A PROPERTY OWNER'S GUIDE TO

Protecting Your Bluff

UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

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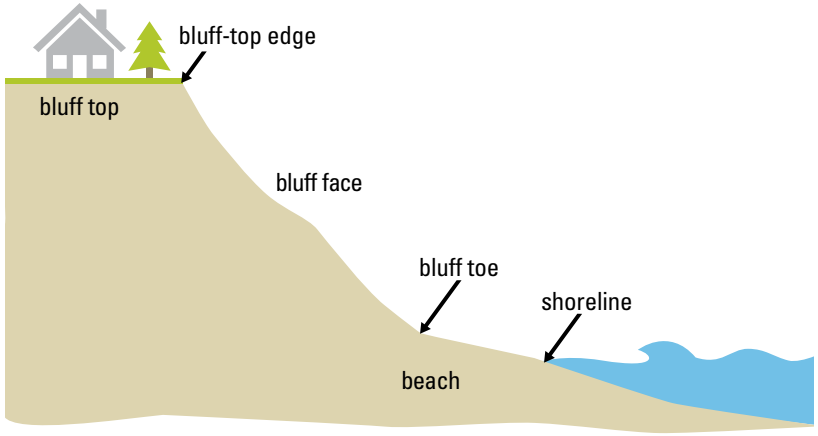
CONTENTS

CHAPTER 1 INTRODUCTION

LIVING ON A GREAT LAKES COASTAL BLUFF

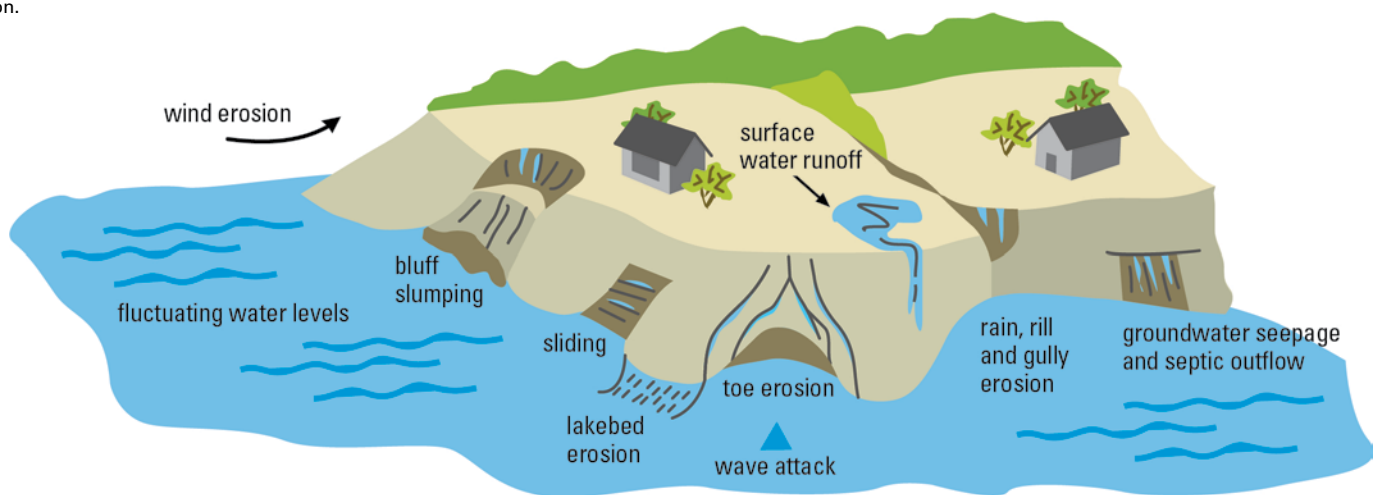
This guide is intended to help Great Lakes coastal bluff property owners maintain and enhance the stability of their bluffs, as well as recognize obvious signs of bluff stability issues that may need further attention. Great Lakes coastal bluffs are a unique place to live because of the dynamic coastal processes that continually shape and change them. The recession, or landward erosion, of coastal bluffs is a natural phenomenon that occurs in response to processes acting from both the land and the water, across all zones of the bluff from the top to the bottom. The bluff top is where coastal investments like homes, businesses and infrastructure are often located. The sloping zone below the top is known as the bluff face or bluff slope. The bluff toe is at the base of the bluff and is where the bluff interacts with the lake. The beach lies between the bluff toe and the shoreline, which is the point at which the lake meets the land.

Bluff stability is the balancing act between the force of gravity pulling down on the bluff and the bluff's shear strength, which is the ability of the bluff soils to resist those forces. If the force of gravity becomes greater than the shear strength, the bluff slope becomes unstable and may collapse. An unstable bluff can fail rapidly in a large slump or progressively in a series of slides that work their way up the bluff over a period of years. Bluff stability is influenced by the bluff soil material, bluff slope angle, wave erosion, Great Lakes water levels, nearshore sediment transport, surface water runoff, groundwater saturation and seepage, and human activities on or near the bluff.



Major zones and features of coastal bluffs.

Causes and effects of coastal erosion.



Bluff soils

Wisconsin's Great Lakes bluffs are composed primarily of glacial till — a mixture of sand, silt, clay and rocks — in varying layers left behind when the glaciers retreated about 10,000 years ago. These different soil types have different stability properties and differing resistance to erosion. Clay can stand as very steep slopes when dry only to fail as large landslides when wet or severely undercut. Sand is easily eroded but holds a gentler slope and rarely fails catastrophically. Exposed bedrock is more resistant than clay or sand to erosion, but it eventually succumbs to the force of freezing and expanding water within cracks and the continuous attack of waves.

Bluff slope angle

As the bluff slope angle becomes steeper, the balance between gravity and shear strength shifts and the bluff becomes less stable. For a given bluff sediment type, the steepest angle for which that material is generally stable is known as the "stable slope angle." A bluff may stand at an angle that is steeper than this stable slope angle for some time until a failure is initiated by heavy rainfall, rapid snowmelt, freeze-thaw or further steepening by wave erosion.

Wave erosion

Waves that reach the toe of the bluff wear away sediments, causing toe erosion. As toe erosion steepens the bottom of the bluff, upper portions of the bluff can become destabilized and fail. Wide beaches can provide a natural buffer to wave energy, causing the waves to break and release energy before reaching the bluff toe.

Water levels

Great Lakes water levels naturally fluctuate over a range of several feet from year to year. Water level fluctuations are primarily driven by climactic influences like precipitation, runoff and evaporation. High water levels make it easier for waves to reach the bluff toe more often and with greater height, increasing erosion. The Great Lakes have experienced numerous years-long periods of both high and low water levels in the past and this variability is expected to continue into the future.

Sediment transport

Beaches are built and maintained by the transport of sediments like sand and gravel in the nearshore area by waves and currents. When sediment transport becomes interrupted, such as by shore protection structures, it can lead to the loss of beaches that protect bluffs.

Surface water runoff

Surface water runoff that flows over the bluff-top edge and down the bluff face gradually loosens and removes exposed soil on the bluff face. As surface water flows concentrate, they can cut into the soil to form small erosion channels known as rills or larger channels known as gullies.

Groundwater

Excess groundwater can add extra weight to the bluff slope and weaken the shear strength, both of which destabilize the bluff. Groundwater that seeps out of the bluff face can also erode soil from the bluff face, a process called "sapping." Some bluffs contain "perched groundwater" — saturated zones above the main water table that are caused by layers of sediment that restrict the downward movement of water through the bluff. Groundwater problems are most severe during times of greatest water infiltration, such as during storms, spring snowmelts or lawn irrigation. Human influences like septic system seepage can also contribute to groundwater problems on bluff properties.

For a more detailed description of Great Lakes coastal processes, see "Living on the Coast" from the United States Army Corps of Engineers and Wisconsin Sea Grant: go.wisc.edu/rj39ez.

TAKING STEPS TO PROTECT YOUR PROPERTY

All coastal bluff properties can benefit from efforts to enhance bluff stability and limit the effects of human development on the bluff. Since bluff stability can be impacted from both the land and the lake, it is important to think about managing the whole bluff from top to toe. There is also no "one-size-fits-all" solution to bluff erosion because of the variability of Great Lakes coastal conditions from site to site, even between adjacent properties. However, there are a number of general guiding principles for maintaining and enhancing stability on nearly any bluff:

- Manage land use to keep structures and other assets as far away from the bluff-top edge as is feasible
- Avoid adding excess weight and other disturbances near the bluff-top edge
- Direct surface water runoff away from the bluff-top edge
- Minimize inputs to the groundwater and remove excess groundwater that causes slope stability issues
- Maintain and enhance bluff vegetation, especially deep-rooted native species
- If absolutely necessary, use well-designed shore protection structures and slope stabilizing earthwork to address bluff instability that threatens buildings

Following these principles, this guide will help users assess their bluff-tops (Chapter 2) and the bluff face and toe (Chapter 3) to look for obvious signs of bluff stability problems and think through potential management practices to enhance bluff stability. Considerations for selecting deep-rooted native bluff vegetation are described in Appendix A, including a list of herbaceous ground cover, shrubs and tree species that are suitable for southeastern Wisconsin's coastal bluffs.

Many of the practices described in this guide require professional evaluation by a qualified coastal engineer, geologist or contractor. Wisconsin Sea Grant maintains a partial list of known Great Lakes coastal engineering firms and contractors: go.wisc.edu/lu905u.

For those concerned that bluff failure is an imminent threat to their own safety and that of their home, seek a professional evaluation from an experienced coastal engineer, geologist or contractor. Appendix B: When Your Home Is at Imminent Risk From Bluff Failure contains further considerations for properties in this situation.

For those planning to build near a coastal bluff, there is an opportunity to make informed planning decisions so that not only are new structures reasonably safe from the risk of bluff failure but also that development has as little impact on the bluff's stability as possible. Appendix C: Special Considerations for New Construction contains further information tailored for properties in this situation.

CHAPTER 2 BLUFF-TOP MANAGEMENT

The top of the bluff is where coastal investments like homes, businesses and infrastructure are often located. Because of this, the bluff top is where many human activities can either improve bluff stability or work to destabilize the bluff. This section describes the obvious signs of bluff stability problems that may be present at the bluff top and a number of bluff-top practices to promote bluff stability through managing land use, surface water runoff, groundwater infiltration and vegetation.

BLUFF-TOP INDICATORS OF SLOPE STABILITY ISSUES

There are a handful of visual signs that may appear at the bluff top that indicate stability issues with the bluff. It should be noted that there may be visual signs of bluff stability issues present on the bluff face or toe prior to indicators appearing at the bluff top. These signs are covered in Chapter 3: Bluff Face and Toe Management. While visual cues can be indicators of ongoing coastal bluff stability issues, they may not always be present before a bluff failure occurs. A professional evaluation is the only true way to determine whether a bluff is stable. Nevertheless, routine monitoring for visual indicators of bluff issues may give notice of ongoing issues and signal a need for further investigation by a professional.

Ground cracks

Ground cracks at the bluff top may indicate the slope has started to slide or slump lakeward. This movement in the slope is likely to continue.

Tilted trees

Trees or shrubs that are leaning toward the lake may indicate that the slope is unstable and a bluff failure is beginning.

Runoff drainage over the bluff-top edge

Pathways for runoff to collect and drain over the edge of the bluff can increase bluff erosion locally as water flows down the bluff face and removes soil particles. These concentrated drainage pathways usually result in rills and gullies on the bluff edge and bluff face.

Noticeable ponding of water or wetland vegetation on the bluff top

Areas of the bluff top that routinely have standing water after rains or sustain wetland vegetation like cattails may indicate high groundwater conditions in the bluff. These areas of ponding could also be locations

CLOCKWISE FROM TOP Horizontal ground cracks at the top of the bluff that preceded a slope failure. *Gene Clark*

Trees leaning lakeward on an unstable bluff slope. *Adam Bechle*

Runoff drained to a low spot on the bluff top and flowed over the edge, resulting in a bare, eroding face that was the only unstable portion on this stretch of bluff. *Adam Bechle*

where surface water drainage needs to be improved, as areas of ponding could be focusing a large input of water to the bluff's groundwater in a single location.

