NEW YORK STATE REDI: BUILDING RESILIENCE IN RECOVERY

Homeowner Program Guidance for Shoreline Management on the Great Lakes and St. Lawrence River

LAKE ONTARIO REDI
Resiliency & Economic Development Initiative

NEW YORK STATE

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For an electronic version of this document that provides numerous links to additional information, data, and guidance, please visit: https://on.ny.gov/rediguidance

BUILDING RESILIENCE IN RECOVERY

To build resilience, reduce the risk of future property damage, and minimize natural resource impacts, the New York State Department of Environmental Conservation (DEC) has compiled general guidelines for coastal design and development projects through the Lake Ontario Resiliency and Economic Development Initiative (REDI). The goal of these guidelines is to share technical and regulatory requirements, best practices, and available resources for rebuilding and maintaining erosion protection along the shorelines of Lake Ontario, Lake Erie, and the St. Lawrence River For an electronic version of this document and numerous links to additional information, data, and guidance, please visit: **http://on.ny.gov/rediguidance.**

The purpose of this document is to provide information on shoreline natural processes, structure design, and the permitting process to help engineers, surveyors, contractors, and landowners select the shoreline management alternative that minimizes project impacts while achieving the necessary protection. Properly evaluated and designed shoreline management strategies (ranging from no-action to hard structural measures) provide greater reliability and stability to homeowners and municipalities (photos 1–3). While this document is intended to be an informational resource to homeowners, it does not substitute for hiring a licensed Professional Engineer (PE) to develop plans and prepare permit applications. DEC recommends hiring a licensed PE experienced in coastal development in order to develop an appropriate design and make the permitting process as efficient as possible An engineered design will also increase the odds of long-term success and stability

While the focus of this document is the permitting and design of erosion protection measures, individual properties are part of a larger, connected coastal system and resiliency to extreme high and low water levels is influenced by the surrounding landscape. The State has invested considerable resources through REDI to improve critical public infrastructure, which can become vulnerable if adjacent projects are not developed in a complementary way. The State also is working with communities through the Coastal Lakeshore Economy and Resiliency (CLEAR) initiative to develop comprehensive resiliency strategies and plans that reflect the diverse perspectives, needs, interests, and watersheds within each region. It is important to discuss your project early on with all relevant regulatory agencies to determine the best path forward through the regulatory process and ensure a project will be successful in the context of these broader efforts. Specific requirements for plans, surveys, and other documentation to include in an erosion protection permit application can vary depending on the location of the proposed project and which types of permits are required. If you are proposing complex, multi-permit projects, you are strongly encouraged to schedule a pre-application conference with your DEC Regional Office or appropriate agency

It is also important to talk to your local municipality when designing a project. Municipalities may require a building permit. Any development in a FEMA identified Special Flood Hazard Area (also known as the 100 Year Floodplain) will require a Floodplain Development Permit from the local Floodplain Administrator. Special Flood Hazard Areas can be found on FEMA Flood Insurance Rate Maps, which can be accessed here:

https://msc.fema.gov/portal/home.

PHOTO 1. Elevated home in Town of Scriba

PHOTO 2. Lake Bluff Road in Town of Huron

PHOTO 3. Rock revetment in Town of Hamlin

COMMON TERMINOLOGY

BEACH is the zone of unconsolidated earth that extends landward, from Mean Low Water to the waterward toe of a dune or bluff

BLUFF is any bank or cliff with a steeply sloped face that is along a body of water

COASTAL EROSION is a loss of land along the coastline due to factors such as wave action, currents, tides, wind-driven water, and waterborne ice

COASTAL EROSION HAZARD AREAS (CEHAs) are areas identified by DEC to be Natural Protective Feature Areas or Structural Hazard Areas. Homeowners in CEHAs must obtain a permit before starting their project. For more information please visit the DEC's Coastal Management webpage at https://www.dec.ny.gov/lands/28923.html

DUNE is a ridge or hill of loose, windblown, or artificially placed sand and its vegetation.

HARD STRUCTURAL MEASURES are permanently fixed engineered features used to disrupt natural processes by absorbing wave energy and preventing erosion and flooding. Hard structural measures can disrupt natural features and costal processes, and have limited or no living components. While they can be necessary to protect critical infrastructure, they can negatively affect natural features that reduce risk Some examples include levees, bulkheads, seawalls, revetments, dams, structural stream channels, and stormwater pipes and tunnels.

IGLD85 is the International Great Lakes Datum of 1985. It is a vertical datum that is used as a reference point for measuring elevations along the shorelines of the Great Lakes.

LOWEST FLOOR means the lowest floor of the lowest enclosed area (including a basement or cellar).

MEAN HIGH WATER (MHW) means the approximate average high-water level for a given body of water at a given location, that distinguishes between predominantly aquatic and predominantly terrestrial habitat as determined by elevation (DEC's Protection of Waters Regulations 6 NYCRR Part 608 identifies the MHW elevations as 573.4 feet IGLD85 on Lake Erie and 247.3 feet IGLD85 on Lake Ontario) and the characteristics set forth in subdivision (r) of 6 NYCRR Section 608.1 (available at https://on.ny.gov/part608) DEC staff have the final determination in where the MHW at a site is located. It is necessary to identify approximate MHW on the plans in your permit application, which can be done using the process in *Appendix 1*

MEAN LOW WATER (MLW) is defined in NYCRR Part 505 as the approximate average low-water level for a given body of water at a given location, determined by reference to hydrological information concerning water levels or other appropriate test.

NATURE-BASED FEATURES are those that mimic characteristics of natural features, but are created by human design, engineering, and construction to provide erosion or flood protection. Nature-based features typically incorporate or promote the growth of living materials, limit disturbance to existing habitat, and help ensure the natural coastal processes that maintain natural protective features are maintained.

NATURAL PROTECTIVE FEATURES are features that help reduce the risk of flooding and erosion. Some act as barriers to resist the flow of water while others create friction to slow the flow of water, reducing its energy and power to cause damage Other natural features store and/or absorb excess water, stabilize the movement of sediment, supply sediment to other features, and facilitate or enhance the drainage of water. Examples of natural features are bluffs, beaches, and dunes.

NON-STRUCTURAL MEASURES can be used to conserve natural features that reduce risk. These actions do not involve the direct management of water flows, but instead manage flooding and erosion by moving structures out of areas at risk or preventing the siting of new structures in these areas. They include elevating or relocating assets out of vulnerable areas, using setbacks to prevent the siting of new structures in vulnerable areas, and adapting structures so they are not harmed during flood events. They are effective at reducing both short-term and long-term flood damage while maintaining natural processes.

ORDINARY HIGH WATER MARK (OHWM) defines the boundaries of aquatic features for a variety of federal, state, and local regulatory purposes. Under the Clean Water Act, the OHWM defines the lateral limits of federal jurisdiction for non-tidal waters of the U.S. in the absence of adjacent wetlands (including Section 404, which regulates the discharge of dredge and fill material into waters of the U.S.). For the purposes of this document, the OHWM can be assumed to be the same as Mean High Water

RESILIENCE is the capacity for a community and its ecosystem to withstand extreme events or other forces or risks; quickly recover the interconnected social, economic and ecological systems' structure and function in the aftermath of a disaster; and develop ongoing adaptability to rapidly changing environmental conditions and forces.

SCOUR is a specific form of erosion. Scour involves the localized removal of sediment by water passing around or otherwise being redirected by an obstruction in the water

SLOPE ANGLES are given in terms of rise (in feet) for a given horizontal distance (in feet). For example, a bluff slope of 1V:2H means the bluff face rises one vertical foot over a distance of two horizontal feet The slopes in this publication are all given in a vertical:horizontal ratio

STABLE BLUFF ANGLE is the steepest stable angle of a slope composed of granular material, such as sand, soil, or gravel. The angle is specific to the type and moisture level of the granular material.

STRUCTURAL HAZARD AREAS are shorelands located landward of natural protective features and having shorelines receding at a long-term average annual recession rate of one foot or more per year. These areas are identified on DEC's Coastal Erosion Hazard Area Maps.

TOE is the lowest point on a slope of a dune, bluff, or structure

VERTICAL DATUM is a surface of zero elevation to which heights of various points are referenced This zero elevation can be set to any level, but is generally set close to sea level. The most commonly used vertical datum on the Great Lakes is IGLD85.

Step-by-Step Permit Application Process for New Erosion Protection

Step 1: Identify Your Need for Erosion Protection

At the beginning of the design process, you should evaluate the need for erosion or flood protection and how much protection is necessary. Each site is different and should be evaluated to determine which type of protection is best suited for the site and the best way to provide that protection. For example, a vacant lot along Lake Ontario may only require a small amount of work to stabilize an eroding shoreline, while a house immediately adjacent to the edge of an eroding bluff may require a vertical wall to ensure it will be well protected.

Keep in mind that alternatives to reduce flooding may differ from alternatives to reduce erosion, so it is important to understand the risks for your specific project and design accordingly. The source of any erosion must also be considered. Erosion caused by surface water runoff or groundwater seepage may require different alternatives than erosion caused by waves at the toe of a dune or bluff.

Step 2: Conduct an Alternatives Analysis

After evaluating your project need, you or your design professional need to conduct an alternatives analysis to identify a strategy that provides the appropriate protection while preventing or minimizing negative impacts.

Non-structural and nature-based measures are preferred to hard structural measures for erosion and flood management. Where non-structural solutions are inadequate to protect human life and existing development, nature-based features may be appropriate. Nature-based features offer many benefits compared to most hardened shorelines by maintaining coastal processes, providing habitat for flora and fauna, and filtering pollutants. If non-structural and nature-based features will not meet the needs of the project, hard structural measures may be considered.

Please refer to the *Erosion and Flood Protection Measures* section for methods that may be used to manage shoreline erosion.

Hard structural measures, such as seawalls, bulkheads, revetments, and groins, can have negative impacts on adjacent properties. For this reason, hard structures, while sometimes necessary, should be avoided unless there are no other viable options. You should select the alternative that minimizes project impacts while achieving the necessary protection.

