defining the boundaries (such as between a driveway and lawn), which can channelize runoff and concentrate erosive forces. Replace curbs or walls with vegetated swales or rain gardens that promote infiltration and avoid channelization.
- If road runoff is an issue on your property, contact your town or city to determine if there is a drainage easement (an attachment to a property deed which states that access to part of the property is given to a third party, usually a community, for the purpose of maintaining drainage). If there is no easement, consider rain gardens parallel to the roadside to promote infiltration of road runoff. If there is an easement, work with your local officials to address the issue.

Heavy Equipment Use

If heavy equipment is needed for a project to address runoff, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and protected species habitat; and related impacts. When mechanical equipment is being

used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substance.

Permitting and Regulatory Standards

Most options for addressing runoff will likely require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission if they are within 100 feet of any "wetland resource area" defined under the Act (these resource areas include coastal banks, dunes, beaches, and floodplains). For very large projects, additional permits may be needed from the local, state, or federal agencies. Permits or approvals may also be required from other state agencies and local departments, depending on the location and the work involved. Often, Conservation Commission staff are available to meet with applicants early in the design process to go over the important factors that need to be considered.

Generally, regulatory programs are supportive of runoff control projects, provided they do not interfere with the ability of coastal landforms to naturally move and shift. To obtain a permit, projects need to be designed to minimize impacts to neighboring properties and sensitive resource areas (e.g., beaches and dunes) and prevent impacts to salt marsh, which is protected by the various regulatory programs.

Professional Services Required

Certain techniques that do not alter the property, such as reducing lawn irrigation or installing a rain barrel, can be easily done by the homeowner without a permit. Other simple projects, like planting a buffer strip of native vegetation along the top of a bank or replacing a paved driveway with crushed shell, can often be permitted and conducted by the homeowner in consultation with the local Conservation Commission. A homeowner may also be able to install rain garden or vegetated swale, depending on the complexity of the design. Because of the impacts that can be caused by inappropriately directed runoff, however, projects in or adjacent to sensitive resource areas (e.g., endangered species habitat) or that redirect the flow of runoff are likely to require professional services. A registered professional civil engineer, registered landscape architect, or other environmental professional with experience in managing runoff and landscaping for runoff control can be chosen to: 1) study the landscape and identify the current runoff sources under various storm conditions; 2) identify options to increase permeability, reduce channelization, and redirect runoff away from the shoreline without impacting sensitive resource areas or neighboring properties; 3) determine if any permits are required for the project; 4) identify regulatory requirements and ensure the project fully conforms with those requirements; 5) prepare plans for permitting; 6) prepare design specifications for construction; and, if needed, 7) oversee construction, monitoring, and maintenance.

Project Timeline

It may take as little as two to six months to design, permit, and install a runoff control project, assuming only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters and sensitive resources to be protected), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), and/or the weather conditions during construction.

Maintenance Requirements

Many runoff control techniques, such as reducing impervious surfaces and regrading the site away from the shore, require no maintenance when designed and installed successfully. Other techniques require only routine maintenance similar to other yard maintenance requirements. For example, runoff reduction projects using live plants require replacement of dead plants and may require watering during periods of drought.

For rain barrels, debris must be cleared away from the inlets on a regular basis. In addition, unless the rain barrel can withstand freezing temperatures, it should be cleaned out at the end of the fall and stored indoors. Keep roof gutters and other pipes clean to minimize the amount of sediment and other particulates that may enter a rain barrel, dry well, or French drain. Dry wells and French drains should be inspected regularly and cleaned to maintain proper function and drain time, which is 72 hours or less. If soils become compacted or clogged, they will not be able to handle additional water and may cause water to back up. The dry well or French drain may need to be replaced if drain times fall below the specified requirements.

When rainfall exceeds levels the project was designed to handle, more intensive maintenance activities are necessary. For example, a berm may require reconstruction if it is eroded or may need to be replanted if vegetation is damaged during severe rains (immediate repairs may be needed to ensure no further deterioration). After a severe rain event is a good time to evaluate whether the runoff control project functioned as intended. A brief consultation with the professional who designed the project can help to determine whether any modifications are needed.

Project Costs

With runoff control projects, there is typically a range of options available that address increasing runoff quantities. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of runoff control projects are the severity of erosion, volume of runoff that needs to be redirected, size of the area that needs to be addressed, quality of materials used, and complexity of project design and permitting. In addition, the type of runoff control and size of the area to be addressed will determine the construction and maintenance costs. In comparison with shoreline stabilization options, runoff control projects typically have relatively low costs for design and permitting, construction, and maintenance. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Related techniques covered in the CZM StormSmart Coasts menu of shoreline stabilization options are *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* and *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*.

The following resources also provide valuable information on runoff control:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- CZM's CZ-Tip - Keep Waterways Clean by Filtering Pollutants with Plants discusses reducing runoff impacts by planting vegetated buffers.
- The Massachusetts Department of Environmental Protection's (MassDEP) Vegetated Buffer Strips: Slow the Flow to Protect Water Quality explains how vegetated buffer strips function and how to create them.
- The U.S. Environmental Protection Agency's (EPA) National Menu of Stormwater Best Management Practices has searchable fact sheets on berms, regrading, swales, and other stormwater control practices.
- EPA's GreenScaping: The Easy Way to a Greener, Healthier Yard provides information on yard maintenance to reduce water usage.
- *Rain Gardens Across Maryland* (PDF, 14 MB) discusses locating, siting, and designing rain gardens and calculating impervious surfaces (rainfall depths and plant species are specific to Maryland).

- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- MassDEP's *Erosion & Sedimentation Control Guidelines* (PDF, 4 MB) give best management practices for managing sediment and runoff.
- MassDEP's *Massachusetts Stormwater Handbook* provides design specifications for rain gardens, drywells, and swales.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

Commonwealth of Massachusetts
Charlie Baker, Governor

Executive Office of Energy and Environmental Affairs
Matthew A. Beaton, Secretary

Massachusetts Office of Coastal Zone Management
Bruce K. Carlisle, Director

Massachusetts Office of Coastal Zone Management | 251 Causeway Street, Suite 800 | Boston, MA 02114 | (617) 626-1200
CZM Information Line: (617) 626-1212 | CZM Website: www.mass.gov/czm

This is a publication of the Massachusetts Office of Coastal Management (CZM) pursuant to the National Oceanic and Atmospheric Administration Award No. NA12NOS4190086. This publication is funded (in part) by a grant/cooperative agreement from the National Oceanic and Atmospheric Administration (NOAA). The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies. ***This information is available in alternate formats upon request.***

Publication Date: December 2013, with updates in 2018