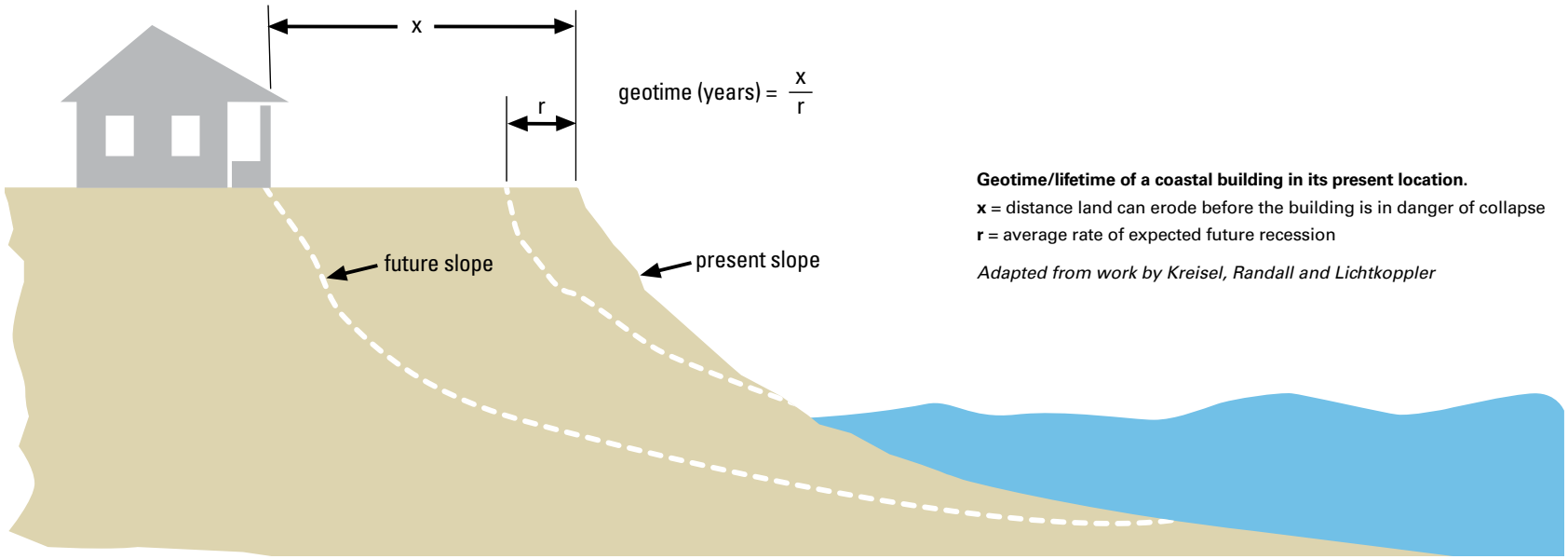
Decreased distance between buildings and the bluff-top edge

The distance a building sits away from the bluff-top edge is known as the "setback distance." This setback distance can be viewed as the geological lifetime of the building, which is the time until erosion and bluff failure encroach upon and consume the building. Monitoring the distance from the bluff-top edge to a structure can help you recognize changes in how the bluff-top edge is receding.

Whether a building is adequately set back from the bluff-top edge depends on a number of site-specific factors, including the following:

- Rate at which the bluff-top edge is expected to recede (i.e., feet of recession per year)
- Height of the bluff
- Bluff stability, including slope angle, soil type and height of groundwater
- Remaining useful life of the building (the total useful life of residential buildings is typically assumed to be 60 to 100 years, though many buildings last much longer)
- Amount of room needed to relocate the building if necessary

A professional evaluation by a qualified engineer or geologist can help determine what geological lifespan can be expected for a building on a given site, as well as an adequate setback distance to ensure the safety of the building over its remaining useful life.



Geotime/lifetime of a coastal building in its present location.
x = distance land can erode before the building is in danger of collapse
r = average rate of expected future recession

Adapted from work by Kreisel, Randall and Lichtkoppler

BLUFF-TOP MANAGEMENT PRACTICES

Bluff stability can be promoted through bluff-top management of land use, surface water, groundwater and vegetation. Property owners should also be sure to avoid common mistakes that work against bluff stability.

Land use

Locate structures an adequate distance away from the bluff-top edge. This reduces the risk that the structure will be affected by bluff failure during its useful life. This also reduces the chance that costly shoreline erosion control or bluff earthwork will be needed to protect the structure in the future. An adequate building setback minimizes the structure's impact on bluff stability from the additional weight placed on the bluff and changes to surface water drainage patterns. A professional evaluation by a qualified engineer or geologist can help determine an adequate setback distance for a given site. Before adding any new structure or other additions to a site, consult with your local planning and zoning office to see if ordinances specify a minimum required setback distance for these additions.

To enjoy scenic views, locate lightweight and easily moved minor structures like small gazebos and decks nearer to the bluff edge than the primary structure. Compared to a house, these types of structures will add much less weight to the bluff-top edge, are much smaller monetary investments and can be more easily relocated if threatened by bluff instability. Before adding any new secondary structure or other additions, consult with your local planning and zoning office to see if ordinances specify a minimum required setback distance for these additions.

Avoid adding excess weight or other disturbances near the bluff-top edge. Adding weight near the bluff-top edge from earthwork, machinery, buildings, pools or other heavy additions increases the loads on the bluff and reduces stability. Limit substantial digging or other ground disturbances near the bluff-top edge. Also avoid unnecessary compaction of soil on the bluff top during landscaping or construction. Compaction of soil can limit the soil's ability to absorb water, leading to increased runoff.

Lake view from a home with a more-than-adequate setback from the bluff-top edge. *Sara Stathas*

Permeable pavers used for bluff-top parking spots. *Adam Bechle*

LEFT Before moving, 2007. *Wisconsin Coastal Management Program and David Mickelson.* RIGHT After moving, 2018. *Capt. Dennis Carr, Wisconsin Wing, Civil Air Patrol*

Minimize use of impervious surfaces, especially near the bluff-top edge. Paved driveways, patios, paths, tennis courts and other impervious surfaces prevent water from infiltrating into the soil, which can increase the amount of rainfall and snow melt that travels over the bluff-top edge. Limit the footprint of impermeable surfaces like driveways and patios as much as is feasible. The use of permeable materials like porous pavement, pavers and geogrids can also reduce the impact of these traditionally impermeable features. For any impervious surfaces on the bluff top, runoff should be directed away from the bluff-top edge. (See Surface Water Runoff section for practices.)

Consider the feasibility of building relocation as a future option to protect your home. Relocating a building an adequate distance away from the bluff-top edge is one option to protect a home threatened by bluff instability. Even if your home is not at imminent risk of bluff failure, it is wise to plan for how you might protect your home from future erosion. Relocating a building involves moving the building landward from the bluff-top edge, constructing a new foundation, reconnecting utilities and landscaping. Moving a home may seem like a daunting process, but it can actually be a viable option for Great Lakes coastal property owners. In fact, relocation can oftentimes be the most cost-effective option to protect a home from erosion and bluff failure compared to trying to slow or halt erosion.

A professional building mover can help assess the feasibility of moving a home and the associated costs. The following professional associations maintain contact information for their members.

- Wisconsin Building Movers Association, wisbma.org
- International Association of Structural Movers, iasm.org/iasm-members/member-directory

Monitor changes in land development occurring landward and adjacent to the property. Construction and reconstruction of roads, ditches, sewer lines, homes, commercial buildings, industrial plants and other structures can alter surface and groundwater flow to the detriment of coastal slope stability nearby. Contact the party responsible for the project and the government agency that regulates the development

to express any concerns and inquire about analysis of the impacts on nearby slope stability.

Surface water

Any water that is not absorbed into the soil after a rain event, snow melt or even watering the lawn will flow over the land surface as runoff. Bluff-top site drainage is an important consideration to minimize the amount of surface water that flows over the bluff-top edge and down the face of the bluff.

Direct roof downspout drainage away from the bluff-top edge or capture roof runoff for later use. Point downspouts away from the bluff-top edge to avoid directing these concentrated flows of water over the bluff-top edge. Downspout extensions such as corrugated plastic pipe may be needed to direct discharge to an appropriate drainage location. Roof runoff drainage can also be captured in a rain barrel or cistern for later use, such as to water plants. It is also possible to route roof runoff drainage to a municipal or private drainage system (see next practice).

Direct runoff from paved or other impervious surfaces toward a storm sewer or private drainage system that routes water away from the bluff edge. If the water leaving paved or other impervious surfaces flows over the bluff-top edge or ponds in areas, consider a drainage system that reroutes runoff to a municipal storm sewer system (if available and allowable by local ordinance) or through a private drainage pipe to the base of the bluff or a ravine on the property. On stable bluff slopes, a properly designed rock spillway may also allow surface water runoff to flow down the bluff-top edge without eroding soil particles. Seek professional expertise in determining and designing appropriate drainage systems on your bluff.

Monitor drainage systems for leaks and perform routine maintenance. Regular monitoring and maintenance of drainage systems is critical to ensure that they actually route surface water to appropriate discharge points at the base of bluffs or ravines. Drainage pipes may become disconnected or severed over time with movements of the bluff. This could result in direct discharge of water to undesired locations like the

Downspout draining away from bluff-top edge. *Sara Stathas*

Drainage pipe carrying water to the base of the bluff. The pipe is located in a gully that surface water runoff previously eroded into the bluff. *Adam Bechle*

LEFT A small, vegetated berm prevents runoff from flowing over the bluff-top edge. Land surface profile is represented by the dashed line showing the berm rising slightly near the slope edge. *Lydia Salus* CENTER Rock spillway to take runoff to the base of the bluff without eroding bluff face soils. *Adam Bechle* RIGHT Surface runoff drainage pipe has become disconnected in multiple locations, depositing flows of water to the middle of the bluff rather than the base of the bluff. *Adam Bechle*

middle of the bluff slope, where surface erosion or unwanted inputs to groundwater could occur.

Construct a small berm to prevent surface water runoff from flowing over the bluff-top edge. Berms are elevated landscaping features that can redirect surface water runoff away from flowing over the bluff-top edge. To avoid adding significant extra weight to the bluff-top edge, berms should only be high enough to stop most flows of water. Berms should be well vegetated to hold the soil against erosion. (See the Vegetation section.)

Limit use of rain gardens or other infiltration features near the bluff-top edge, locating them as far from the bluff-top edge as possible. Rain gardens, dry wells and other features that collect and infiltrate surface water may contribute to a bluff's groundwater issues. For this reason, rain gardens may not be the best choice for managing surface water on a bluff. Rain gardens should be located as far from the bluff-top edge as possible, at least 50 feet away from the edge. Rain gardens may also be constructed with an underdrain that routes water that has been filtered through the rain garden to the bottom of the bluff or ravine.

Groundwater

Excess groundwater on coastal bluff properties can add extra weight to the bluff and reduce soil strength, both of which can destabilize the bluff. While many groundwater issues may be due to site geology, some groundwater issues on coastal bluffs start with human activities at the

LEFT A cleanout pipe is all that is visible of this French drain system that collects water that ponded at this location and routes the water to the base of an adjacent ravine. *Adam Bechle*
CENTER AND RIGHT Deep-rooted native vegetation compared with turfgrass root depth. *Sara Stathas*

bluff top. Bluff-top practices to address groundwater issues focus on minimizing inputs to the groundwater from land use and surface water drainage issues.

Minimize septic system inputs to groundwater near the bluff-top edge. To limit the impact of septic systems on groundwater, locate these systems as far from the bluff-top edge as possible and direct their discharge away from the bluff. If possible, locate these systems landward of the house. If a septic system is already in place on site, consider relocating it when it comes time to replace the system.

Intercept shallow groundwater at bluff-top areas that are routinely wet or pond water. An underground network of perforated pipes surrounded by gravel known as a French drain or trench drain can be used to collect excess shallow groundwater. This water can be routed to an appropriate discharge point, either in a municipal storm sewer or at the base of the bluff or ravine. Note that you do not want to eliminate all groundwater, or deep-rooted vegetation will not be able to establish. Seek professional expertise in determining and designing appropriate groundwater drainage systems on your bluff.

Vegetation

Plants play an important role in maintaining natural hydrological processes that capture, infiltrate, store and transpire surface water and groundwater. In addition to helping strengthen and stabilize bluff soil, plants also improve water quality and add aesthetic value and provide wildlife habitat. Managing vegetation for bluff stability is an important balancing

TOP A well-vegetated bluff top with a mixture of native ground cover and shrubs. *Sara Stathas* BOTTOM A framed Lake Michigan view over the top of low-growing vegetation. *Sara Stathas*

act between the aesthetic and property use preferences on the bluff top with landscaping practices that protect the integrity the bluff.

Maintain and enhance bluff vegetation, especially deep-rooted native species. Deep-rooted vegetation helps to stabilize the bluff by removing moisture from the soil and increasing the bluff's shear strength. By comparison, turfgrass offers little stabilization benefits due to its shallow roots. Avoid removing established native plants and manage the site for invasive species. If some vegetation must be removed, utilize practices like trimming, pruning or thinning to retain as much vegetation as possible rather than clearcutting.

The benefits of bluff-top vegetation can be enhanced by planting multiple native species that have well-mixed root networks and offer bluff stabilization benefits as well as aesthetic appeal. Ornamental or invasive plants are not recommended because they can outcompete native species, require more maintenance and have negative impacts on the local habitat. A mixture of trees, shrubs and herbaceous plants will provide a network of diverse, interwoven root structures to increase the strength of the bluff's soil. Further considerations for selecting plant species to enhance your bluff's vegetation are given in Appendix A: Selecting Suitable Vegetation for Enhancing Lake Michigan Coastal Bluff Stability in Southeastern Wisconsin.

Frame lake views through areas of low-growing and selectively pruned vegetation rather than removing vegetation. Views of the lake may become obscured by high-growing vegetation. Frame desired sightlines of the lake by pruning low tree limbs and planting low-growing vegetation in these areas. There are also several shrubs and trees that tolerate, or even thrive, when aggressively cut back, such as willows, cottonwoods and aspen. Find out more about how you can choose low-growing species by reading Appendix A: Selecting Suitable Vegetation for Enhancing Lake Michigan Coastal Bluff Stability in Southeastern Wisconsin.