At a minimum, the alternatives below should be considered and evaluated:

- **No-action alternative:** Describe the outcomes if the proposed project is not undertaken.
- **Non-structural measures:** Evaluate at least one alternative that adjusts the land use, footprint, and/or site design to avoid or minimize risks to public or private property and conserves natural features and processes that reduce risk over the project lifespan. Applicants should consider options such as moving structures away from the shoreline to reduce their risk from flooding and erosion, reducing or adjusting the structure footprint, elevating structures, and incorporating a vegetated buffer between land use and natural features.
- **Nature-based features:** If a non-structural solution is not feasible, evaluate at least one alternative that restores natural features or processes to the project site or uses nature-based features that mimic natural features and processes. Applicants should consider options such as living shorelines, beach/dune nourishment, and bluff/bank re-grading with vegetative plantings.
- **Hard structural measures:** If none of the above alternatives are feasible, evaluate at least one hard structural alternative These alternatives include things like groins, seawalls, bulkheads, and revetments. If a hard structural measure is warranted at your property (photo 4), a sloped structure like a rock revetment is preferred over vertical walls. This is because vertical walls reflect more wave energy and can have a greater impact to neighboring properties and the nearshore area than sloped structures.

If at any point you have questions regarding which forms should be included or what to include in a permit application to DEC, please call your DEC Regional Office. Contact information for DEC Regional Permits Offices can be found at **https://www.dec.ny.gov/permits/89368.html.**

PHOTO 4. Bluff erosion adjacent to shoreline protective structures, Richland, N.Y.

Step 3: Select Your Permit Application Form

Option 1: Joint Application Form and other associated forms:
For most permits or authorizations from DEC, DOS, OGS, and USACE, a Joint Application Form can be used. A link to this form can be found on DEC's website at https://www.dec.ny.gov/permits/6222.html, along with instructions on how to fill out the form. These forms cover multiple-permitting programs at each agency and are designed to simplify the permitting process. The instructions also identify what other forms you may need to include in your application, such as an Environmental Assessment Form (EAF) or Consistency Assessment Form (CAF). In most instances, a copy of these forms and your application package can be sent to each agency listed above that has jurisdiction in the project area. If you have any questions, please contact your DEC Regional Permits Office

Option 2: General Permit Application Form:
After the high-water events on Lake Ontario in 2017 and 2019, DEC issued General Permits for typical activities undertaken by property owners to repair and stabilize their properties damaged by high water levels. DEC issues these types of General Permits to make the permitting process quicker and simpler for shoreline recovery projects. General Permits may also streamline permits from DOS and USACE. To determine if any General Permits are in effect for the type of work you are considering and your project location, please visit: https://www.dec.ny.gov/permits/89343.html

When is USACE authorization required?
Generally, any activity that is being constructed below the Ordinary High Water Mark requires authorization from USACE. Please see the Common Terminology section for an explanation of Mean High Water versus Ordinary High Water Mark; these terms generally refer to the same water elevation. For consistency, Mean High Water is used in this booklet.

Many USACE authorizations are provided by General Permits, which allow for an expedited review process.

When is DOS authorization required?
When an activity that requires USACE authorization is within the NYS Coastal Area, DOS authorization is also required. DOS authorization may also be required when any federal authorization is necessary. The NYS Coastal Area boundary is viewable at https://www.dos.ny.gov/opd/atlas/

When is OGS authorization required?
Generally, any activity that is being undertaken in, on, or over state-owned lands underwater requires authorization from OGS. For Lake Ontario and Lake Erie it would be below mean low water. For the St. Lawrence River it would be below ordinary high water, meaning the line which the water impresses on the soil by covering it for sufficient periods of time to deprive it of vegetation. Please visit https://ogs.ny.gov/real-estate/lands-now-or-formerly-underwater for more information.

Step 4: Complete and Submit Your Permit Application
If you are completing an application for a General Permit, follow the written instructions that are provided with the General Permit application form. If you are completing an application for an individual permit, below is a list of project information and details that are typically required in a permit application. If you have any questions on what to include in your permit application, please call your DEC Regional Permits Office for assistance Note that this is not an exhaustive list, and DEC or other agencies may request additional information based on the specifics of your project.

1. A completed Joint Application Form (available at https://www.dec.ny.gov/permits/6222.html);
2. A completed federal Coastal Consistency Assessment Form (available at https://www.dos.ny.gov/opd/programs/consistency/index.html);
3. A completed short Environmental Assessment Form, Part 1 (available at https://www.dec.ny.gov/permits/6191.html);
4. A description of your proposed project and why it is your preferred alternative If a hard structural measure is proposed, include an explanation of why a non-structural or nature-based approach is not appropriate to manage risk for the site and/or use;
5. A site plan (top-down view of the project) and cross-section plan (a view of the project from the side). The plans need to show existing conditions in comparison to proposed work and Mean High Water The site plan should include the location of property boundaries. All proposed work and construction access must be within the limits of the owner's property unless appropriate easements or written permission(s) from adjacent property owners are obtained. For examples of project plans and how to determine Mean High Water, refer to Appendix 1.
6. Photos of the project location.
7. A description of your construction methods (e g., how the rock will be placed, how the wall will be constructed, how you will access the shoreline, what equipment will be used, etc.). If access from property that is owned by someone other than the applicant is necessary, DEC will need confirmation, in writing, that the property owner is allowing you to access the property;
8. A description of potential adverse impacts to adjacent areas and natural features, and how unavoidable losses or impacts on natural features and processes will be minimized or mitigated;
9. A Maintenance Plan if you are within a DEC-identified Coastal Erosion Hazard Area A sample maintenance plan is provided in *Appendix 2* of this document.

If the proposed project is within a DEC identified Coastal Erosion Hazard Area (CEHA), you may use the CEHA permit application checklist. For more information on the CEHA Program and a copy of the checklist, please visit https://www.dec.ny.gov/permits/6064.html

COASTAL PROCESSES

Natural coastal processes continually change the Lake Erie, Lake Ontario, and St. Lawrence River shorelines. Developing appropriate flooding and erosion protection measures while also minimizing the impacts to natural coastal processes can be best accomplished with an awareness of the key coastal processes that influence the shoreline These processes are discussed in this section.

Coastal Processes and Effects

The coastlines of the Great Lakes are dynamic areas. Waves and currents move sediment both on and off the shore and along the shoreline. Generally, incoming waves are not exactly perpendicular to the shoreline and come in at a slight angle As the waves break, they create a current parallel to the coastline; this, combined with other natural currents, is known as a longshore current (see Figure 1). Because waves can lift sediment particles from the lakebed, the sediment will be transported with the longshore current from one place to another This process is called littoral drift or sediment transport. Sediment transport is a key concept in coastal management because it helps feed beaches and offshore bars, which provide natural protection against storm events. Sediment transport also maintains and supports natural habitats within the waterbody Erosion is an important source of this sediment. Hard structural erosion protection cuts off the supply of sediment at the project location and causes cumulative negative impacts along the shoreline as the overall amount of sediment in the system is reduced. This sediment reduction can reduce the size of dunes and width of beaches, and deepen the nearshore area. The impacts to these features can reduce their protective potential and make shoreline properties more vulnerable to flooding and erosion damage

While hard structural erosion protection is sometimes necessary to protect existing development, it should only be used as a last resort. The best solution to deal with erosion is to move existing structures back and ensure new construction is sited an appropriate distance from the shoreline. This will minimize the risk of damage to the structure and allow the natural processes to continue.

Coastal erosion can, in general, be divided into two main processes:

1. Erosion associated with historical processes, which gradually adjusts the shoreline and is influenced by the shape of the shoreline, water depth, lakebed conditions, natural currents, groundwater, and surface water; or
2. Erosion due to short-duration, high-intensity storm events, generally associated with waves and high water levels, but groundwater seeping through a bluff and surface water runoff may also be factors.

It can be beneficial to distinguish between these types of erosion because of the different processes causing the erosion and different measures that may be needed to mitigate the erosion.

In a natural situation without erosion protection, as the shoreline erodes, it provides sediment into the system, and feeds beaches and the area directly offshore, known as the nearshore area. When any type of erosion protection is installed, it causes a lack of sediment in the system. This lack of sediment can result in the nearshore area becoming deeper and the beaches becoming narrower. Eventually, without sediment input, the beaches disappear, and the lakebed becomes steeper with increased water depths close to the shore The maximum height of a wave near the shoreline is generally directly related to the depth of the water The deeper the water is, the larger the wave that can be carried to the shoreline, causing more erosion when it breaks on the coast. Hard structural erosion protection can also cause the energy from breaking waves to be pushed downward when the waves hit the structure This causes the nearshore area in front of the structure to scour, increasing the depth of the water in front of the structure This can cause stability issues and increase the maximum wave height in the same way a deepening of the nearshore can.

Short-term erosion occurs during storms and is dependent on the waves and water levels during a storm event (photo 5). In general, a wide beach will reduce wave energy and protect the bluff behind the beach; however, with storm surge and large waves, the bluff might be exposed to short-term erosion. Like beaches, bluffs naturally erode due to natural processes; however, they will not rebuild naturally over time. Vegetation on bluffs can help hold the bluffs together and is an easy way to provide greater stability Please see the *Maintaining Existing Vegetation* section for more details.

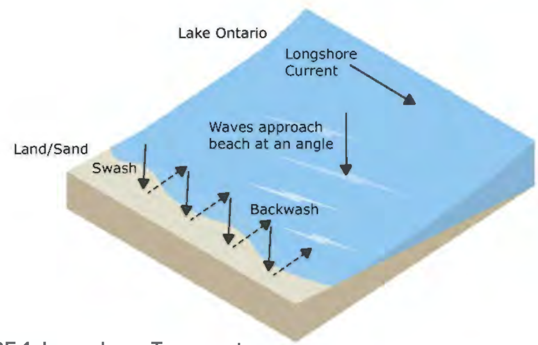


FIGURE 1: Longshore Transport

PHOTO 5. Shoreline erosion associated with the 2017 and 2019 high-water level events along Lakeshore Rd., Carlton, N.Y.