Remove large trees near the bluff-top edge. Large trees can add excess weight to the bluff-top edge. Trees near the bluff-top edge may tip over, tearing out a large portion of the bluff top with them. As erosion encroaches upon large bluff-top trees, consider cutting or top-killing the tree to

remove the excess weight. The remaining root system will continue to hold the soil in some capacity.

Practice lawn care that encourages healthy, deep-rooted grass. While a turfgrass lawn has limited bluff stabilization benefits, certain lawn care practices can encourage grass to grow deeper roots. Set the mower height high to leave longer grass, leave grass clippings on the lawn and water only as needed.

Refrain from mowing along the bluff-top edge. Leaving an unmowed area near the bluff-top edge allows the vegetation there to grow deeper roots to hold soil in place and naturally dewater the bluff edge. This unmowed buffer should be at least 10 feet wide, though more is better.

Plant a vegetated buffer of deep-rooted native plants at the bluff-top edge. If the bluff top has turfgrass up to the bluff-top edge, consider replanting this area with a strip of deep-rooted, native plants for better stabilizing benefits. A vegetated buffer should be at least 10 feet wide, though more is better.

Do not dispose of yard waste, grass clippings or brush over the bluff-top edge. Disposing of yard waste over the bluff-top edge and onto the bluff face can smother live vegetation and add excess weight to the bluff. Compost yard waste or take it to a municipal disposal center instead.

Limit irrigation of lawns and gardens near the bluff-top edge. Irrigation can help maintain certain types of vegetation, but it can also create excess runoff and add more groundwater to the bluff. To reduce the amount of irrigation required on your property, allow lawns to go dormant (i.e., turn brown) in the summer if natural rains are insufficient. Turfgrass does not typically die in this situation. As an alternative to turfgrass, native, deep-rooted plants that are naturally drought resistant can require little to no irrigation. If irrigation is needed, try to use practices that minimize water use, like drip irrigation.

Avoid creating tilled gardens and flower beds near the bluff-top edge. Tilled areas on the bluff top may become significant recharge areas for surface water to move into the groundwater. Locate these features as far from the bluff-top edge as is feasible.

A tree cut down near the bluff-top edge reduces weight on the bluff. *Adam Bechle*

Bluff top mowed with a buffer away from the bluff-top edge. *Adam Bechle*

Vegetated buffer with limited mowing close to bluff-top edge. *Sara Stathas*

CHAPTER 3 BLUFF FACE AND TOE MANAGEMENT

Stability issues may appear on the face and toe of the bluff before they work their way to the bluff top and impact homes. The bluff face and toe are treated together in this chapter because many of the physical processes that can affect these zones are connected and often need to be managed together to stabilize a bluff. This section describes the obvious signs of bluff stability problems that may be present at the bluff face and toe and a number of practices to promote bluff stability through managing land use, surface water runoff, groundwater infiltration and vegetation. If there are major bluff stability problems that threaten a home, some combination of bluff regrading and toe protection may need to be considered to stabilize the bluff.

BLUFF FACE AND TOE INDICATORS OF SLOPE STABILITY ISSUES

There are a handful of visual signs that may appear on the bluff face and toe that indicate stability issues with the bluff. These signs may be present before recession of the bluff top occurs. While visual cues can be indicators of ongoing coastal bluff stability issues, they may not always be present before a bluff failure occurs. A professional evaluation is the only true way to determine whether a bluff is stable. Nevertheless, routine monitoring for visual indicators of bluff stability issues may give notice of ongoing issues and signal a need for further investigation by a professional.

Surface water drainage rills or gullies

Rills, which are small channels eroded into the bluff face, can indicate that water is flowing from the bluff top over the slope and causing surface erosion of the bluff face. Gullies indicate that water drainage down the slope is concentrated enough to erode small valleys. Bluff crest recession is often more severe where gullies have formed.

Groundwater seepage

Wet areas in the middle of an otherwise dry bluff face may indicate that groundwater is seeping through the bluff face. Because saturated soils have a less stable slope angle than dry soils, the presence of groundwater in the bluff can reduce slope stability. Groundwater seepage may also cause “sapping,” in which the seeping water erodes soil from the bluff face.

TOP Rills on the face of the bluff caused by surface water drainage down the slope. *Sara Stathas* BOTTOM A small gully channel where surface water drains over the bluff face. Note the increased crest recession at the top of the gully compared with the surrounding bluff crest. *Adam Bechle*

TOP Water seeping out of the middle of the bluff face. *Adam Bechle* BOTTOM Cattail growth on the lower bluff face. Groundwater was visibly seeping from the face and likely contributing to the erosional scarp. *Sara Stathas*

Wetland vegetation growing on the bluff face

The presence of wetland vegetation like cattails on the bluff face likely indicates that groundwater is saturating the bluff face and providing an environment for these water-loving plants to thrive.

Tilted or curved vegetation

Trees or shrubs that are leaning toward the lake may indicate that the slope is unstable and beginning to move. Trees with trunks that are curved in the upslope direction may indicate slow lakeward slope movement known as “creep.”

Slides or slumps

Slides or slumps of the bluff face indicate recent slope movement. Future failures may be likely, especially if slides have not made their way to the bluff top yet.

LEFT Curved tree trunk on a slowly creeping bluff slope. *Adam Bechle* ABOVE Slides have led to trees falling into the lake. With the lower portion of the bluff destabilized additional slides are likely to continue further up the bluff. *Adam Bechle*

Lack or loss of vegetation

A loss of vegetation on the bluff face may indicate recent slope movement has occurred. A bare non-vegetated bluff face indicates that erosion is too rapid for plant growth to be established. Bluff slopes with minimal vegetation are also more susceptible to surface erosion from water flowing over the slope face.

Bluff toe erosion

Steep, near-vertical slopes at the base of the bluff known as scarps indicate that waves have begun to erode the bluff toe. Toe erosion can destabilize upper portions of the bluff face and lead to failure.

LEFT This non-vegetated slope is too steep for plants to take root. *Adam Bechle* ABOVE Significant toe erosion has led to steep scarps at the base of the bluff. *Chin Wu* RIGHT A partially vegetated bluff slope, with some vegetation loss due to slumping. *Sara Stathas*

IMPROVING YOUR PROPERTY'S BLUFF FACE AND TOE STABILITY

Bluff stability can be improved through management of bluff face and toe land use, surface water, groundwater and vegetation.

Land use

If shoreline access is desired, create dedicated low-impact pathways down the bluff. Unmanaged access up and down the bluff, especially over unstable areas, can cause surface erosion, damage beneficial vegetation and lead to the formation of unintended drainage channels. When planning access paths down the bluff, utilize naturally stable slope areas for access ways to beach and water. A switchback trail style can help to avoid creating a direct pathway for water discharge down the bluff. Minimize the widths of paths and stairs and limit the use of impervious surfaces to construct paths. Stairs down the bluff can be difficult to maintain due to slope movements. If stairs are needed, use open-backed steps to allow light to reach vegetation underneath. Before constructing

Bluff access path with open-backed steps. *Sara Stathas*

Brush and logs staked in to the bluff to slow the flow of surface water runoff. *Adam Bechle*

an access path, consult with your local planning and zoning office to see if there are ordinances on bluff access.

Surface water

Slow down water flowing over the bluff face. Implement practices to slow down the flow of surface water over the bluff face. Examples include coir logs with plantings, brush bundles, biodegradable blankets or live stakes, which are cuttings from tree branches. Also be sure to limit the amount of water flowing over the bluff-top edge as much as possible using practices described in Chapter 2: Bluff Top Management.

Groundwater

Remove excess groundwater with a drainage system. A drainage system can remove the excess groundwater in your bluff and route it to an appropriate discharge point to improve the bluff's stability. Only the excess water that could cause soil instability needs to be removed, as draining too much groundwater can inhibit the growth of deep-rooted vegetation. Common drainage types used on coastal bluffs include horizontal drains and wick drains. Horizontal drains are drilled directly into water-bearing soil layers, discharging down the bluff face through pipes or tubes. Wick drains are corrugated "wick" pipes that are directionally drilled from the bluff top to an outlet near the bluff toe, draining the water-bearing soil layers that the pipe intercepts. A professional with experience in solving groundwater problems should be consulted to design and construct appropriate drainage systems.

Vegetation management

Maintain and enhance bluff vegetation, especially deep-rooted native species. On the bluff face, the root network of plants strengthens and stabilizes the soil, helping to reduce surface erosion, soil creep and shallow slides. Plants can also slow down erosive runoff over the bluff face and help remove excess groundwater from the slope. A mixture of deep-rooted shrubs, herbaceous ground covers and small trees provides a network of diverse, interwoven root structures. Considerations for selecting native

plant species that can tolerate the dynamic bluff face environment are given in Appendix A: Selecting Suitable Vegetation for Enhancing Lake Michigan Coastal Bluff Stability in Southeastern Wisconsin.

Use temporary stabilization measures to help new plants establish on the bluff face. Soil movements and high-velocity surface water runoff on the bluff face can hinder the ability of vegetation to establish and thrive. In some cases, erosion-control matting, coir logs or synthetic geotextiles may be necessary to help stabilize soil on the bluff face while the vegetation establishes. Use of live stakes can help some plants like willows or dogwoods establish on the bluff face.

It can be nearly impossible to establish vegetation on a bluff face that is too steep, has ongoing slides or has significant runoff flowing down the face. These bluff faces are typically rather bare of existing vegetation already and likely need to be regraded before vegetation can establish. In this situation, consult with a professional engineer or geologist to evaluate the stability of the bluff (see Bluff Regrading Section on page 20).

Well-vegetated natural shoreline and bluff toe showing no signs of wave erosion, even at high water levels. *Adam Bechle*

Healthy bluff vegetation on the bluff face. *Sara Stathas*

Coir logs staked into the bluff to slow surface water flow down the bluff face and help vegetation establish. *Lydia Salus*

Where possible, establish natural shorelines at the bluff toe. A well-vegetated natural bluff toe and beach can provide some level of protection against toe erosion as well as habitat benefits and pleasing aesthetics. Natural shorelines may not fully withstand erosive forces from the lake but can help slow erosion by stabilizing bluff sediments and reducing the impacts of wave energy. If wave impacts to the beach and bluff toe are not significant, natural shorelines can be a sustainable option to help protect the bluff toe from erosion.

STABILIZING THE BLUFF FACE AND TOE

If bluff instability threatens a building that cannot be relocated, some combination of regrading the bluff face and slowing toe erosion may need to be considered to stabilize the bluff. These practices are often used in tandem, as regrading without addressing toe erosion can lead to slope stability problems in the future. On the other hand, a bluff already destabilized by toe erosion can continue to fail after toe erosion is slowed.

Regrade the bluff to a stable configuration

Unstable bluffs can be regraded to a less steep slope to improve stability, provided there will be enough space between the building and the edge of the regraded bluff. If toe erosion is a root cause of the bluff instability, slope regrading will not be effective in the long term until toe erosion is mitigated. Slope regrading options include the following:

- **Cutback:** Slope material is removed, and the new bluff slope is reshaped to a stable slope angle.
- **Fill:** Appropriate materials are added to the current bluff slope to create a new slope that is shaped to a stable slope angle.
- **Cut-and-fill:** Slope material is removed in some places and appropriate materials are used to fill in other locations of the bluff in order to make a new bluff slope that is shaped to a stable slope angle — a combination of cutback and fill methods.
- **Terracing:** Retaining walls or other structures are used to resist sliding of the slope, which allows a stable slope to be achieved over a shorter horizontal distance.

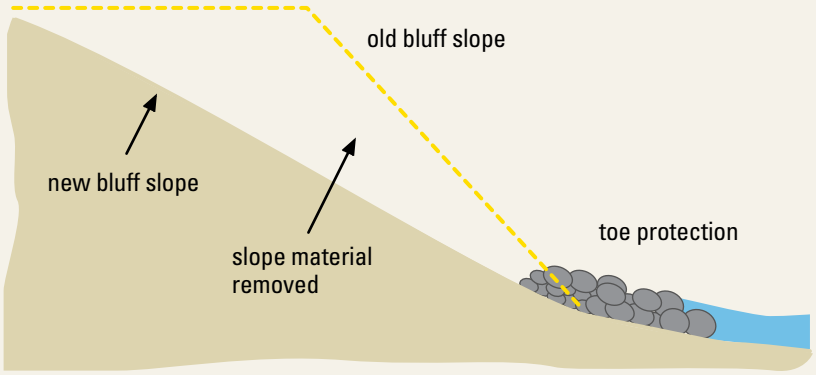
Check with local zoning offices and state regulatory agencies to learn what slope modification options are allowable in your area, as filling methods that require encroachment on the lakebed may not be permitted. Consult with a qualified engineer or geologist to discuss regrading options that may be suitable for your specific site.

Well-designed shore protection structures

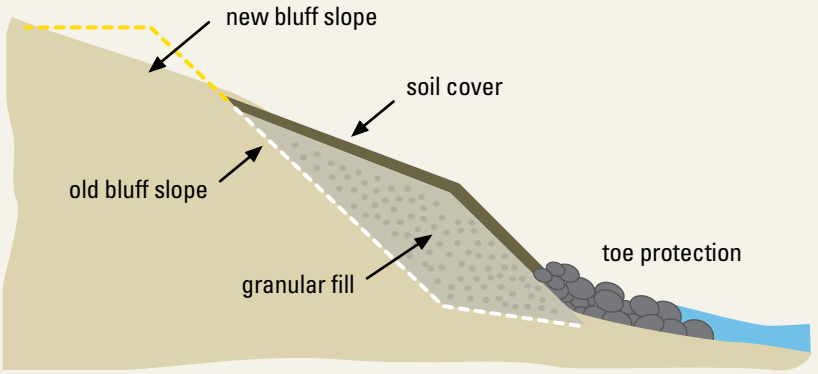
If absolutely necessary, use well-designed shore protection structures to slow toe erosion while also addressing bluff stability issues. Engineered shore protection structures should only be considered for properties with buildings that are at risk from bluff failure and where it would be extremely expensive or impossible to relocate the building. Shore protection structures fundamentally impact the natural processes of bluff erosion and transport of beach sediments along the shore. Construction of shore protection can in some cases lead to permanent loss of the beach in front of the structure, increased erosion at nearby properties and reduction in beach widths far down the shore. For these reasons, engineered structural protection at the toe of the bluff is often considered an option of last resort. While shore protection can slow toe erosion, existing bluff slope instability issues may still need to be addressed because an unstable bluff can continue to fail after toe protection is in place. Consider the other practices described in this guide, including regrading, water management and vegetation, with any shore protection project.

A number of shore protection types are used in the Great Lakes to slow toe erosion, including the following:

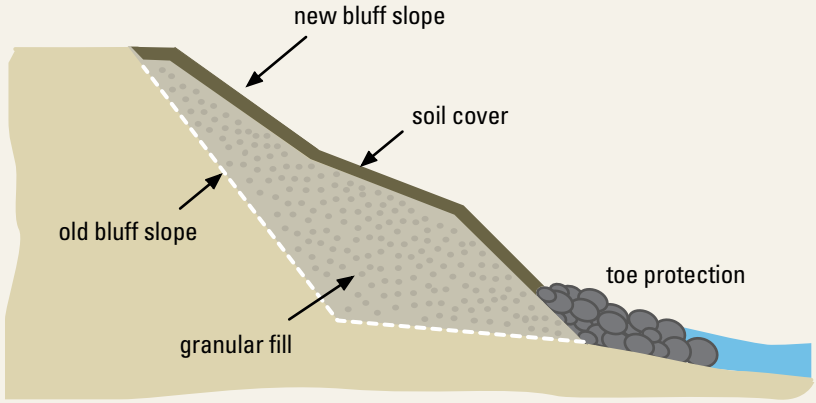
- **Revetment:** Interlocking pieces of stone or concrete on a gentle sloping face to directly protect the shore from erosion.
- **Seawall:** Vertical concrete or stone wall to protect the shore from erosion.
- **Breakwaters:** Stone or concrete structure built off shore to reduce wave energy at the coast.
- **Groins:** stone or concrete structure built perpendicular to the shore to trap sand and hold beach material in place.



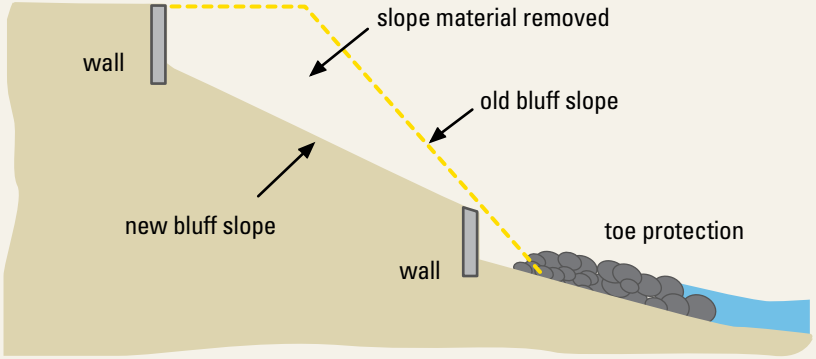
Cutback Slope Stabilization Method



Cut-and-Fill Slope Stabilization Method



Fill Slope Stabilization Method



Terraced Bluff Stabilization Method

Before and after a cut-and-fill bluff regrading project with shore protection. *Adam Bechle*

The Wisconsin Sea Grant publications "Living on the Coast" go.wisc.edu/rj39ez and "Great Lakes Coastal Shore Protection Structures and Their Effects on Coastal Processes" go.wisc.edu/95bo18 contain more detailed discussion of these types of shore protection.

Revetments constructed of large armor stones are by far the most commonly used armoring structures in the Great Lakes. A good revetment design will include the following:

- Armor stone layers of quality material sized for wave conditions at the site
- Filter fabric and a graded filter layer of smaller stone to prevent erosion of sediments through the gaps between the larger armor stone
- Appropriate slope for structure stability
- Sufficient structure height to prevent overtopping by waves
- Structure toe reinforcements to prevent undermining
- Flank protection at horizontal ends of the revetment
- A plan for inspection and maintenance
- Considerations to limit the impact of the structure on neighboring properties

Work with a qualified engineer and contractor

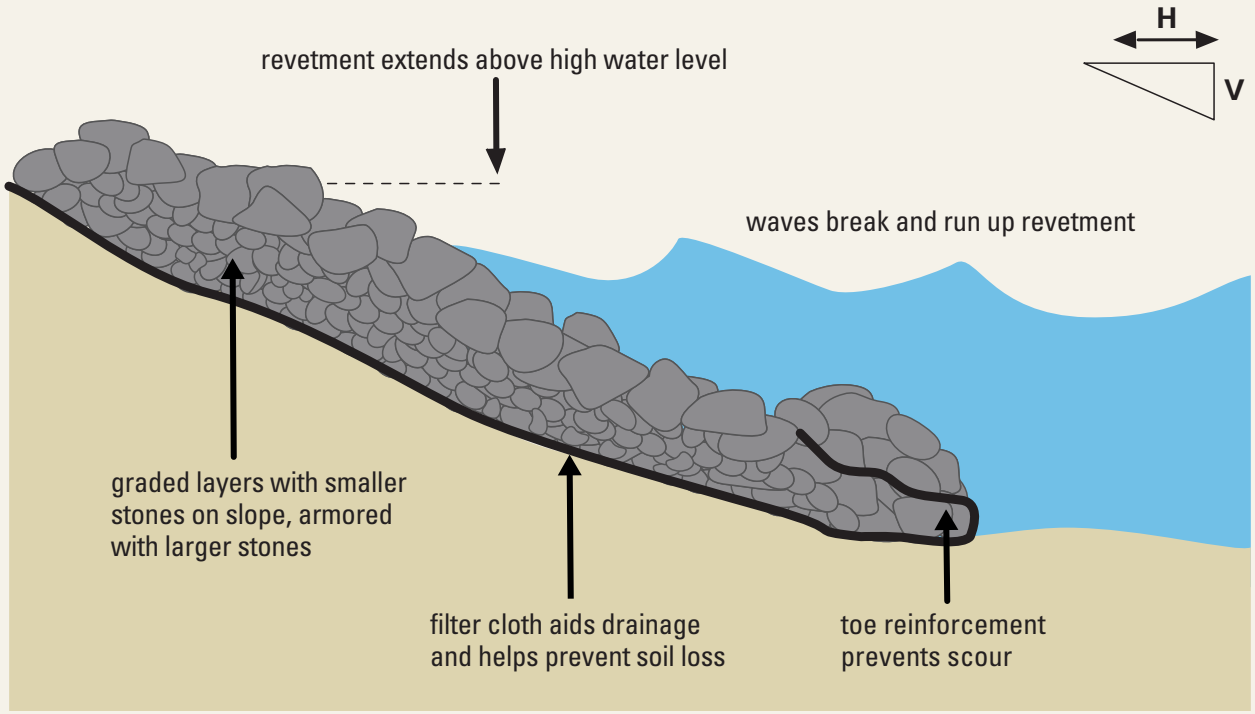
Shore protection as a do-it-yourself project is often done as a series of failed short-term experiments. Qualified and experienced professionals are necessary for finding long-term solutions. They can support the permitting process and help deal with concerns about a planned project. An investment in these services is the best way to achieve the desired performance and reduce costs during the period of ownership.

See "Wisconsin Sea Grant Fact Sheet: Working With Engineers and Contractors on Shore Protection Projects" go.wisc.edu/q856dt for additional information.

Wisconsin Sea Grant maintains a partial list of known Great Lakes coastal engineering firms and contractors: go.wisc.edu/lu905u.

ABOVE A stone revetment at the bluff toe. *Sara Stathas*

RIGHT Typical elements of a properly designed revetment. V:H describes the slope.



Work with neighbors on shore protection needs

If a shore protection structure is necessary to save a home at one property, neighbors may also have a similar need. Cooperating with neighbors on a larger shore protection structure can lead to cost savings on the project. With one larger project rather than multiple smaller projects, efficiencies in design may be realized, construction equipment is only mobilized once and access to the lake may be easier over multiple properties. Working together may allow the structure to be tied into existing shore protection structures on adjacent properties. Additionally, if each neighbor were to build a coastal structure individually, erosion could increase on unarmored shorelines next to each structure. While a cooperative shore protection structure may still lead to increased erosion at unarmored adjacent shorelines, these effects will not occur between each participating property.

Monitor and maintain shore protection structures

No shore protection structure is invulnerable to failure, which means that inspection and maintenance are essential to ensure continued toe protection. Shore protection structures most often fail incrementally during storms, which can reduce the effectiveness of the structure and lead to future failures. Shore protection structures should be inspected for signs of damage routinely, at least once per year. A thorough evaluation of shore protection structures requires a professional coastal engineering inspection and analysis. Property owners should also monitor their shore protection structures to identify common signs of structure failures, especially after large storms. These signs can include the following:

- **Flanking:** Erosion at and around unprotected ends of a structure.
- **Overtopping:** Erosion that is occurring on the land behind a structure, indicating that the structure is not constructed high enough to adequately protect against waves.
- **Displacement of armor stone:** Movement of armor stone that can destabilize the structure and expose the lighter core material to washout by waves.

LEFT Flanking around the unprotected end of the revetment has led to accelerated erosion. *Chin Wu*
RIGHT Overtopping of this revetment has led to erosion on the back side of the armor stone. *Adam Bechle*

CLOCKWISE FROM TOP Steel rebar in concrete rubble can rust and be a hazard to beach users. *Sara Stathas*

Poorly interlocked concrete blocks are easily moved by large waves. *Gene Clark*

Flat pieces of concrete rubble do not interlock well and may be easily moved by strong waves. Concrete rubble pieces are also easily broken apart under the force of waves. *Adam Bechle*

TOP Displaced armor stone has exposed the underlying filter layer to wave forces. *Adam Bechle* BELOW Cracked armor stone has split into smaller pieces. *Adam Bechle*

- **Cracked armor stone:** Armor stone that has split into smaller pieces that are likely of insufficient weight to resist wave forces. Stone with natural seams like limestone and dolomite is especially vulnerable to cracking due repeated freezing and thawing of water in the seams.

Plan for the eventual removal or replacement of unsuitable shore protection materials

Materials like concrete rubble can appear to offer toe protection but often fail to provide protection from erosion during large wave events and high water levels. Plan to remove unsuitable materials and either reestablish the natural shoreline or replace with an appropriate toe protection structure. Common materials that may not be suitable for use in shore protection on the Great Lakes include the following:

- **Concrete rubble and other construction site debris:** These types of materials were not intended to be used on the coast and tend to crack when used as shore protection.
- **Elongated, round or flat stone and concrete pieces:** Materials of these shapes do not usually interlock with each other, making them more easily displaced by wave forces.
- **Small stone or concrete pieces:** Armor material of insufficient weight (i.e., light enough for a strong adult to lift) can be easily moved by strong waves.
- **Materials with rebar or other metals:** When exposed, rebar rusts and presents a hazard to people on the coast.
- **Sandbags:** While sandbags can offer protection against flood waters, they will be easily displaced by large waves.
- **Timber or small concrete block walls:** Walls made with materials purchased at home centers typically will not stand up to large wave action.