GENERAL PROJECT DESIGN CRITERIA

The information provided here is for general guidance purposes and does not delve into the calculations necessary for erosion protection design. Methods for the final project design should be determined by a licensed PE. Detailed engineering guidance for the design of erosion protection can be found in the USACE Coastal Engineering Manual at **https://on.ny.gov/rediguidance.**

In order to ensure your project will provide adequate protection and will be built to last, it is important to calculate the proper height of the structure you are designing. This can be done in a number of ways, from a series of mathematical calculations based on conditions at the site to complex computer modeling. Regardless of the process used, generally, several key factors play a part in most designs. These factors include the level of protection, the design water level, the design wave height, and wave runup The proposed design of your project should take all of these factors into account.

Other important design considerations such as slope, stone size, types of vegetation, and other factors vary, depending on the type of structure being proposed. These factors are discussed in the *Erosion and Flood Protection Measures* section.

Level of Protection

At the beginning of the design process, you should evaluate the need for erosion or flood protection and how much protection is necessary The amount of protection provided by the structure is known as the level of protection. This is generally expressed as a storm return period. If an erosion protection measure is designed to have a 30-year level of protection, it means that the structure will provide protection from at least a 30-year storm without the expectation of significant damage or overtopping. Each site is different and should be evaluated to determine which type of protection is best suited for the site and the necessary level of protection. For example, a vacant lot along Lake Ontario may only require a small amount of work to stabilize an eroding shoreline that provides a low level or protection, while a house immediately adjacent to the edge of an eroding bluff may require a much higher level of protection to ensure it will be well protected.

Design Water Level

Surface water levels vary as a result of natural processes, and on Lake Ontario, water-level management. Design water level (DWL) is the elevation of surface water engineers use in the design of shoreline structures, and should take into account seasonal water level variations and storm surge. Typically, the DWL is based on historic data obtained from water level gauge readings throughout the waterbody, which are broken down into return periods. A 50-year design water level is a good place to start for your design. The design water level is then used to determine the design wave height, and the design wave height is used to determine the wave run-up

Guidance on water level return periods for Lake Ontario, Lake Erie, and the St. Lawrence River can be found at https://on.ny.gov/rediguidance, and can help you determine the appropriate design water level for your project.

Real-time (and historical) water level data for a variety of Great Lakes locations are available on the NOAA webpage at https://tidesandcurrents.noaa.gov/water_level_info.html

Because these return periods are based on historical data, it is important to also consider the high-water levels of 2017 and 2019 in your evaluation. Within Coastal Erosion Hazard Areas, DEC requires that an erosion protection structure have a reasonable probability of lasting 30 years with regular maintenance, so, generally, a 30-year design water level should be the minimum considered in those cases where hard structural erosion protection is necessary Data on the 50-year water level return period is more commonly available than the 30-year and is therefore recommended as a starting point for your evaluation.

Design Wave Height

Waves exert forces on structures along the shoreline, which can cause increased erosion and damage. Waves are generally formed in deep water, and upon reaching the nearshore area, break when the water depth can no longer support the height of the wave. A variety of calculations and modeling can be used to establish design wave heights.

To determine water depth, it is necessary to not only know the design water level, but also the elevation of the lakebed at the project location. This underwater topography is known as bathymetry and is generally necessary to determine the design wave height.

Design wave height calculations are outside of the scope of this manual, but more information can be found in the USACE's guidance manual, *Design of Coastal Revetments, Seawalls, and Bulkheads* A digital version of this guidance manual can be found at https://on.ny.gov/rediguidance

Run-up and Overtopping of Structures

Wave run-up is the additional height above the DWL that the design wave will wash upward along the slope or over a structure Water and wind-driven spray from run-up can cause flooding and erosion, which can damage shoreline structures and nearby assets. Run-up calculations differ based on the type of structure being built. Additional information can be found in the USACE's guidance manual, *Design of Coastal Revetments, Seawalls, and Bulkheads* A digital version of this guidance manual can be found at https://on.ny.gov/rediguidance

Overtopping refers to the volume of water that runs up and over the structure It is ideal that the proposed structure be high enough to prevent overtopping for the design storm; however, this is not always possible Overtopping can wash out material behind the structure, causing damage and reducing stability It can also be a safety concern on access structures and portions of erosion control structures that have access points, as the water can cause a slipping hazard and direct injury if the overtopping waves are large enough. The overtopping volume can be used to design drainage features for structures to minimize hazards to the extent possible

A SHORT OVERVIEW OF THE IMPORTANT FACTORS AND PROCESSES FOR COASTAL EROSION

Bluff erosion:
Shoreline erosion can create undercuts along bluffs, increasing the chance of bluff erosion, sloughing, and collapse Many bluffs in the Great Lakes system are naturally erosive and contribute sediment into the system (photo 6).

Nearshore erosion:
Nearshore erosion is the process in which waves disrupt and transport sediment out to deeper waters. As the nearshore lakebed erodes, it causes increased water depths and allows for larger waves to reach the shore

River considerations:
Movement of sediment particles in riverine systems can occur along the riverbed or in the water and is called fluvial transport. This process can remove or deposit particles in river bends or at the mouth of the river. Fluvial transport can also erode shorelines during periods of elevated water levels. Ice jams, which are more problematic in river systems, can contribute to upstream or downstream flooding when the jams release This type of flooding can be particularly severe because the space for additional water to be stored is typically less than in lake environments.

Return period:
The return period identifies how often a specific water level is expected to occur on average. For example, a 25-year return period means that, on average, a specific lake level can be expected to occur or be exceeded once every 25 years. The larger the number of years in a recurrence interval, the smaller the chances of experiencing that lake level in any given year Recurrence intervals can also be expressed as a probability by dividing 1 by the return period and then multiplying by 100 For example, a 25-year return period is equivalent to a 4% chance of occurring in any given year

Sediment transport:
Longshore sediment transport occurs when waves contact the shoreline at a slight angle This, in combination with natural currents, moves sand and other materials laterally along the shoreline Sediment moves from its source with the current and is often deposited downdrift. Wave energy generally determines the size of material that moves with the current. This process can create both sediment deficits and surpluses. Natural patterns of sediment transport can be disrupted by shoreline hardening, dredging, and fill. This can result in negative impacts to shoreline stability, habitat, and natural protective features in both sediment source and downdrift locations.

Shoreline erosion:
Shoreline erosion is the endless reshaping of shorelines by waves, currents, storms, ice, rain, and groundwater seepage Human activities, like construction, dredging, excavation, and vegetation removal, can accelerate erosion of beaches, dunes, and bluffs, reducing the natural protection these features provide against flooding and property damage

Shoreline ice:
While ice may prevent wave damage by dampening storm surges and decreasing open water surface area, it can also directly cause damage and erode the shoreline Although ice sheets may help protect shorelines, ice that is mobilized by wind and currents can be driven inland, potentially causing significant damage to shoreline infrastructure and waterfront homes. Accumulated ice can also cause damage to natural or built shoreline features by its movement or through freeze/thaw cycles.

Storm surge/water levels:
During storms, water levels may rise above normal. The water level is affected directly by wind, which pushes more water into the nearshore area, and by the low pressure usually connected to a storm. This increased water level change is called storm surge With this increased water level, the height of the wave that can impact the shoreline also increases. Therefore, it is important to consider storm surge when evaluating erosion protection options.

Waves:
Waves drive sediment transport within the coastal zone The size of waves in deep water (far offshore) are determined by the distance of water the wind travels over (known as fetch), the wind speed, and the duration of sustained wind. When approaching the shore, a range of different factors will affect waves. Wave height near the shoreline is generally determined by the depth of the water. The deeper the water, the larger the wave that can impact a proposed erosion protection structure This is why it is important to evaluate both the water level and wave height at a given location during the design of an erosion protection structure

PHOTO 6. Steep unvegetated bluff showing signs of slope failure after the 2019 high water event in Oswego, N.Y.

WHAT TYPE OF EROSION PROTECTION IS RIGHT FOR MY PROPERTY?

As discussed in the previous sections, identifying the right type of erosion or flood protection for your property must take into account many different factors, including the project's location, type of structure, needed level of protection, existing erosion/flood protection at the site, and cost. The table below is designed to help you identify what might work for your property A Professional Engineer (PE) or other design professional can provide a more detailed evaluation to ensure your proposed project will meet the needs of your individual property

Table 1 - Shoreline Management Strategy Alternatives Matrix

ALTERNATIVE	APPLICABILITY	CONSTRAINTS	SHORELINE CLASSIFICATION	SEE PAGE
NON-STRUCTURAL				
Elevation, moving back from the shoreline, flood-proofing structures	Use non-structural measures whenever possible	Size of property, type and size of structure, cost	All shoreline types	14
NATURAL AND NATURE-BASED MEASURES				
Vegetation management	Pre-existing vegetative areas	Size of property, available undeveloped shoreline	All shoreline types	14
Groundwater management	Areas with slope face seepage	Size of property, depth to groundwater	All shoreline types, but mostly applicable to bluffs	14
Surface water management	Shorelines with steep slopes, areas with impermeable surfaces	Size of property	All shoreline types, but mostly applicable to bluffs	15
Dune and beach restoration	Areas with an existing dune/beach	Existing beaches or dunes, must have adequate sand available to support a beach/dune system	Beach and dune shorelines	15
Bluff and bank stabilization with toe protection	Unvegetated bluffs, steep slopes, areas undercut by wave action	Size of property, width of property, proximity of development to shoreline	Bluffs	17
Stone sill	Shallow water areas (3–5 ft) with low to moderate wave energy, protective coves and bays	Requires a shallow near-shore area and existing or former wetland	Existing wetland areas	19
HARD STRUCTURAL MEASURES				
Rock revetment	Large waves, long fetch length, open coast, sites with pre-existing hard structures.	Shoreline width	All shorelines	19, 23
Joint planted revetment	Large waves, long fetch length, open coast, pre-existing revetments	Shoreline width, slope	All shorelines	21
Bulkheads/seawalls	Harbors, marinas, other working waterfronts, areas without room for a rock revetment	Large waves	Bluffs	21, 23
Groins	Existing beaches with adequate sand available in the system to be captured by the groin	Extensive study needed to avoid detrimental impacts downdrift	Beaches	21

The table below discusses options to consider based on existing erosion or flood protection at the property

Table 2 - Options for Improvement or Repair Of Existing Erosion Protection Structures

EXISTING STRUCTURE TYPE	ISSUE	WHAT CAN I DO?	SEE PAGE
No current shore protection	Bluff erosion	Maintain existing vegetation, re-grade and plant vegetation, move structures at risk, install upland drainage, evaluate if hard structural measures are required	12
No current shore protection	Dune erosion	Maintain and plant vegetation, sand fencing, sand replenishment	12
No current shore protection	Flooding	Elevate structure(s) at risk, install a flood protection wall	14, 22
Rock revetment	Bank erosion behind existing rock	Increase the height of the revetment; re-grade slope, plant vegetation	19, 23
Rock revetment	Rocks dislodging or sliding	Increase size of stone on slope and toe stone, key in toe stone, construct a more gradual slope, use irregularly shaped stone instead of flat-surfaced stone	19, 23
Rock revetment	Flooding	Elevate structure(s) at risk, install a flood protection wall upland	14, 22
Seawall/bulkhead (vertical wall)	Erosion behind the wall from wave splash	Fill in eroded areas behind the wall, increase height of wall, place rock on lakeside to reduce wave energy	21, 23
Seawall/bulkhead (vertical wall)	Cracking, forward movement (tipping) of the wall	Replace seawall, install drainage, repair structure by installing new anchor system and footer, place rock on lakeside to reduce wave energy	21, 23
Seawall/bulkhead (vertical wall)	Erosion (scour) under the wall, bank erosion behind the wall	Fill in eroded areas behind and under the wall, install or repair footer, place rock on lakeside to reduce wave energy	21, 23

EROSION AND FLOOD PROTECTION MEASURES

The sections below discuss a variety of different measures that can be employed to reduce erosion and flooding risk.

There are a variety of shoreline management strategies (ranging from no-action to hard structural flood and/or erosion protection measures) that may be appropriate in a given setting. Homeowners, municipalities, and other vested parties should consult a PE for assistance in the process of evaluating which strategy is most favorable in a given situation and developing that strategy into a detailed design.

Selecting an appropriate shoreline management strategy requires careful consideration of site-specific problems, shoreline conditions, and land use, among other possible considerations (e g., budget, or accessibility). As you design your project, it is important to evaluate ground elevations, erosion, utilities, current and future predicted water levels, flooding risk, wave climate, and land-use characteristics. Consider whether the design must address erosion, flooding, or both. Erosion protection and flood protection may have different design considerations. For example, a vegetated bluff or revetment will not necessarily help with upland flooding associated with storm events, though it may help reduce erosion. Defining the problem is an initial step taken by you, the homeowner, and your engineer during the alternatives and feasibility analysis

Natural features and processes aren't limited to a single project site. As erosion protection is constructed along the shoreline, impacts collectively affect natural features or processes over time as the amount of sediment in the system is reduced with the construction of each structure Hard structural erosion protection can also cause direct impacts to adjacent properties. As discussed in the *Coastal Processes* section, waves generally break along the shoreline at an angle When waves break at the ends of an erosion protection structure, this can cause increased erosion at the adjacent property or damage to erosion protection structures This should be taken into consideration during the design process to ensure no damage to adjacent properties takes place

Project planning must consider effects to adjacent and downdrift properties. Measures to address site-specific erosion or flooding issues without consideration of their effect on nearby properties or natural features can negatively impact adjacent properties. This may motivate nearby property owners to install additional hard structural measures and lead to larger-scale impacts.

Non-structural Solutions

Non-structural solutions, such as using setbacks (Figure 2), moving development back from the shoreline, home elevation, and flood-proofing structures, can reduce the risk of damage from flooding and erosion. These options allow for the risk to a structure to be reduced while also maintaining natural processes and protection. Non-structural measures are often the best option for long-term risk reduction and minimal maintenance and should always be evaluated as part of an alternative analysis. Non-structural solutions may not always be viable to lot size or other restrictions, and may be combined with natural and nature-based solutions or structural solutions if warranted. FEMA has several guidance documents on non-structural measures, including the "Homeowner's Guide to Retrofitting," which has a section on home elevations. The document can be found at https://www.fema.gov/sites/default/files/2020-07/fema_nfip_homeowners-guide-retrofitting_2014.pdf.

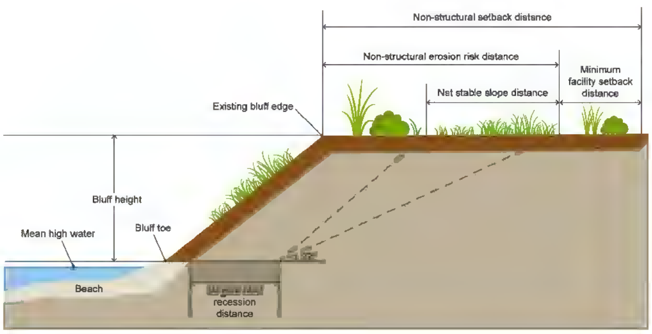


FIGURE 2: Typical detail, setback

Natural and Nature-Based Features

Maintain Existing Vegetation

The proper management of existing vegetation can reduce shoreline erosion associated with wave action, wind, and surface runoff, and increase the ecological function of the shoreline (photo 7). Vegetation management strategies may include:

- Remove invasive species and replace them with native species appropriate for the shoreline conditions. Potential native plant species for shoreline use are discussed later in this section. Native species should be managed to help facilitate bank stability, increase biodiversity, and provide wildlife, pollinator, fisheries, and avian habitat;
- Discontinue mowing up to the edge of the water or bluff, and maintain a naturally vegetated buffer along the shoreline to provide stability and reduce runoff (photo 8)—a 100-foot unmowed buffer is recommended; however, site-specific buffer widths should be taken into consideration;
- Maintain native woody plants to the extent possible, such as eastern cottonwood, or silver and red maple;
- Evaluate trees for common pests and pathogens, such as emerald ash borer, and take needed management actions DEC provides additional information on common pests and pathogens here: https://www.dec.ny.gov/animals/7253.html;
- Eliminate, to the extent possible, chemical pesticides and fertilizers;
- Dispose of leaves, brush, and other vegetation biomass in a compost pile away from the shoreline edge, or with the assistance of a local/municipal yard waste collection program; and
- Plant and maintain natural vegetation on the slope of a bluff The root systems of plants can help hold the slope of a bluff together, making it more resistant to erosion.

PHOTO 7. Vegetative buffer at Gratwick Park along the Niagara River

PHOTO 8. Stone revetment with a vegetative buffer in Waddington, N.Y.

Groundwater Management

It is important to consider groundwater management when preventing or reducing shoreline erosion and damage to existing erosion protection structures. Excess groundwater can render a slope unstable and lead to a slope or structural failure, even if the slope is considered stable under normal conditions. Groundwater management involves removing excess water before it reaches the shoreline and reducing seepage at the face of the slope, which can exacerbate instability Figure 3 identifies potential structural components used for groundwater management.

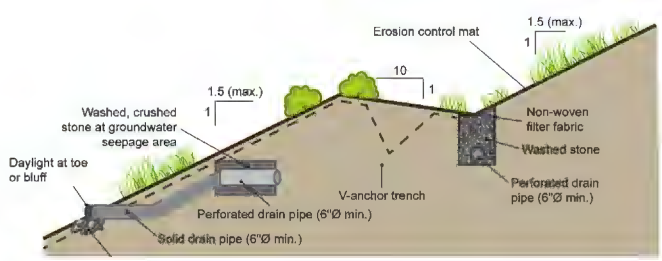


FIGURE 3: Typical detail, groundwater management. Please note that for this typical detail and others in this document, additional detail will be needed for design, permitting, and construction purposes.

Surface Water Management

Management of surface water is important to control erosion, particularly on and above the shoreline and/or bluffs. Surface water runoff controls can include the following:

- Collect and divert runoff from the face of the slope (Figure 4);
- Maintain green space;
- Install rain gardens;
- Avoid conveying runoff from impermeable surfaces (e g., parking areas, roofs) toward the bluff edge, which could lead to formation of low spots and bluff instability; and
- Use vegetation to slow runoff and spread water to promote infiltration.

Vegetative strategies to control surface water runoff, such as a vegetative buffer strips, are preferred. These strategies provide additional ecological benefits and minimally disrupt natural shoreline processes. Where vegetation buffers are not viable, or additional management strategies are needed, structural components to control surface runoff, such as those in Figure 4, may be appropriate

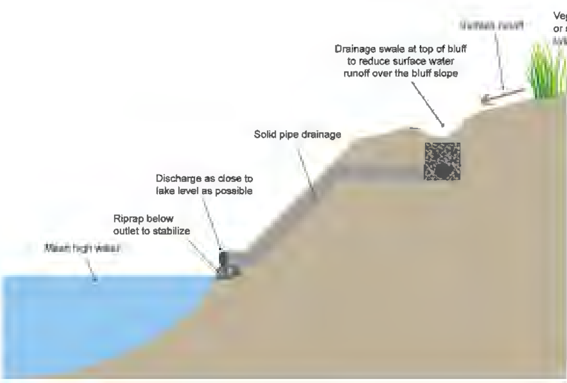


FIGURE 4: Typical detail, surface water diversion

Dune and Beach Restoration

Beaches can protect the coast by providing a buffer that breaks waves farther away from development. Dunes are natural coastal features formed by sand that blows inland from the beach and is deposited in the area behind the coastline (photo 9). During storm events, dunes act as natural barriers to flooding and erosion. After a storm event, there is often damage to a natural beach or dune system, which is slowly repaired by natural processes over time, if the coastal processes (sediment within the system) have not changed.