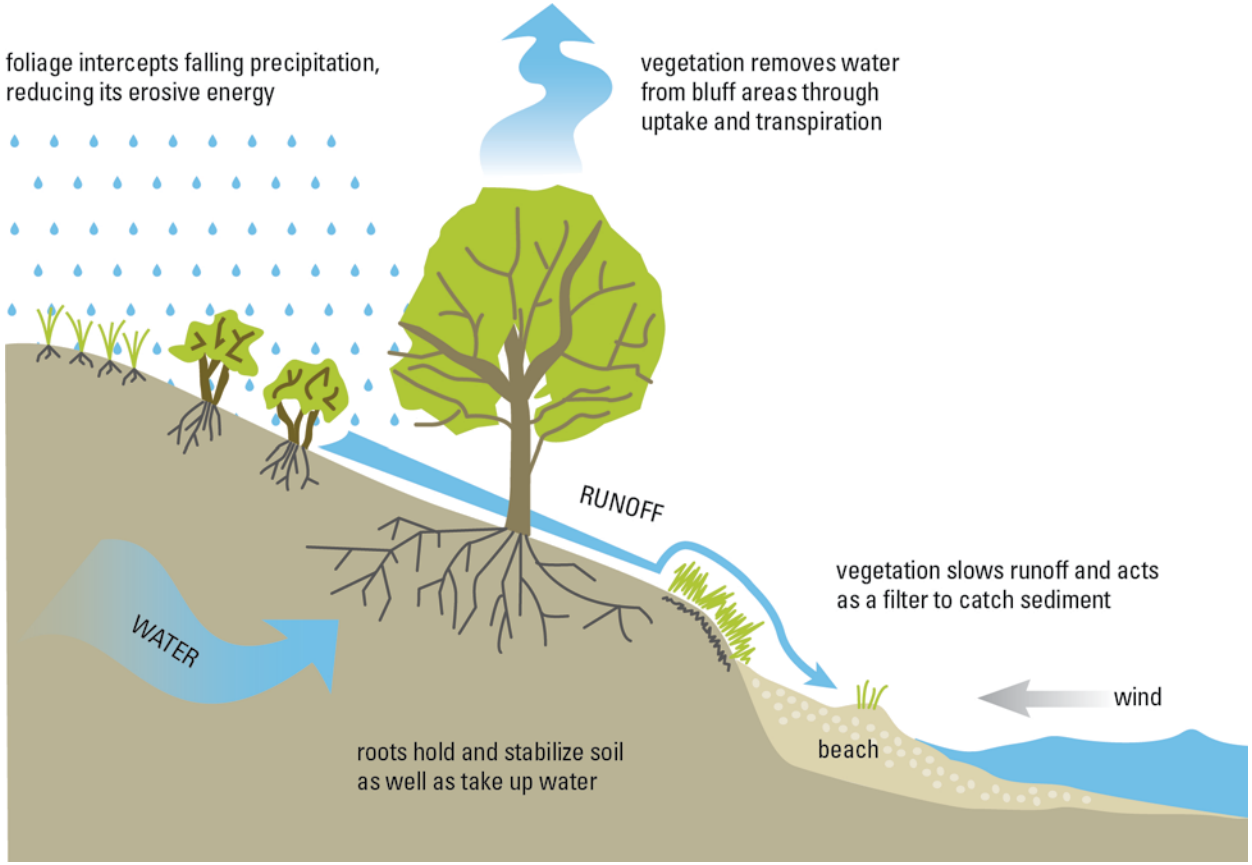
APPENDIX A

SELECTING SUITABLE VEGETATION FOR ENHANCING LAKE MICHIGAN COASTAL BLUFF STABILITY IN SOUTHEASTERN WISCONSIN

DAN CARTER, formerly with the Southeastern Wisconsin Regional Planning Commission
ADAM BECHLE, Wisconsin Sea Grant
LYDIA SALUS, Wisconsin Sea Grant
TIERNEY BOCSI, University of Wisconsin-Madison, Department of Forest and Wildlife Ecology

Vegetation is a significant line of defense against bluff erosion and failure, working in many ways to slow erosion and enhance stability (see figure on the next page). Under the ground, roots hold and add strength to the soil while also absorbing excess moisture and returning it to the atmosphere through transpiration. Above the ground, vegetation slows the velocity of runoff to limit its erosive capacity, captures eroded surface soil particles and intercepts precipitation as it falls to reduce runoff. These services combine to help reduce the amount of moisture in the soil and increase the bluff's shear strength, helping to stabilize the bluff. Vegetation also provides habitat for wildlife and attracts pollinators.

The tables on pages 32-37 provide information about native species that are generally suitable for Lake Michigan bluffs in southeastern Wisconsin. Many listed species may also be applicable outside this region — check with local horticulture extension specialists or nurseries to be sure. Selecting the appropriate vegetation for a bluff site can depend on stabilization needs, site characteristics and the intended purpose of the space. For each species listed, a set of stability, site use and plant growth characteristics are provided, as defined on the following page. Photos and descriptions of notable species are provided after the tables.



The benefits of vegetation (herbaceous, shrub and tree) on bluff slope stability.

To help identify a set of native vegetation species that would be suitable at a specific property, consider the overall stabilization needs of the site and how that aligns with how the space is used. Determine what areas of the bluff need stabilization as well as what types and heights of plants will fit the desired use of that space (i.e., aesthetics, open space, lake views, etc.). For example, a densely vegetated bluff top with tall shrubs and trees may maximize stability benefits but may block views of the lake. In this case, framing views of the lake with shorter shrubs and herbaceous cover may be a good compromise. Selecting vegetation that has a mixture of root types will provide a dense, interwoven network of roots that intersects multiple soil layers. Once the appropriate vegetation types, heights and root systems are identified to meet the stability needs and use of the space, select species that will tolerate the soil, moisture and sunlight conditions at the site.

STABILITY AND SITE USE CHARACTERISTICS

The following characteristics described for each species indicate how well suited a plant is for enhancing the stability of the bluff in tandem with how the space will be used.

Note: All plants listed in this guide are native to the southeastern Wisconsin area. Before using any alternatives, please check the Wisconsin Department of Natural Resources list of terrestrial invasive species at go.wisc.edu/136q3w to avoid using these potentially harmful species.

Plant type

The types of plants selected should align with the intended use of the space. Using a diverse mixture of plant types can combine the strengths of each type.

- **Herbaceous** plants do not have woody stems above ground. Herbaceous plants are generally low growing compared to shrubs and trees. Some herbaceous plants are fast growing and can be the first to establish at a site. The often fibrous or mixed root types of these plants contribute to erosion control.
- **Shrubs** are woody, perennial plants. They are smaller than trees, and their root systems are generally deeper and more extensive than herbaceous plants. In addition to erosion control, shrubs can provide privacy between properties.
- **Trees** are large woody plants. Their extensive root systems can penetrate deep through several soil layers, which helps to stabilize soil. However, large trees can add additional weight to the bluff and should not be planted near the bluff-top edge.

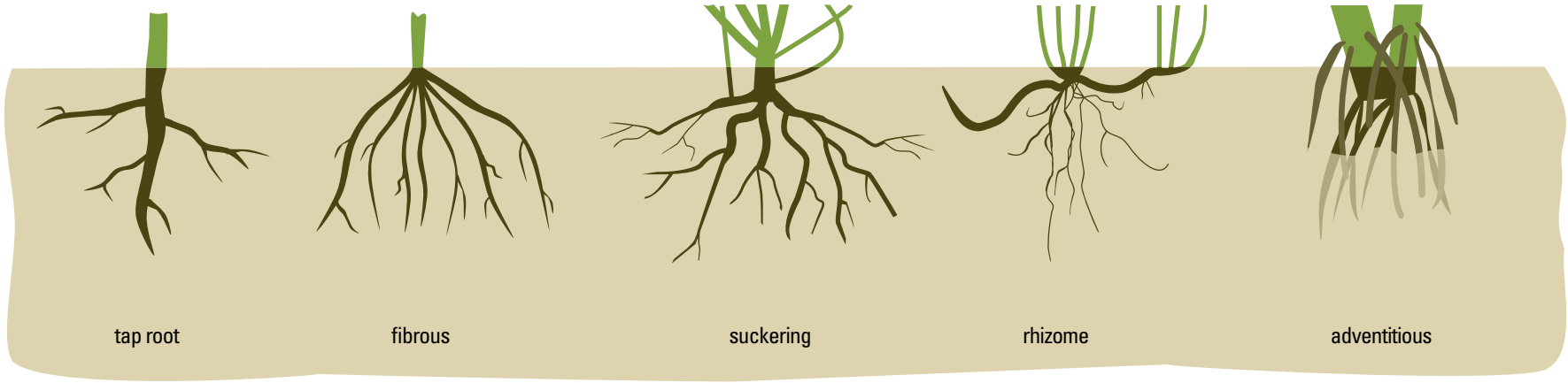
Usage Area

The characteristics of the bluff area that will be vegetated can affect what species may survive and thrive. This is particularly important regarding the stability and movement of soil typical at the site, as very steep or unstable slopes may be difficult to successfully vegetate.

- **Top:** The top of the bluff from the flat upland to the bluff crest or edge. May also be called the "table." The top is the most stable growing area of the bluff. Vegetation on the top acts to reduce surface water flows over the bluff edge and remove water from the soil. Vegetating a buffer strip in the dynamic zone near the bluff-top edge increases soil strength and reduces surface erosion. Large trees should be avoided near the bluff-top edge.
- **Face:** The slope of the bluff between the top and the toe. The face may experience soil slumps and slides, so vegetation in this area should be able tolerate some soil movement. Vegetation on the face helps hold the soil while also helping to slow surface water runoff. Be aware that the bluff face can be home to a variety of soil and light conditions.
- **Toe:** The base of the bluff to the water line. Vegetation at the toe should be somewhat resistant to dynamic changes in shore conditions, moisture and erosion processes. Vegetation at the toe may be used alone or in combination with shore protection structures to help slow soil erosion from wave action, splash and spray.

Mature Height

The height of vegetation can impact views of the lake. Be sure to select vegetation that allows the desired views of the lake or selectively place shorter vegetation to frame lake views.



Root type

A mixture of root types gives a dense, interwoven root network that increases the bluff's shear strength.

- **Taproot:** large vertical roots with lateral branches
- **Fibrous:** horizontally spreading roots, especially near the soil surface
- **Suckering:** produces a new shoot from original plant roots, creating a cluster of stems around the perimeter
- **Rhizome:** modified stem that grows horizontally, sending out new roots and shoots to spread and fill a larger area
- **Adventitious:** roots that develop from nonroot materials like stems in response to stressful conditions like burial

PLANT GROWTH AND TOLERABILITY CHARACTERISTICS

The following characteristics dictate how a specific species may survive and thrive at a site depending on the soil type, soil moisture, sun exposure and wildlife stressors.

Soil Type

Most species outlined in the table can live in almost any soil type commonly found in southeastern Wisconsin. The table notes plants that have preferences for certain soil classifications (sands, silts, clays or loams, which are composed of mostly sand or silt with little clay) or soil pH (acidic, neutral or alkaline).

Moisture Tolerance

The soil moisture at a bluff site can depend on the area of the bluff considered. For example, a site with a bluff top that has medium soil moisture may have a bluff face with moist or wet soil conditions near seepage seams in the bluff.

- **Wet:** saturated or soggy soil
- **Moist:** soil that does not completely saturate after normal rains or become dry between rains or watering
- **Medium:** soil that is thoroughly wetted but the surface dries before the next rain or watering
- **Dry:** no moisture present in the soil; soil grains are loose and a crust may form

Sun/Shade Tolerance

The amount and duration of sunlight a bluff site receives depends on the area of the bluff considered, the orientation of the bluff and shade provided by surrounding buildings and vegetation. Bluff faces and toes on the western coast of Lake Michigan are east facing, which means they receive light early in the day and are shaded during the afternoon. The bluff top is less affected by orientation.

- **Full sun:** vegetation gets six or more hours of direct sunlight per day
- **Partial sun:** vegetation gets approximately four to six hours of direct sunlight per day
- **Full shade:** vegetation gets less than four hours of direct sunlight per day

Wildlife and Pollinator Considerations

In addition to stabilization benefits, certain vegetation species can help support pollinators and provide habitat for local wildlife. Some wildlife, like deer, may also affect vegetation survivability as they browse, or eat, the leaves and buds of plants. The tables note important considerations where relevant.

- **Deer browse:** if deer are common, vegetation needs to tolerate deer browse in order to thrive
- **Wildlife:** seeds, nuts and bark of some vegetation can provide food for wildlife
- **Pollinators:** attracting butterflies, bees and other pollinators can be an added benefit of planting

HERBACEOUS GROUND COVER

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
White Snakeroot	*Ageratina altissima*	Top, ravine, toe	Fibrous with shallow rhizomes	1-3′	Any	Moist to somewhat dry	Partial sun to shade	Deer tolerant; flowers support native bees, butterflies and moths; host plant for moths
Common Milkweed	*Asclepias syriaca*	Top, face, toe	Fibrous, spreading rhizomes	2-6′	Any	Moist to dry	Full sun to partial sun	Deer tolerant, flowers support butterflies and native bees,* host plant for monarch butterflies
Sedges	*Carex* spp. and *Scirpus* spp.	Top, face, ravine, toe	Fibrous, some species spreading by rhizomes	0.5-3′	Any	Wet to dry, depending on species	Full sun to shade, depending on species	Deer tolerant, host plants for moths, seeds eaten by birds and small mammals
Wild Ryes	*Elymus* spp.	Top, face, ravine, toe, quick to establish	Fibrous	3-5′	Any	Moist to dry, depending on species	Full sun to shade, depending on species	Deer tolerant, host plant for moths and butterflies, seeds eaten by small mammals
Tall Boneset	*Eupatorium altissimum*	Top, face, toe	Fibrous	3-4′	Any	Medium to dry	Full sun to partial sun	Deer tolerant, flowers support many native bees and butterflies, host plant for moths
Great Blue Lobelia	*Lobelia siphilitica*	Top, ravine, toe	Fibrous, shallow	2-4′	Any	Moist to medium	Full sun to partial sun	Deer tolerant; flowers support hummingbirds and native, long-tongued bees like bumblebees
Bergamot	*Monarda fistulosa*	Top, face, toe	Deep fibrous roots and shallow rhizomes	3-4′	Any	Moist to somewhat dry	Full sun to partial sun	Deer tolerant, flowers support native bees*
Warm-Season Grasses (Switchgrass, Big Bluestem, Little Bluestem, Indiangrass, Rough Dropseed, etc.)	*Panicum virgatum, Andropogon gerardii, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus compositus,* etc.	Top, face, toe	Fibrous, deeply penetrating root systems, some species spreading by rhizomes (esp. switchgrass)	2-8′	Any	Moist to dry, depending on species	Full sun	Deer tolerant, host plant for moths and butterflies, seeds eaten by birds and small mammals, provides good winter cover for wildlife.