Natural beach and dune rebuilding can take a long time Beach and dune nourishment are nature-based techniques that quickly repair these features to restore their protective functions after a storm or high water event. Nourishment includes the placement of sand to increase the area, height, or width of a dune or beach. This material can be strategically placed so that the benefits extend along the shoreline as material is moved by wave action (sediment transport). Material used for nourishment should be clean fill of equal or slightly larger grain size It can be obtained from quarries or dredging. The scraping of sand off the beach to build a dune is generally prohibited.

Sand fencing can be used to trap windblown sand and help increase the size of existing dunes, repair scarps, or rebuild dunes destroyed by a storm. Sand fencing should be placed parallel to the shoreline, away from the beach area that has frequent wave run-up, and as close to the dune as possible Where no dune exists, sand fencing should be placed near the landward limit of the beach. Sand fencing with 50% open space and 50% slats optimizes sand deposition. Using wider slats will mimic a solid wall and likely cause erosion from wind and waves. Wider gaps will not properly deposit sand and will promote scour. Posts should be placed a minimum of 4 feet apart and post size should be no larger than 2x4 inches for rectangular posts and 3-inch diameter for circular posts. Smaller posts are recommended, as opposed to larger posts, to minimize the potential for erosion around the post base from wind and water

Vegetative plantings are an important component of dune construction. The root system of plantings holds the dunes together, while the plants help capture wind-blown sand, increasing the size of the dune Sand/snow fencing may be used to retain wind-blown sand and build up dunes while vegetation is being established. Afterwards, the dunes can be protected by regulating their use, e g., by prohibiting access and motor traffic, among other disturbances.

New York's Great Lakes dunes ecosystems are a critically imperiled natural ecological community As a result, when working to restore or enhance dune vegetation, it is important to do so in the most ecologically conscious means available This work includes, when possible, the use of local varieties of plant stock when re-establishing native vegetation—particularly the key dune grass in New York, *Ammophila beviligulata spp. champlainensis* (Champlain beachgrass). Unless otherwise recommended by DEC or other local conservation organizations, *Ammophila breviligulata* Fern ("Cape" American beachgrass) should not be used for Lake Ontario dune projects. Contact your local DEC Regional Office for assistance locating local varieties of plants to include in your dune project.

Additional recommended plant species can be found in Table 3 and at https://guides.nynhp.org/great-lakes-dunes/ provided by the New York State Natural Heritage Program.

PHOTO 9. Example of vegetative dune protection in Ellisburg, N.Y., after the high water events of 2019

Table 3 - Dune Planting Recommendations

PLANTS GENERALLY APPLICABLE IN BACK/HIGH DUNE AREAS WITH MOST DEVELOPED FOREST CONDITIONS		
SCIENTIFIC NAME	**COMMON NAME**	**GROWTH FORM**
Acer rubrum	red maple	tree
Fagus grandifolia	American beech	tree
Juniperus virginiana	eastern red cedar	tree
Picea glauca	white spruce	tree
Pinus banksiana	jack pine	tree
Pinus resinosa	red pine	tree
Populus deltoides	eastern cottonwood	tree
Prunus pennsylvanica	pin cherry	tree
Quercus rubra	red oak	tree
PLANTS GENERALLY APPLICABLE IN INTERIOR AREAS AND MODERATELY STABILIZED DUNE CRESTS		
SCIENTIFIC NAME	**COMMON NAME**	**GROWTH FORM**
Cornus sericea	red osier dogwood	shrub
Cornus amomum	silky dogwood	shrub
Hudsonia tomentosa	beach-heather	shrub
Myrica pennsylvanica	northern bayberry	shrub
Prunus pumila	sand cherry	shrub
Rosa rugosa	beach rose	shrub
Rubus alleghniensis	common blackberry	shrub
Salix cordata	sand dune willow	shrub
Vitis riparia	riverbank grape	vine
PLANTS GENERALLY APPLICABLE IN THE FOREDUNE AREAS THAT ARE EXPOSED TO THE EXTREMES OF ENVIRONMENTAL STRESSES		
SCIENTIFIC NAME	**COMMON NAME**	**GROWTH FORM**
Ammophila champlainensis	Champlain beachgrass	grass
Artemisia campestris spp. caudata	sand woodworm	forb
Cakile edentula	American searocket	forb
Deschampsia flexuosa	tufted hairgrass	grass
Elymus canadensis	Canada wildrye	grass
Eragrostis spectabilis	purple lovegrass	grass
Lathyrus japonicus var. maritimus	beach pea	forb
Polygonella articulate	coastal jointweed	forb
Pteridium aquilinum	western brackenfern	ferns and fern allies
Solidago sempervirens	seaside goldenrod	forb

Bluff and Bank Stabilization with Toe Protection

Surface water runoff, groundwater, wave action, and ice can destabilize bluffs and banks and increase erosion. Re-grading to a more gradual slope, combined with vegetation plantings and adequate toe protection, as necessary, can increase stability and reduce the risk of erosion (photo 10). Bluffs contribute important material supporting sediment transport; therefore, stabilization should only be performed when necessary Figure 5 illustrates the components to consider when developing a bluff stabilization project. In general, the recommended re-graded slope is 1V:3H (18°) to 1V:2H (27°). Where space is not available, the re-graded slope should not exceed 1V:1.5H (33°). The angle of the slope needed to stabilize is determined by the soil type and water content of the bluff Re-grading of a slope involves the addition (fill) or removal (cut) of material to reach the desired slope The two most common methods used to re-grade bluffs, the cut-back (Figure 6) and the cut-and-fill methods (Figure 7), are illustrated.

To prevent undercutting from wave action, toe protection may also be necessary (photo 11). Options for toe protection range from fiber rolls at low wave-energy sites to rock at sites with more severe wave action.

Newly graded bluff areas should be stabilized with erosion protection materials and vegetation as soon as practicable after earthwork is completed (photos 12 and 13). The United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) provides helpful information regarding the selection and establishment of vegetation for "critical areas" such as bluffs. It can be found at http://on.ny.gov/rediguidance

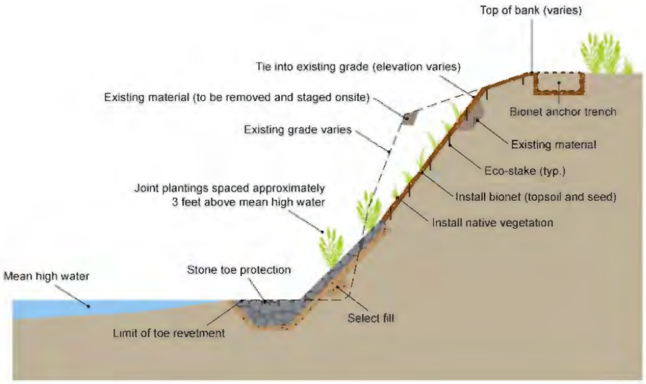


FIGURE 5: Typical detail, joint planted revetment. Also illustrating potential need to modify adjacent bank

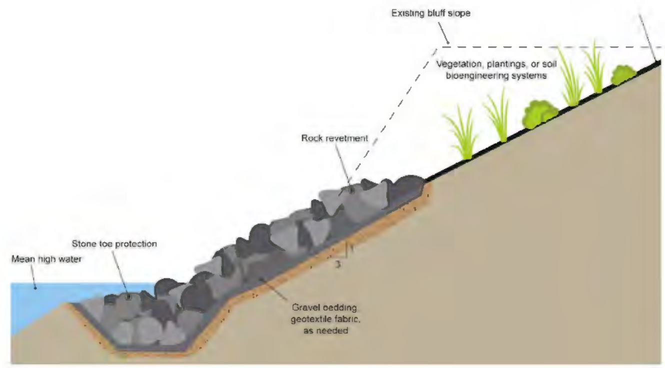


FIGURE 6: Typical detail, bluff stabilization with cut back bank

PHOTO 10. Vegetative bank with toe protection, Lakeside Park Rd., Carlton, N.Y.

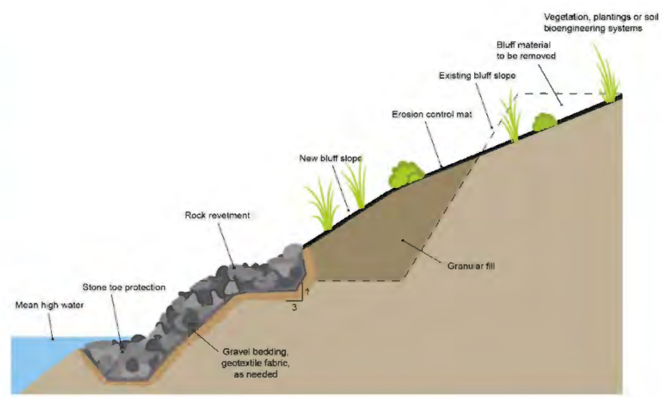


FIGURE 7: Typical detail, bluff stabilization with bank fill

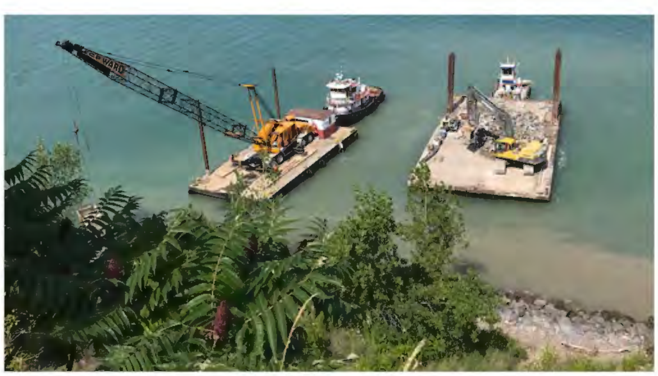


PHOTO 11. Construction of rock revetment bluff toe protection at Crescent Beach, Rochester, N.Y.

PHOTO 12. Placement of erosion control and a seed mix on a re-graded slope on Lake Ontario near Sodus Bay. Construction was completed in 2008.

Table 4 - Bluff Planting Recommendations

NATIVE SPECIES GENERALLY APPLICABLE TO BLUFF AND BANK STABILIZATION PROJECTS		
SCIENTIFIC NAME	**COMMON NAME**	**GROWTH FORM**
Andropogon gerardii	big bluestem	grass
Asclepias syriaca	common milkweed	forb
Asclepias tuberosa	butterfly weed	forb
Baptisia tinctoria	yellow wild indigo	forb
Bouteloua curtipendula	sideoats grama	grass
Carex lurida	shallow sedge	grasslike
Carex scoparia	blunt broom sedge	grasslike
Carex vulpinoidea	fox sedge	grasslike
Chamaecrista fasciculata	partridge pea	forb
Coreopsis lanceolata	lanceleaf coreopsis	forb
Dalea purpurea	purple prairie clover	forb
Dichanthelium clandestinum	deertongue	grass
Elymus canadensis	Canada wildrye	grass
Juncus tenuis	path rush	grasslike
Heliopsis helianthoides	false sunflower	forb
Lupinus perennis	wild blue lupine	forb
Monarda fistulosa	wild bergamot	forb
Panicum virgatum	switchgrass	grass
Rudbeckia hirta	black-eyed Susan	forb
Schizachyrium scoparium	little bluestem	grass
Sisyrichium montanum	blue-eyed grass	forb
Solidago rigida	stiff-leaved goldenrod	forb
Sorghastrum nutans	Indian grass	grass
Spartina pectinata	prairie cordgrass	grass
Symphyotrichium novae-angliae	New England aster	forb
Symphyotrichium novi-belgii	New York aster	forb
Verbena hastata	blue vervain	forb

PHOTO 13. Re-graded slope with toe protection and vegetative planting near Sodus Bay

Stone Sill

Appropriate for low wave-energy environments, stone sills are low-profile rock structures placed waterward of a natural or constructed open water wetland (Figure 8). These structures provide wave attenuation, while maintaining the associated open wetland ecosystem by allowing flooding of the area. Low-profile sills can be continuous or intermittent, depending on the level of wave energy and amount of water exchange determined appropriate for a specific project. This feature was recently implemented successfully at Gratwick-Riverside Park on the Niagara River (photo 14).

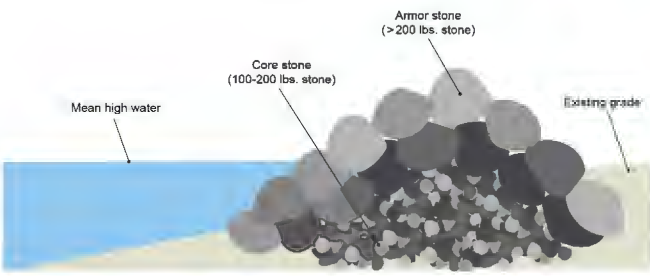


FIGURE 8: Typical detail, stone sill

PHOTO 14. Rock sill at Gratwick Park along the Niagara River

Hard Structural Measures

Rock Revetment

When a hard erosion protection structure is necessary, properly designed and installed sloped rock revetments (Figure 9) are preferred over vertical seawalls or bulkheads due to their ability to better absorb and dissipate wave energy and to provide shoreline habitat. The main difference between a revetment and a seawall is that a seawall may protect against erosion and flooding while revetments generally only protect against erosion. Rock revetments typically only extend to the top of bank and are not effective at preventing flooding of low-lying areas. They should be sited as far landward as possible, and preferably above Mean High Water

The components of an armor stone revetment are as follows More detailed design guidance can be found in USACE's guidance manual, *Design of Coastal Revetments, Seawalls, and Bulkheads*. A digital version of this guidance manual can be found at https://on.ny.gov/rediguidance

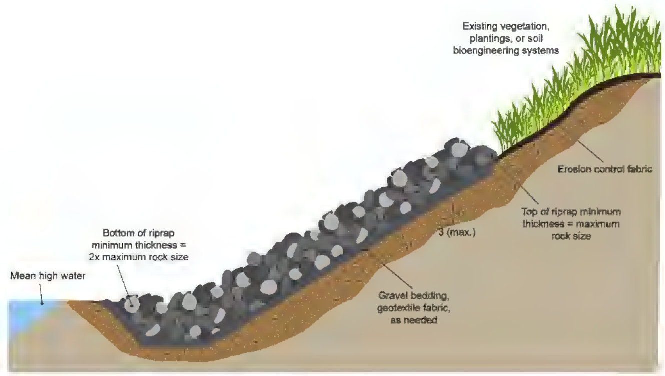


FIGURE 9: Typical detail, rock revetment

1. **The filter layer (with geotextile layer) –** The long-term stability of the rock revetment rests, in part, on the design of the filter layer. The filter layer, also known as the bedding layer, typically consists of graded rock or riprap, and most importantly, geotextile fabric. This layer acts as a transition between the underlying soil and the armor stones and prevents fine soil particles on the bluff slope from migrating through voids in the rock revetment. Additionally, it distributes the weight of the armor material for more uniform settlement and provides relief of hydrostatic pressures within the soil.
2. **The armor stone layer –** The armor stone layer consists of adequate stone material, slope, stone size, and thickness to ensure the structure's effectiveness and longevity (photo 15). Additional details for each component of the armor stone layer are below

   a) **Stone material –** Rock that is angular and resistant to cracking and erosion is preferred. Angular rocks naturally lock together and are recommended over flat-surfaced rocks to minimize sliding and movement. The preferred type of armor stone is limestone or dolomite

   b) **Slope –** In practice, revetment slopes range from 1V:1.5H to 1V:5H. The recommended slope of an armor stone revetment is generally between 1V:2H and 1V:3H. A 1V:1.5H is the steepest recommended slope and results in the smallest footprint along the shore Slopes steeper than 1V:1.5H tend to be unstable. Where possible, revetment slopes should be selected to match the existing bluff/bank slope's stable angle In order to correctly install a shore structure, debris must be removed and disposed of in an upland area.

PHOTO 15. Rock revetment with vegetative planting on the west side of the Genesee River. Photo taken in 2019 after the high water level events.

c) **Stone size –** During the design of a rock revetment, it is common to use Hudson's Equation to determine the appropriate stone size Details on this equation can be found in USACE's *Design of Coastal Revetments, Seawalls, and Bulkheads* It is common to specify a range of stone size using the value calculated from Hudson's Equation. When a range of sizes is used, the larger stones should be placed on the exposed layer, directly receiving wave forces. The USACE Buffalo District recommends using a 0.9 to 2.0 multiplied by the result of Hudson's Equation for armor stone as a best engineering practice. Additionally, due to waterborne ice, the minimum average stone diameter should be at least 3 feet.

d) **Thickness –** The thickness of the armor layer is determined by the dimensions of the stone size. Most commonly, and often most economical, the recommended thickness is two layers of armor stone. A single layer would not have long-term stability and would not be effective in protecting against erosion.

Table 5 provides typical thickness dimensions for a two-unit layer for different limestone types. If a large size range is specified, often the armor layer thickness will be slightly less than the values in this table due to the tighter packing of stones

Concrete rubble is not permitted by DEC and should not be used in the construction of erosion protection structures. It easily cracks and breaks apart, which reduces the effectiveness of the revetment.

Table 5 - Armor Stone Weights and Dimensions

ARMOR STONE WEIGHTS AND DIMENSIONS (FOR LIMESTONE)

TONS[1]/NYSDOT STONE TYPE[2]	POUNDS PER STONE	STONE DIAMETER (FT)	TWO-UNIT LAYER THICKNESS (FT)
8–9	17,000	4.75–5	9.5
7–8	15,000	4.5–4.75	9
6–7	13,000	4.25–4.5	8.5
5–6	11,000	4.0–4.25	8
4–5	9,000	3.75–4.0	7.5
3–4	7,000	3.5–3.75	7
2–3	5,000	3.0–3.5	6
1–2	3,000	2.5–3	5.5
NYSDOT "Heavy"	1,200	2	4
NYSDOT "Medium"	150	1	2
NYSDOT "Light"	20	0.5	1
NYSDOT "Fine"	3	0.25	0.5

[1]*Ohio Coastal Design Manual*

[2]*NYSDOT (New York State Dept. of Transportation) Standard Specifications*

Toe stone

This is a heavier stone placed at the lakeward edge of the revetment to prevent slipping of the upper stones. Where possible, toe stone should be keyed into the lakebed or pinned to help minimize movement and provide stability for the rest of the structure In general, toe stone is recommended to be at least 1 ton larger in size than the stone above it (armor stone layer). Toe stone is typically recommended to be at least 4 tons for open water conditions. Larger or smaller stone may be appropriate depending on your specific site conditions.

Crest

This is the upper elevation of the armor stone and is determined by the calculated run-up elevation of the design wave Homeowners, municipalities, and other vested parties should consult a PE for assistance in the process of a detailed design.