*including the federally endangered rusty patched bumble bee

HERBACEOUS GROUND COVER

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
Virginia Creeper / Woodbine	*Parthenocissus quinquefolia* and *P. inserta*	Top, face, ravine, toe	Extensive woody root system	1′ (on the ground), 30-50′ in trees	Any	Moist to somewhat dry	Full sun to shade	Frequently browsed by deer, but vigorous enough to recover; inconspicuous flowers support native bees; host plant for several different sphinx moths; berries eaten by songbirds and mammals
Foxglove Beardtongue	*Penstemon digitalis*	Top, face, toe	Fibrous	2-3′	Loamy, but adapt-able	Moist to medium	Full sun to partial sun	Deer tolerant, flowers support native bees*
Mountain Mint	*Pycnanthemum virginianum*	Top, face, toe	Fibrous with shallow rhizomes	2-3′	Any	Moist to medium	Full sun to partial sun	Deer tolerant, flowers support native bees*
Yellow Coneflower	*Ratibida pinnata*	Top, face, toe	Fibrous	3-5′	Any	Medium to dry	Full sun	Deer tolerant, flowers support native bees, host plant for moths and butterflies, seeds eaten by goldfinches
Goldenrods	*Solidago* and *Euthamia* spp.	Top, ravine, face, toe	Fibrous, some species spreading by rhizomes	2-6′	Any	Wet to dry, depending on species	Full sun to shade, depending on species	Deer tolerant, flowers support native bees,* host plant for many moths and butterflies, important nectar source for migrating monarch butterflies
Asters	*Symphyotrichum* and *Eurybia* spp.	Top, ravine, face, toe	Fibrous, some species spreading by rhizomes	1-4′	Any	Wet to dry, depending on species	Full sun to shade, depending on species	Deer tolerant, flowers support native bees,* host plant for many moths and butterflies, important nectar source for migrating monarch butterflies
Blue Vervain	*Verbena hastata*	Top, toe	Fibrous	3-5′	Any	Wet to moist	Full sun	Deer tolerant, flowers support native bees, host plant for moths and butterflies, seeds eaten by small mammals

*including the federally endangered rusty patched bumble bee

SHRUBS

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
Round-Leaved Dogwood	*Cornus rugosa*	Top, ravine, toe	Deep, extensive, suckering	10-15′	Any	Medium to somewhat dry	Partial sun	Somewhat deer tolerant, flowers support native bees, host plant for many moths and butterflies, fruits consumed by birds and mammals
Red Osier Dogwood, Gray Dogwood and Silky Dogwood	*Cornus sericea, Cornus racemosa* and *Cornus amomum*	Top, ravine, face, toe	Deep, extensive, suckering	6-15′	Any	Wet to medium, depending on the species	Full sun to partial sun	Somewhat deer tolerant, flowers support native bees, host plant for many moths and butterflies, fruits consumed by birds and mammals
Common Ninebark	*Physocarpus opulifolius*	Top, ravine, face, toe	Spreading, fibrous, extensive, suckering	5-10′	Any	Moist to somewhat dry	Full sun to partial sun	Deer tolerant, flowers support native bees, host plant for moths and butterflies
Chokecherry	*Prunus virginiana*	Top, ravine, toe	Spreading, suckering	5-30′ (shortest in sunny, exposed locations)	Any	Moist to somewhat dry	Full sun to full shade	Deer tolerant, flowers support native bees,* host plant for many moths and butterflies, fruits consumed by birds and mammals
Hop Tree	*Ptelea trifoliata*	Top, face, toe	Extensive, but does not sucker from roots or rhizomes	10-20′	Any	Medium to dry	Full sun to partial sun	Seldom browsed significantly by deer, flowers support native bees, host plant for the giant swallowtail butterfly
Staghorn Sumac and Smooth Sumac	*Rhus typhina* and *Rhus glabra*	Top, ravine, face, toe	Spreading, suckering to form large colonies	15-25′	Any	Medium to dry	Full sun	Deer tolerant, flowers support native bees (mason bees also hollow out stems for nests), host plant for moths and butterflies, fruits consumed by birds and mammals
Pussy Willow, Missouri River Willow and Bebb's Willow	*Salix discolor, Salix eriocephala, Salix bebbiana*	Top, ravine, face, toe	Extensive, fibrous, suckering	6-20′	Any	Wet to moist	Full sun to partial sun	Deer tolerant, early spring floral resource for bumblebees,* host plant for many moths and butterflies
Sandbar Willow	*Salix interior*	Top, ravine, face, toe	Extensive, fibrous, suckering to form large colonies	8-20′	Sands and loams	Wet to moist	Full sun to partial sun	Deer tolerant, early spring floral resource for bumblebees,* host plant for many moths and butterflies

*including the federally endangered rusty patched bumble bee

SHRUBS

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
Common Elderberry	*Sambucus nigra* ssp. *canadensis*	Top, ravine, toe	Extensive, suckering	5-12′	Any	Moist to somewhat dry	Full sun to partial sun	Deer tolerant, flowers support native bees (mason bees also hollow out stems for nests), host plant for moths and sawflies, fruits consumed by birds and mammals
Red Elderberry	*Sambucus racemosa*	Top, ravine, toe	Spreading, suckering	8-14′	Any	Moist to medium	Partial sun	Deer tolerant, flowers support native bees (mason bees also hollow out stems for nests), host plant for moths and sawflies, fruits consumed by birds and mammals
Soapberry	*Shepherdia canadensis*	Face, toe	Spreading, suckering	3-9′	Neutral to alkaline	Moist to dry	Full sun to partial sun	Vulnerable to deer (best on bluff face positions seldom accessed by deer), flowers support native bees, fruits consumed by birds and mammals
Common Snowberry	*Symphoricarpos albus*	Top, ravine	Spreading, suckering	2-5′	Any	Moist to dry	Full sun to partial sun	Deer tolerant; flowers support many pollinators, including native bees, moths and hummingbirds; host plant for several moths; fruits consumed by birds and mammals
Blackhaw Viburnum	*Viburnum prunifolium*	Top, ravine	Branching, woody, suckering	10-15′	Any	Somewhat moist to somewhat dry	Full sun to partial sun	Deer tolerant, flowers support bees, host plant for moths and butterflies, fruits consumed by birds and mammals
American Highbush Cranberry Viburnum	*Viburnum trilobum*	Top, ravine, toe	Spreading, suckering	8-15′	Any	Moist	Full sun to partial sun	Deer tolerant, flowers support native bees; host plant for several native moths and butterflies (including the hummingbird clearwing); fruits are intitially tart and persists through much of winter, ultimately providing an important late winter food source to birds and mammals
Nannyberry Viburnum	*Viburnum lentago*	Top, ravine, toe	Spreading, fibrous, suckering	14-25′	Any	Moist to medium	Full sun to partial sun	Deer tolerant, flowers support bees, host plant for moths and butterflies, fruits consumed by birds and mammals

*including the federally endangered rusty patched bumble bee

TREES

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
Red Maple	*Acer rubrum*	Top, ravine, face, toe	Shallow roots	50-80′	All but the highest pH (>7.4) soils	Moist to medium	Full sun to partial sun	Deer tolerant, host plant for many moths and butterflies, seeds and buds are eaten by birds and mammals
Paper Birch	*Betula papyrifera*	Top, ravine, face, toe	Shallow, spreading root system	50-70′	Any	Moist to somewhat dry	Full sun	Deer tolerant; host plant for many moths, butterflies and sawflies; birds eat buds and use exfoliating bark as nesting material; squirrels eat seeds
Alternate-Leaved Dogwood	*Cornus alternifolia*	Top, ravine	Shallow, spreading root system benefits from leaf litter	15-25′	Loamy	Well drained, moist to medium	Full sun to partial sun (understory tree)	Vulnerable to deer browse while small, flowers attract many types of bees and other insects, host plant for moths and butterflies, fruits consumed by many birds and mammals
Hawthorn	*Crataegus* spp.	Top, ravine, toe	Spreading, shallow to medium depths	15-35′	Any	Moist to somewhat dry	Full sun to partial sun	Deer tolerant, host plant for moths and butterflies, fruits consumed by birds and mammals, provides habitat for songbirds
Black Walnut	*Juglans nigra*	Top, ravine	Tap root, produces compound that inhibits growth in some other plants	80-120′	Prefers loams, but adaptable	Moist to somewhat dry	Full sun	Deer tolerant, host plant for many moths, nuts are an important food source for mammals
Hophornbeam	*Ostrya virginiana*	Top, ravine	Variable, shallow in heavy soils	25-50′	Any	Well drained, moist to somewhat dry	Full sun to partial sun (understory tree)	Deer tolerant, host plant for moths, seeds are consumed by birds and mammals
Eastern Cottonwood	*Populus deltoides*	Face, ravine, toe	Roots are shallow and spreading, suckers when top-killed	60-120′	Any	Moist to somewhat dry	Full sun	While deer browse cottonwood, it grows quickly enough to recover; host plant for many moths, butterflies and other insects
Quaking Aspen	*Populus tremuloides*	Face, ravine, toe	Extensive suckering roots form large colonies	30-60′	Any	Moist to dry	Full sun	While deer browse quaking aspen, it grows quickly enough to recover; host plant for many moths, butterflies and other insects

*including the federally endangered rusty patched bumble bee

TREES

Common Name(s)	Scientific Name(s)	Usage Area	Root Type	Mature Height	Soil Type	Moisture	Sun/Shade Tolerance	Wildlife/Pollinators
Wild Plum	*Prunus americana*	Top, ravine, face, toe	Spreading, shallow to medium depths	15-25′	Any	Medium to dry	Full sun	Browsed by deer, but generally vigorous enough to regenerate; host plant to many moths and butterflies; flowers support native bees;* fruits consumed primarily by mammals
Black Cherry	*Prunus serotina*	Top, ravine, face, toe	Tap root with shallow spreading roots, some roots up 4 feet deep	45-80′	Any	Medium to dry	Full sun to partial sun	Vulnerable to heavy deer browse, flowers support native bees;* host plant to numerous moths and butterflies, fruits consumed by many birds and mammals
Oaks (Esp. Bur Oak and Chinquapin Oak)	*Quercus* spp. *(*Esp. *Quercus macrocarpa* and *Quercus muehlenbergii)*	Top, ravine (where relatively stable)	Deep and wide-spreading roots, will resprout from stump/crown if top-killed	40-120′	Any	Wet to dry, depending on species	Full sun	Vulnerable to deer browse while small, host plants to the greatest number of moths and butterflies, acorns consumed by birds and mammals, cavities provide nesting and den sites, best trees for wildlife
Peach-Leaved Willow	*Salix amygdaloides*	Top, ravine (especially along waterways), face, toe	Dense, shallow roots, forms adventitious roots when base is buried	35-70′	Any	Wet to moist	Full sun	While deer will browse, it grows quickly enough to recover; flowers support native bees;* host plant to moths and butterflies
Black Willow	*Salix nigra*	Top, ravine (especially along waterways), face, toe	Dense, shallow roots, forms adventitious roots when base is buried	30-60′	Any	Wet to moist	Full sun	While deer will browse, it grows quickly enough to recover; flowers support native bees;* host plant to moths and butterflies
Eastern Arborvitae	*Thuja occidentalis*	Top, ravine, face	Shallow, spreading root system	40-60′	Loams and clays	Moist to medium	Full sun to partial sun	Vulnerable to deer browse, especially in winter; host plant for moths; seeds are consumed by birds and mammals; important shelter tree for birds and nesting site in summer
Basswood	*Tilia americana*	Top, ravine, toe	Mostly lateral roots, can form adventitious roots	50-100′	Any	Moist to somewhat dry	Full sun to partial sun	Vulnerable to heavy deer browse, host plant for many moths, old trees often develop cavities used by cavity-nesting birds

*including the federally endangered rusty patched bumble bee

HERBACEOUS PLANTS

Early Goldenrod. *Dan Carter*

Giant Goldenrod. *Dan Carter*

Gray Goldenrod. *Dan Carter*

1. **Goldenrods** *(Solidago* and *Euthamia* spp.*)*

   Goldenrods are perennial plants that provide an important late-season resource for pollinators, including monarchs in migration. There are goldenrods suitable for almost any bluff environment, and bloom time can be extended by planting several species.