Splash apron

This is smaller stone located above the crest to help dissipate any remaining wave run-up, splash, or spray

Figures 10 and 11 indicate the required elements to be shown in design drawings submitted for agency review

Sample Cross Section

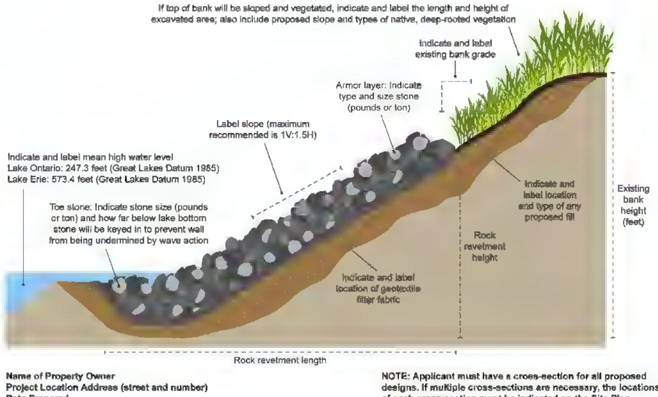


FIGURE 10: Required elements of a stone revetment cross-section drawing

Sample Site Plan

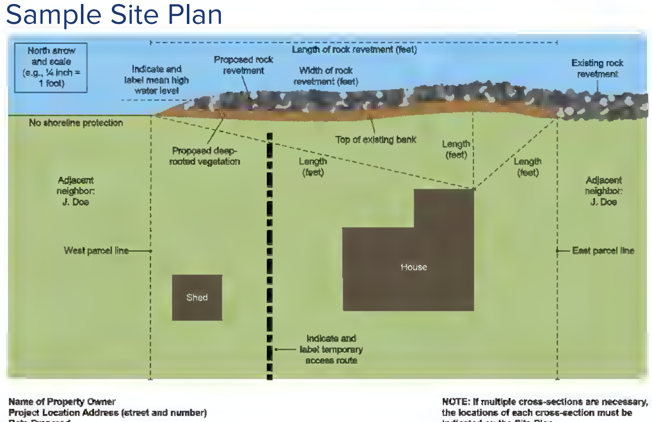


FIGURE 11: Required elements of a stone revetment plan-view drawing

Joint Planted Revetment

A joint planted revetment uses hard armoring components of a rock revetment in conjunction with vegetative planting to stabilize and reduce erosion along sloped shorelines. The general slope of the revetment should match that of the natural shoreline conditions, though the maximum recommended slope of a joint planted revetment is 1V:3H. Once the rock armoring is in place, live stakes (typically native willow or dogwood species) should be driven in gaps between stones into the embankment at sufficiently tight spacing (usually 2-foot centers) to become structurally beneficial (Figure 6).

Bulkheads

Primarily designed as soil-retaining structures, protection from waves and flooding are often secondary functions of a bulkhead. Bulkheads are typically built of concrete, stone, steel, or timber, and are normally smaller than seawalls (Figures 12 and 13). Bulkheads are appropriate where space is limited and flood mitigation is needed. In those cases in which hard erosion protection is necessary, revetments are preferred to bulkheads and seawalls. Bulkheads should be sited as far landward as possible, and preferably above Mean High Water When proposing a bulkhead or seawall, the proposed design should avoid abrupt, squared-off ends at the property line, and instead slope to the meet the existing bluff or bank contours. This will reduce the potential for impacts to adjacent properties and minimize erosion around the ends of a structure (photo 16), which could cause bluff or seawall failure If there are existing seawalls or bulkheads on adjacent properties, the proposed design must tie into those structures as appropriate

Seawalls

Seawalls are onshore structures with the principal function of preventing overtopping by waves and flooding, and erosion associated with waves and storm surges. Because they reflect more energy than a revetment, nearshore erosion in front of the structure needs to be considered to ensure structural stability To decrease the danger of instability caused by erosion at the toe of the structure, seawalls are often used together with a system of toe protection (photo 17). Seawalls should be sited as far landward as possible, and preferably above Mean High Water

In those cases in which hard erosion protection is necessary, revetments are preferred to bulkheads and seawalls.

Groins

Groins are designed to block longshore transport of sediment. Groin structures extend perpendicular to the shoreline, trapping sediment and preventing it from moving downdrift. While this practice generally results in holding sediment updrift of the groin, it can often cause erosion downdrift because the sediment being trapped is no longer able to move to these areas. Therefore, complex modeling and analysis is often necessary to ensure there will be no downdrift impacts if a groin is installed. As with new seawalls, new groins are typically discouraged.

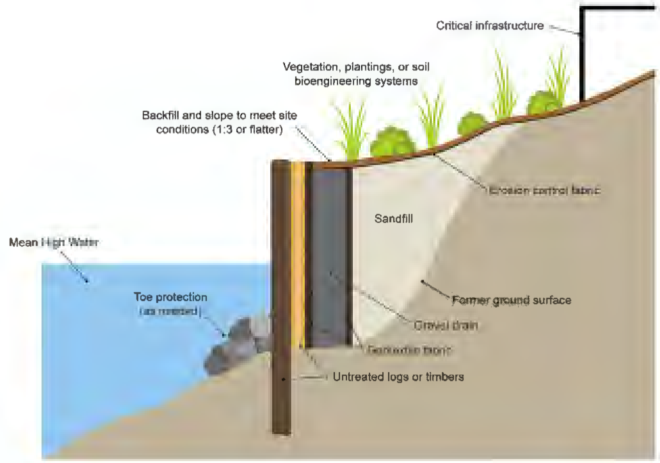


FIGURE 12: Typical detail, timber bulkhead

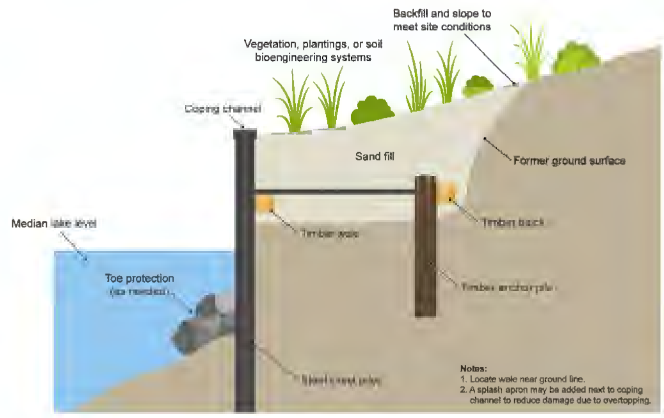


FIGURE 13: Typical detail, sheet pile bulkhead

PHOTO 16. Flanking observed at a bulkhead located on Lake Erie

PHOTO 17. Undermining of a seawall along Lake Erie

Flood Defenses

Artificial Dunes

As described earlier, dunes provide natural protection against coastal flooding when they have enough width and height to resist a breach during storm conditions. Construction of an artificial dune is an environmentally sound and sustainable protection method. In nature, dunes are formed by deposited sand that blows inland from the beach. During storm events, the toe of the dune erodes, allowing sand to enter the lake. This process results in sand buildup on adjacent beaches. After the storm, the eroded toe of the dune will gradually be built up again by wind-blown sand.

Discouraged Materials

There are a variety of shoreline management strategies not included in this booklet that are generally discouraged and not generally permitted by DEC. These include:

- *Gabions;*
- *Pouring concrete over existing rock erosion protection structures;*
- *Concrete blocks;*
- *Broken concrete;*
- *Concrete cylinders;*
- *Railroad ties;*
- *Tires; and*
- *Telephone poles.*

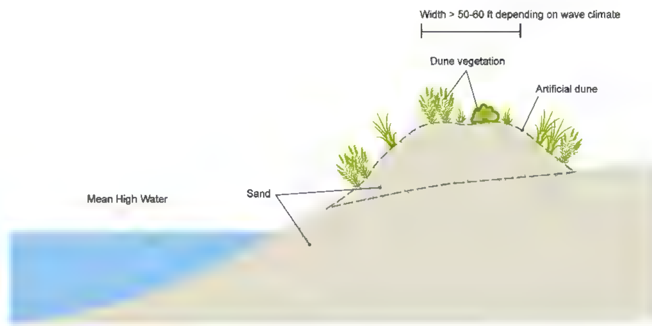


FIGURE 14: Typical detail, artificial dune

Beach grass and sand fencing may be used to trap sand and gradually create a dune; however, this is a slow process, and it is difficult to predict the result. Alternatively, the dune can be artificially constructed by the placement of imported sand of equivalent or slightly larger grain size The dunes are stabilized by planting proper dune vegetation (see *Dune and Beach Restoration* section). An example of a dune is shown in Figure 14.

Floodwalls

Floodwalls function similarly to seawalls; however, they are not designed to bear the forces applied by significant wave action. In general, floodwalls should be used in upland settings and not in an open coastal scenario where significant wave action may occur

MONITORING AND MAINTENANCE

During the design of your project, you should develop an inspection and maintenance plan to ensure the project performs as designed, and budget for anticipated repairs. If your project is within a Coastal Erosion Hazard Area, a maintenance plan is required in your permit application. A sample plan is provided in *Appendix 2* of this document. General maintenance includes:

- Periodic monitoring, including visual inspection of the project, to ensure it is performing as intended.
  - ▶ Condition monitoring provides information on the structural integrity of a project and may consist of photograph monitoring or visual inspections of stone movement, deterioration and/or damage, and vegetation growth.
  - ▶ Annual photos can be helpful when periodic maintenance is necessary, to provide a clear progression of changes to your design professional.
- Performance monitoring includes observations of the project's effectiveness. As conditions may change over the design life of a project, performance monitoring should occur continually to determine whether the project is performing as expected or if adaptive management measures are needed to achieve the project goals.
  - ▶ Performance monitoring may also include evaluations of contractor performance during construction (e g., were the types and amounts of materials installed according to the design? Were the live plantings and seedings successful to the level required to achieve their success criteria?) It is important to conduct contractor monitoring during the construction period and during any applicable warranty period in order to increase the likelihood that corrective actions are taken.

A statewide shoreline monitoring framework has been developed for the coastal regions of NYS. This framework can help track the performance and condition of projects and can be applied on a wide variety of shoreline features, from natural to nature-based, as well as hard structures. For more information on the framework and how it is applied please see https://www.dos.ny.gov/opd/monitoring.html

Obtaining permits for the maintenance of erosion protection structures from the same agencies described in Section 1 is often necessary; however, the level of analysis for proposed maintenance is usually lower than for a proposal for new erosion protection.

REPAIR

When proposing a revetment, bulkhead or seawall repair or replacement, the proposed design should avoid abrupt, squared-off ends at the property line, and instead slope to meet the existing bluff or bank contours. This will reduce the potential for impacts to adjacent properties and minimize erosion around the ends of a structure, which could cause bluff or seawall failure If there are existing seawalls or bulkheads on adjacent properties, the proposed design must tie into those structures as appropriate

The forces acting on erosion and flood protection structures are immense, and all erosion protection will require periodic maintenance to continue to provide the designed level of protection throughout its life. Regular inspections are key to maintaining your structure and ensuring that small repairs are not neglected, resulting in large and expensive repairs. The following information provides guidelines for the repair of seawalls, bulkheads, and revetments. Note that these activities may require a permit from DEC, OGS, USACE, DOS, and/or your local building department.