   The following species are clump forming or slowly spreading by rhizomes or adventitious shoots from spreading roots. Elm-leaved *(S. ulmifolia)*, zig-zag *(S. flexicaulis)* and bluestem *(S. caesia)* goldenrods occur naturally in ravine and bluff-top woodlands. Early *(S. juncea)*, stiff *(S. rigida)* and gray *(S. nemoralis)* are often found on the bluff top and bluff face and can tolerate dry conditions. Ohio *(S. ohioensis)* and Riddell's *(S. riddellii)* prefer wet to moist conditions around groundwater seeps.

   The following species are more aggressive and spread from long rhizomes to form large colonies that can aid in stabilization. Canada *(S. canadensis)* and tall *(S. altissima)* prefer open sites ranging from moist to somewhat dry conditions. Giant goldenrod *(*S. gigantea*)* prefers wet to medium moisture levels and grows both in open sites and under partial sun. Grass-leaved goldenrod *(E. graminifolia)* prefers open areas with wet to medium moisture levels.

   Goldenrods are widely available from local and regional nurseries that specialize in native plants.

Arrow-Leaved Aster. *Dan Carter*

Drummond's Aster. *Dan Carter*

Smooth Blue Aster. *Dan Carter*

2. Asters *(Symphyotrichum and Eurybia* spp.)

Asters are perennial plants that provide an important late-season resource for pollinators, including monarchs in migration.There are asters suitable for almost any bluff environment, and bloom time can be extended by planting several species.

The following species are clump forming or slowly spreading by rhizomes. Calico *(S. lateriflorum)*, Drummond's *(S. drummondii)*, heart-leaved *(S. cordifolium)*, Short's *(S. shortii)* and arrow-leaved *(S. urophyllum)* asters all typically occur in woodlands in bluff-top or ravine areas with medium to somewhat dry moisture levels. Smooth blue aster *(S. laevum)* is found both in open areas and partial sun, particularly medium to somewhat dry areas near the bluff-top edge. New England aster *(S. novae-angliae)* occurs in open areas that are medium to moist, and frost aster *(S. pilosum,* short-lived) occurs in open areas that are medium to dry.

The following species spread by long rhizomes to form colonies. Ontario aster *(S. ontarionis)* is common in shady riparian areas along ravine bottoms. Big-leaved aster *(E. macrophylla)* occurs on moist to medium, wooded bluff tops and ravine slopes. Panicled *(S. lanceolatum)* and shining *(S. firmum)* asters occur in moist open areas, but the latter prefers soils that are sandy or loamy and/or high in organic matter. Heath aster *(S. ericoides)* prefers sunny, dry bluff top and face areas.

Asters are widely available from local and regional nurseries that specialize in native plants.

HERBACEOUS PLANTS continued

Indiangrass. *Dan Carter*

Little Bluestem. *Dan Carter*

Canada Wild Rye. *Dan Carter*

3. **Warm-Season Grasses** (Several species)

Warm-season grasses generally favor sunny environments and form extensive fibrous root systems that are excellent for stabilizing soil. Some species also spread by rhizomes to form colonies. Most species tolerate both sandy and clay soils. All species described here are perennial.

Switchgrass *(Panicum virgatum)* and prairie cordgrass *(Sporobolus michauxianus,* syn. *Spartina pectinata)* both spread quickly from rhizomes. The former prefers somewhat moist to somewhat dry conditions, and the latter prefers wet to medium conditions.

Big bluestem *(Andropogon gerardii)* and Indiangrass *(Sorghastrum nutans)* spread slowly from rhizomes. The former prefers somewhat moist to dry conditions, and the latter prefers medium to dry conditions.

Little bluestem *(Schizachyrium scoparium)*, rough dropseed *(Sporobolus compositus)* and prairie dropseed *(Sporobolus heterolepis)* all form clumps. All favor medium to dry conditions, though prairie dropseed will also tolerate somewhat moist conditions. The latter is slower growing and best used in open bluff top areas.

Warm-season grasses are widely available from local and regional nurseries that specialize in native plants.

4. **Wild Ryes** *(Elymus* spp.*)*

Wild ryes are relatively short-lived perennial, cool-season grasses that develop quickly from seed to form clumps, providing herbaceous plant cover while slower-growing species develop. Canada wild rye *(Elymus canadensis)* prefers medium to dry sunny areas and occurs naturally on the bluff face. Virginia wild rye *(Elymus virginicus)* prefers moist to medium areas in partial to full shade like those found in ravine bottoms. Silky wild rye *(Elymus villosus)* and bottlebrush grass *(Elymus hystrix)* favor medium to somewhat dry areas of woodlands like those found on bluff tops and ravine slopes.

Wild ryes are widely available from local and regional nurseries that specialize in native plants.

Nodding Bullrush. *Dan Carter*

5. Sedges

There are well over one hundred native, perennial sedges that are suitable for one bluff environment or another.

Woodland sedges that are regularly available from local and regional nurseries that specialize in native plants include Pennsylvania sedge *(Carex pensylvanica)*, Sprengell's sedge *(Carex sprengellii)* and ivory sedge *(Carex eburnea)*. Other woodland sedges like White Bear Lake sedge *(Carex albursina)*, pretty sedge *(Carex woodii)* and pedunculate sedge *(Carex pedunculata)* are less commonly available but are worthy of broader use.

Golden-Fruited sedge. *Dan Carter*

Woolly sedge *(Carex pellita)* is another rhizomatous sedge that occurs in a variety of medium to wet, sunny areas. Nodding bulrush *(Scirpus pendulus)* is a clump-forming sedge found in moist sunny to partially shaded areas in all locations on bluffs. Both of these sedges are at least sometimes available from local or regional nurseries that specialize in native plants.

Golden-fruited sedge *(Carex aurea)* is a rhizomatous, low-growing sedge that is locally abundant on medium to wet clays of the bluff face and toe, usually in sunny areas around the periphery of seeps. It is an attractive sedge that is occasionally available from nurseries but is worthy of increased use.

Virginia Creeper. *Dan Carter*

6. Virginia Creeper and Woodbine
(Parthenocissus quinquefolia and *P. inserta)*

Virginia creeper and woodbine are perennial woody species that both spread along the surface, forming groundcovers that help stabilize soils in a wide variety of environments. Virginia creeper is also capable of becoming a vine, ascending trees using its tendrils bearing adhesive pads. Both species have striking red fall color and exceptional wildlife value. A few local and regional nurseries carry these species, but they may be difficult to find on the market.

SHRUBS

Silky Dogwood. *Doug McGrady*

1. Red Osier, Gray and Silky Dogwood *(Cornus sericea, C. racemosa* and *C. amomum)*

These shrubby dogwoods are recommended as bluff plants because they tolerate a wide range soil types, grow quickly, form extensive root systems, sucker when aboveground portions are removed and can withstand being partially buried by bluff sediments. All prefer moist conditions, though gray dogwood disfavors the very wettest sites and tolerates medium or even slightly dry sites. All can be purchased from local or regional nurseries.

Round-Leaved Dogwood. *Dan Carter*

2. Round-Leaved Dogwood *(Cornus rugosa)*

This large, shrubby dogwood is often found growing in the understory on wooded slopes and ridges near Lake Michigan as well as the transition from the beach to steep, wooded slopes. Like other shrubby dogwoods, it suckers and has an extensive root system, but it tolerates drier and somewhat shadier conditions.This species is exceptionally ornamental with textured leaves, white flowers, white berries and good pink to crimson red fall color.This species is occasionally offered by local and regional nurseries and is worthy of greater use.

Common Ninebark. *F.D. Richards*

3. Common Ninebark *(Physocarpus opulifolius)*

Ninebark occurs naturally on the bluff face, where it occasionally forms large colonies, and it tolerates a wide range of soil types and moisture levels. Ninebark grows quickly, even from small or bare-root nursery stock. It is adorned by profuse clusters of small, white flowers, which are followed by attractive pendant seed capsules that persist into winter. Exfoliating bark provides additional aesthetic interest in the winter. Ninebark is widely available from local and regional nurseries.

SHRUBS continued

Sandbar Willow. *Dan Carter*

4. Sandbar, Missouri River, Bebb's and Pussy Willows *(Salix interior, S. eriocephala, S. bebbiana and S. discolor)*

These willows grow quickly, have extensive root systems, sucker when aboveground portions are removed and can withstand being partially buried by bluff sediments. Most form large, multi-stemmed shrubs, but older Bebb's willow and pussy willow can become small, single-trunked trees. Sandbar willow prefers sandy or loamy soils and tends to sucker and form large thickets from its spreading roots. Not reliably available from nurseries, these species can be propagated from cuttings placed in moist soil.

Non-native willows like purple willow *(Salix purpurea)* are invasive and should be avoided.

Pussy Willow. *Dan Carter*

Smooth Sumac. *Wendell Smith*

Staghorn Sumac. *Dan Carter*

5. Staghorn and Smooth Sumac *(Rhus typhina* and *R. glabra)*

Staghorn and smooth sumac are often among the first woody species to colonize open areas, including bare bluffs. They are useful for stabilization projects because they have dense, shallow root systems that spread extensively and produce suckers that result in the formation of large colonies. Sumacs are adaptable to both sandy and clay soils and are exceptionally tolerant of dry conditions. Sumac foliage turns a brilliant red in autumn and is highly valued by wildlife. The shelter they provide can also foster the eventual establishment of trees on harsher sites. Both species are usually available from at least one local or regional nursery.

SHRUBS continued

Hop Tree. *Dan Carter*

6. Hop Tree *(Ptelea trifoliata)*

Hop tree is a large shrub that thrives in poor, medium to dry soil of all types. It occurs over a huge geographic range that stretches from Canada to southern Mexico and Arizona and Utah to Florida. In coastal Wisconsin, it occurs naturally at the top of bluff slopes, headlands, sandy beach areas that are sufficiently high and open woodlands. It can sucker from the base, but does not produce new plants from roots or rhizomes away from the parent plant. Hop tree's upright clusters of wafer-shaped fruits and yellow fall color are quite attractive. These characteristics along with its tolerance of poor conditions have led to increased production and use of this species, and it is usually available from several local and regional nurseries.

TREES

Red Maple. *Big Cyprus National Park*

1. Red Maple *(Acer rubrum)*

Red maple is a moderately fast-growing and versatile tree that tolerates a wide range of soil types and moisture conditions. Its extensive lateral roots make it good at stabilizing soil. Red maple has excellent red fall color and is widely available from local and regional nurseries.

In addition, two other native maple species, sugar maple *(Acer saccharum)* and black maple *(Acer nigrum)* are more narrowly suited to soils with medium to somewhat moist, loamy soils with good drainage. Such conditions are most likely to exist on bluff-top areas or relatively stable ravine slopes.

Small trees may need to be protected from deer browse until they establish.

Black Walnut. *Nicholas Tonelli*

2. Black Walnut *(Juglans nigra)*

A fast-growing tree that provides abundant nuts for wildlife, black walnut is particularly well suited to bluff-top areas and stable ravines that empty into Lake Michigan — it is often able to thrive in almost any sunny environment. It releases a chemical called juglone that can suppress the growth of other plant species, so care must be taken not to plant black walnut with sensitive species. Juglone-resistant species include ninebark, alternate-leaved dogwood, silky dogwood, willows, elderberries, blackhaw viburnum, sumacs, oaks, native cherries and plums, hawthorns, maples, asters, goldenrods, bergamot and great blue lobelia. Black walnut is widely available from local and regional nurseries.

TREES continued

Quaking Aspen. *USDA NRCS Montana*

3. **Cottonwood and Quaking Aspen** *(Populus deltoides and P. tremuloides)*

   These poplars are particularly suited as bluff plants because they grow very quickly and sucker from extensive root systems if the parent tree is top-killed. Even without top-kill, quaking aspen will sucker from its spreading root system, forming large colonies. Young cottonwood trees are also capable of rooting along their lower trunks if partially buried by sediments. While both species tolerate moist conditions, only cottonwood should be planted in areas subject to periodic, brief inundation.

   Aspens are typically available from a few nurseries although native poplars can be difficult to find.

Black Cherry. *Jan Havlícek*

4. **Black Cherry** *(Prunus serotina)*

   This versatile tree is among the best for wildlife. It has an extensive root system and excels at colonizing harsh, disturbed environments. While it is not tolerant of being buried, its fast growth makes it suitable for nearly all bluff environments that are not too wet or subject to full shade. Black cherry may require protection from deer browse for a relatively brief period while it establishes, but it is vigorous enough that deer browse is only likely to delay maturation. While black cherry is seldom used in ornamental contexts, a few local and regional nurseries offer it.

Paper Birch. *Doug McGrady*

5. **Paper Birch** *(Betula papyrifera* spp.*)*

   Paper birch occurs naturally on bluffs and adjacent areas along the Lake Michigan coastline. Its dense, shallow root system is good for stabilization, and it readily reproduces by seed in open, disturbed areas. Paper birch is valuable to wildlife and attractive in all seasons. Care should be taken to avoid European white birch *(Betula pendula)*, which is very similar in appearance, but potentially invasive and less ecologically valuable. Paper birch is available from local and regional nurseries.

Eastern Arborvitae. *S. Rae*

6. Eastern Arborvitae *(Thuja occidentalis)*

Eastern arborvitae is locally abundant on bluffs and adjacent areas along the Lake Michigan coastline. On bluffs, it most often occurs in relatively stable areas that are located near groundwater seepage areas. It is also common near bluff-top edges as well as in and just above ravines. It is vulnerable to winter deer and rabbit browse when young. Its evergreen foliage provides important shelter for birds in winter and during spring migrations, and many birds nest in arborvitae during the summer months. Eastern arborvitae are available at many local and regional nurseries.

Adam Bechle in Bender Park, Wisconsin. *Sara Stathas*

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The following references were used to develop the descriptions and can be referenced for more information on plant species.

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U.S. Fish and Wildlife Service Midwest Region. 2019. Plants Favored By Rusty Patched Bumble Bee. go.wisc.edu/scwlip

Southeastern Wisconsin Regional Planning Commission. 2021. Plant Species Range Maps. go.wisc.edu/uqyfg9

APPENDIX B

WHEN YOUR HOME IS AT IMMINENT RISK FROM BLUFF FAILURE

LYDIA SALUS, Wisconsin Sea Grant
ADAM BECHLE, Wisconsin Sea Grant

If your house is located near the edge of an unstable bluff, bluff failure can present a serious risk to your home and personal safety. Bluff instability can be caused by a combination of a steep bluff slope angle, wave erosion, groundwater saturation and seepage, surface water runoff, frost heave and human activities. Humans can contribute to bluff instability by removing vegetation, changing drainage patterns and adding excess weight to the bluff edge. An unstable bluff can fail progressively in small increments or rapidly in a large slump. The next wind storm or heavy rain may trigger a bluff failure that can place you and your property in immediate danger.

Is there an emergency? Determining whether your house is at imminent risk of bluff failure

The main factors that determine whether a house is at imminent risk of bluff failure are

1. the distance of the house to the top edge of the bluff,
2. the stability of the bluff and
3. the rate at which the bluff is receding.

Obvious signs of bluff stability issues include ground cracks on top of the bluff, soil slumps on the face of the bluff and severe erosion at the toe, or base, of the bluff. However, bluff failure can be a complex process and visual indicators may not always be apparent before a failure occurs. Therefore, a professional evaluation by a qualified engineer or geologist is the only true way to determine the extent of your bluff's stability and whether your home is at a safe distance away from the bluff-top edge.

Severe toe erosion. *Chin Wu*

Ground crack. *Gene Clark*

Soil slump. *Adam Bechle*

Options for a home at imminent risk of bluff failure

An engineer, geologist or qualified contractor can assist with selecting an appropriate set of actions for your situation.

The actions are not listed in order of severity or cost.

Relocation. Relocate the at-risk home to a safe distance landward of the eroding shoreline or bluff-top edge. This can often be the most cost-effective strategy if there is sufficient space on the lot.

Slow Toe Erosion. Construct a coastal protection structure, such as an engineered rip rap revetment, to reduce erosion at the toe of the bluff.

This can slow erosion, but bluff slope instability issues may still need to be addressed because an unstable bluff can continue to slump after toe protection is in place.

Enhance Bluff Slope Stability. Strengthening the slope of the bluff can reduce the risk of failure. Typically, slope stability practices are used in combination with each other and include removing excess surface and groundwater, re-establishing deep-rooted native vegetation, regrading or terracing the slope and reinforcing the bluff face with geogrids or geocells.

If toe erosion is a root cause of the bluff instability, slope stability practices will not be effective in the long term until toe erosion is mitigated.

Avoid Making Bluff Issues Worse by Managing Water, Vegetation and Land Use. To reduce the impact of stormwater on bluff instability, redirect drainage away from the edge of the bluff top, including downspouts, runoff from pavement, septic drainage or other sources of water discharge. To maintain the strength of the bluff slope, preserve or enhance existing native vegetation, limit mowing close to the bluff edge, avoid adding excess weight near the bluff edge and do not dump yard waste or other materials onto the bluff slope.

BLUFF FAILURE AND SHORELINE EROSION CONTACTS AND INFORMATION

MUNICIPAL OR COUNTY ZONING OFFICE

Contact your local zoning office before beginning any work on the coast to ensure that you are in compliance with local ordinances. Staff may also have experience with similar coastal issues in your area and may be able to provide additional information.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES (DNR)

State law requires any material that is placed in the Great Lakes and along the shoreline to be authorized by the DNR through a permit for a permanent or temporary erosion-control structure. Some actions may be exempt from these requirements, depending on the specific activity and its location. Contact the DNR to assist with your waterway permitting questions.

DNRWMSPublicInquiry@wisconsin.gov
608-267-3125
dnr.wi.gov/topic/Waterways/shoreline/GreatLakesErosionControl

UNITED STATES ARMY CORPS OF ENGINEERS — ST. PAUL DISTRICT

Federal permits are necessary for any work in the nation's navigable waters. In some cases, Wisconsin DNR permits operate as "joint permits" that are shared with the U.S. Army Corps to meet this requirement. U.S. Army Corps staff in your region can assist with federal permitting questions.

usace_requests_wi@usace.army.mil
262-641-5498 (Brookfield, Wis. office)
920-448-2824 (Green Bay, Wis. office)
mvp.usace.army.mil/Missions/Regulatory/

UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

Wisconsin Sea Grant provides coastal engineering expertise to state and local government officials, contractors and lakeshore property owners in all Wisconsin coastal counties. Check the Coastal Processes and Engineering website for information, fact sheets and other publications. Wisconsin Sea Grant's Coastal Engineering Outreach Specialist Adam Bechle can be contacted directly at bechle@aqua.wisc.edu or 608-263-5133.
seagrant.wisc.edu/our-work/focus-areas/coastal-processes-and-engineering

BUILDING MOVERS

A professional building mover can help assess the feasibility of moving a home and the associated costs. The following professional associations maintain contact information for their members.

Wisconsin Building Movers Association, wisbma.org

International Association of Structural Movers,
iasm.org/iasm-members/member-directory/

ENGINEERS, GEOLOGISTS AND CONTRACTORS

Experienced coastal engineering professionals have the expertise necessary to perform a site evaluation, provide recommendations for a course of action and influence the success of a shoreline project, including the permitting process, neighboring impacts, construction and maintenance costs, and life of the project. An investment in the services of experienced professionals is the best way to ensure the long-term success of a coastal protection project and minimize costs during the period of ownership.

Working With Engineers and Contractors on Shore Protection Projects, go.wisc.edu/2y9v2b

Partial list of known Great Lakes coastal engineering firms and contractors, go.wisc.edu/n94a15

APPENDIX C

SPECIAL CONSIDERATIONS FOR NEW CONSTRUCTION

ADAM BECHLE, Wisconsin Sea Grant
LYDIA SALUS, Wisconsin Sea Grant
GENE CLARK, Wisconsin Sea Grant

When building near a Great Lakes coastal bluff, care should be taken to ensure that not only are structures reasonably safe from the risk of bluff failure but also that development has as little impact on the bluff's stability as possible. Coastal bluff failure is a natural process caused by a combination of a steep bluff slope angle, wave erosion, groundwater saturation and seepage, surface water runoff and frost heave. Humans can also contribute to bluff instability by removing vegetation, changing drainage patterns and adding excess weight to the bluff edge. Site layout and management of surface water, groundwater and vegetation can all affect new development's risk of bluff failure and its impact on bluff stability.

Locate structures an adequate distance away from the bluff-top edge

Locating a new building an adequate distance away from the bluff-top edge reduces the risk that the structure will be affected by bluff failure during its useful life. This also reduces the chance that costly shoreline erosion control or bluff earthwork will be needed to protect the structure. An adequate building setback also minimizes the structure's impact on bluff stability that may come from the additional weight placed on the bluff and modified drainage patterns.

An adequate building setback distance from the bluff-top edge typically considers the rate at which the bluff is receding (if this rate is not known at a site, 2 to 3 feet per year is often assumed), the desired useful life of the building (typically 60 to 100 years for residential construction), the bluff height and the stable slope angle of the bluff. A professional evaluation by a qualified engineer or geologist can help determine an adequate setback distance for a given site. Further considerations include:

- Use conservative recession rates, as historic rates may not be accurate predictors of the future.
- Consult with your local planning and zoning office to see if ordinances specify a minimum required setback distance in your area.
- Know that the minimum setback distance allowed by state or local ordinances may not be adequate to ensure safety for the expected useful life of a building.
- Locate critical services like septic systems and propane tanks away from the bluff-top edge and, if possible, landward of the primary structure.

Lake view from an adequately set-back house. *Sara Stathas*

- Use construction methods that will make structure relocation easier should the building need to be moved away from a receding bluff-top edge in the future. In general, structure relocation is easiest for wood-framed, single-floor structures that are built on a basement or crawl space rather than slab-on-grade.
- Locate easily moved minor structures like small gazebos and decks nearer to the bluff edge than the primary structure to enjoy scenic lake views with less long-term risk.
- Avoid encroaching upon natural gullies and ravines.

Minimize excess weight and other disturbances near the bluff-top edge

Adding weight from earthwork, machinery, buildings, pools or other heavy additions near the bluff-top edge increases the loads and stresses on the bluff, reducing stability. Additional considerations include:

- Mound septic systems should be placed landward of buildings due to their heavy weight.
- If possible, keep heavy machinery at least 25 feet away from the bluff-top edge.
- Consult with your local planning and zoning office to see if ordinances specify a minimum required setback distance for secondary structures or other additions in your area.

Minimize inputs to groundwater near the bluff edge from septic systems and other sources

Discharges to shallow groundwater layers from septic systems and stormwater infiltration features like rain gardens or dry wells can saturate the soil, which reduces the soil strength and destabilizes the bluff slope. To limit the impact of development on groundwater, consider the following:

- Locate septic systems as far from the bluff-top edge as possible.
- Avoid placing rain gardens or other infiltration features near the bluff-top edge.

No-mow buffer of low-growing native vegetation to frame lake views. *Sara Stathas*

Direct surface water runoff away from the bluff-top edge

Stormwater management at the site should minimize alterations to the normal surface water patterns on your property. The following considerations should be given to controlling surface water runoff:

- Maintain any existing stormwater runoff patterns to ravines and gullies if possible.
- Collect runoff from impervious surfaces and route runoff away from the bluff edge. For example, collect roof runoff in rain barrels or direct downspouts away from the bluff-top edge.
- When grading landscape work, slope surfaces away from the bluff-top edge.

Minimize use of impervious surfaces, especially near the bluff-top edge

Paved driveways, patios, paths, tennis courts and other impervious surfaces prevent water from infiltrating into the soil, leading to additional runoff. When possible, consider the following:

- Limit the footprint of impermeable surfaces like driveways and patios.
- Use permeable materials like porous pavement, pavers and geogrids.
- Direct runoff from impervious surfaces away from the bluff-top edge.
- Avoid unnecessary compaction of soil on the bluff top from landscaping actions.

Maintain and enhance bluff vegetation, especially deep-rooted native species

Deep-rooted vegetation helps to stabilize the bluff by removing moisture from the soil and increasing the soil's shear strength. By comparison, turfgrass offers little stabilization benefits due to its shallow roots. Consider the following:

- Minimize the removal of existing native vegetation and manage for invasive species.
- Establish views of the lake by pruning or thinning existing vegetation (rather than clear cutting) or planting low-growing shrubs and herbaceous cover.
- Leave a well-vegetated, no-mow buffer of at least 10 feet along the bluff-top edge.

If shoreline access is desired, create dedicated low-impact pathways down the bluff

Unmanaged access up and down the bluff, especially over unstable areas, can cause surface erosion and damage beneficial vegetation. Consider the following when planning designated access paths:

- Use naturally stable slope areas.
- Minimize the widths of paths and stairs.
- Limit the use of impervious surfaces to construct paths. Use sand or gravel when possible.
- Use a switchback trail to avoid creating a direct pathway for water discharge down the bluff.
- Consult with your local planning and zoning office to see if there are ordinances on bluff access.

Sara Stathas

To ensure compliance with laws and ordinances, consult with local, state and federal regulators

MUNICIPAL OR COUNTY ZONING OFFICE

Contact your local zoning office before beginning any work on the coast to ensure that you are in compliance with local ordinances.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES (DNR)

State law requires any material that is placed in the Great Lakes and along the shoreline, such as erosion control, to be authorized by the DNR through a permit.

DNRWMSPublicInquiry@wisconsin.gov
608-267-3125
go.wisc.edu/6513rs

UNITED STATES ARMY CORPS OF ENGINEERS — ST. PAUL DISTRICT

Federal permits are necessary for any work in Great Lakes waters. In some cases, Wisconsin DNR permits operate as "joint permits" that are shared with the U.S. Army Corps to meet this requirement.

usace_requests_wi@usace.army.mil
651-290-5525
mvp.usace.army.mil/Missions/Regulatory/

For concerns about bluff stability or erosion, seek a professional evaluation

Experienced coastal engineers and geologists can perform a site evaluation, provide recommendations for a course of action and influence the success of a coastal project. Wisconsin Sea Grant maintains a partial list of known Great Lakes coastal engineering firms and contractors at go.wisc.edu/lu905u.

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