Revetment Repairs

A revetment may need to be repaired or have preventative maintenance performed following damage from a storm, when periodic monitoring suggests material deterioration or the movement of stones is occurring, or if the structure is not performing as intended. Prior to implementing repairs, it is important to diagnose, if possible, the cause of the problem in order to perform proper repairs. Common problems include inadequately sized toe stone and/or armor stone, slopes that are too steep, and/or no filter layer Consistent monitoring of the revetment (see *Monitoring and Maintenance* section of this booklet) and the surrounding environment may help to identify the underlying cause of problems.

Depending on the extent of the damage, rock revetments may need to be completely rebuilt and/or redesigned. Minor repairs, such as filling in landside voids caused by wave splash or retrieving a couple of dislodged rocks, often can be done without complete reconstruction.

When designing a revetment repair, the crest width should be only as wide as necessary for a stable structure. Generally, the revetment should follow the cross-section of the shoreline and be located as close to the bluff/bank as possible Adequate toe protection is to be included in the design to mitigate sliding failures and movement. Revetments must have an adequate foundation set into the underlying strata.

Bulkhead and Seawall Repairs and Replacements

If you are repairing or adding toe protection, it should be designed to mitigate sliding failures, scour, and undermining at the base of the wall. Seawalls must have an adequate foundation set into the underlying strata.

Drainage and filtration should be accounted for in the design. Water pressure behind the wall may result in cracking and forward movement of the wall. To mitigate this water pressure, weep holes should be installed to allow excess water to drain. Synthetic filter fabric or graded gravel serves as needed filtration when placed behind and beneath the wall to retain soil particles. In some cases, drainpipes may also be needed to direct the water away from the structure so adjacent areas do not erode (Figure 15).

Overtopping can lead to failure of vertical seawalls by removing land behind them (photos 18 and 19). If a structure was not constructed to an adequate height, a splash apron should be constructed behind the top of the structure to prevent erosion by overtopping waves (Figure 15). Drainage should be provided below the splash apron to help remove trapped overtopping water

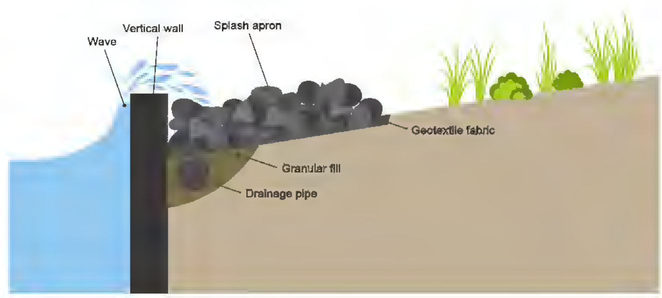


FIGURE 15: Typical detail, splash apron installation in response to erosion from overtopping

Foundation failure of older seawalls is a common issue on Lake Ontario. Sometimes, stone can be placed waterward of the wall to stabilize it, or an undermined foundation can be filled in and stabilized. However, these may only be short-term fixes that will require full replacement in the future. If your wall has foundation issues, DEC recommends you consult with a Professional Engineer to determine the best course of action.

PHOTO 18. Bulkhead on the west side of the Genesee River that was damaged by overtopping. Recently repaired by backfilling with soil, and planted. Photo taken in 2019 after the high water level events.

PHOTO 19. Wall that was damaged by overtopping and undermining, Lyndonville, N.Y.

IMPORTANT NOTE ON FEMA REQUIREMENTS

Local communities that participate in the National Flood Insurance Program regulate development in Special Flood Hazard Areas (SFHA), also known as 100-Year Floodplains. All development within an SFHA is subject to local floodplain development permits issued by your local floodplain administrator Under the National Flood Insurance Program, FEMA defines development as any man-made change to improved or unimproved real estate, including, but not limited to, constructing buildings or other structures, mining, dredging, filling, grading, excavation, drilling, or storing equipment or materials. New or substantially damaged/improved residential buildings must have their lowest floor and utilities elevated at least two feet above the published base flood elevation, or at least three feet above the highest adjacent grade when there is no published base flood elevation. Base flood elevations are identified on Flood Insurance Rate Maps and in the associated Flood Insurance Study prepared by FEMA. When there are no published base flood elevations, your floodplain administrator, or other agencies, such as DEC, may have information to estimate a base flood elevation. In such cases, this elevation data should be used as best available data when designing your project. In some areas along the Great Lakes, draft work maps may be available. These work maps are not regulatory maps, but can be considered best available data and used where they are more restrictive than the current effective Flood Insurance Rate Maps to ensure your project is as resilient as possible. Your local community can assist with questions you may have regarding development within an SFHA.

On September 22, 2014, Governor Andrew Cuomo signed the Community Risk and Resiliency Act (CRRA). As part of CRRA, there is additional guidance for the construction of buildings within the SFHA. These recommended standards can be found in the "Additional Guidance" section at **https://on.ny.gov/rediguidance**

APPENDIX 1.
APPROXIMATING MEAN HIGH WATER IN THE FIELD

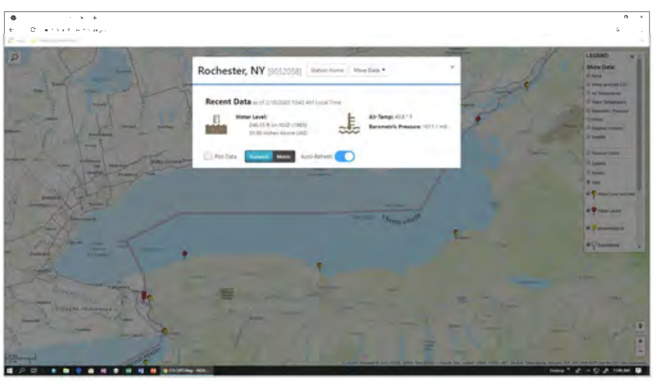
This document provides a general method to approximate the location of Mean High Water (MHW) on any given day It may be used to approximate the location of MHW on permit application plans but cannot be relied on for jurisdictional determinations. Final determinations on the location of MHW are the sole responsibility of DEC staff and depend on the required review of additional site-specific characteristics and conditions.

St. Lawrence and Niagara Rivers

To determine MHW at your shoreline on the St. Lawrence or Niagara River, you will need to look at drift lines, stain lines, scouring and changes in vegetation. There is no nominal elevation for the MHW elevation on the St. Lawrence and Niagara Rivers. For more information see NYCRR Part 608.1(r) located at **https://on.ny.gov/part608**

Lake Ontario and Lake Erie

The nominal MHW elevations for Lake Erie and Lake Ontario are contained in DEC's Protection of Water Regulations (6 NYCRR Part 608). The nominal elevation for Lake Ontario is 247.3 IGLD85 and the nominal elevation for Lake Erie is 573.4 ft IGLD85.

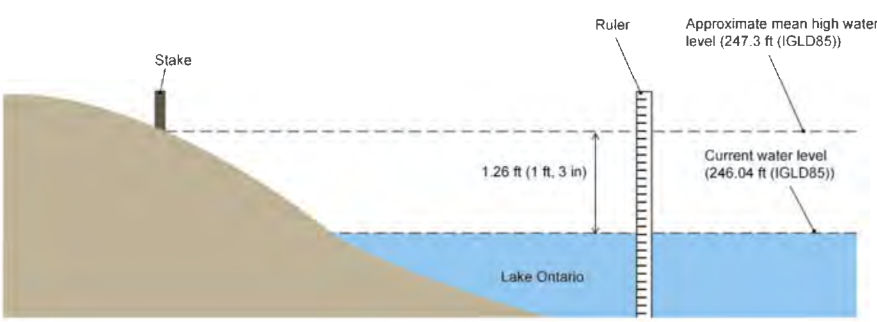


Process to approximate Mean High Water in the Field

Your contractor or surveyor can determine the location of Mean High Water at your shoreline, or you can use the method outlined below

In our example, we will use a project near the City of Rochester, Lake Ontario, to determine the location of Mean High Water on the shoreline

1. Pick a day that is calm, because you will be using the surface of the lake for your measurements and choppy water will greatly reduce your accuracy. It is best to make your measurements early in the day, when the surface of the water may be calmer
2. The Mean High Water (MHW) elevation for Lake Ontario is 247.3 ft IGLD85. The current day's water elevation fluctuates and may be higher or lower than the MHW elevation.
3. Refer to the NOAA Tides and Currents website (https://tidesandcurrents.noaa.gov/map/index.html) to locate a water level station closest to your project. Click on the icon to bring up the current conditions.
4. From the website, determine that day's water level. For our example, the level of Lake Ontario is 246.04 ft IGLD85, which is 1.26 feet below the Mean High (247.3 ft -246.04 ft = 1.26 ft.), or about 1 ft 3 in.
5. Using a yardstick or other measuring device, measure 1 ft 3 in vertically from the surface of the water This elevation is the approximate Mean High Water for Lake Ontario If the current water level was higher than the MHW elevation, you would measure from the surface of the water to a point below the water surface
6. Using a laser level or string level, shoot the estimated Mean High Water to the shoreline
7. Have an assistant place stakes along the shoreline at the location of Mean High Water
8. Transfer the shoreline location of Mean High Water to your plan-view drawing that you will submit to DEC.



Finding Mean High Water level in the field, in Lake Ontario, based on a current water level of 246.04 ft (IGLD85).

APPENDIX 2.
SAMPLE MAINTENANCE PLAN

Sample Shoreline Stabilization Project—30-Year Maintenance Plan Agreement

1: Structure Type: Limestone Rock Riprap Revetment

This Maintenance Plan is intended to be used in conjunction with sheet __ of the project drawings (Construction Details and Maintenance Plan), which details structure components, vegetation plans, and additional long-term maintenance requirements.

2: Inspection

Periodic inspections of the limestone rock riprap revetment will be performed to ensure that no failure has occurred. Inspections will be performed at least once a month and immediately after any storm in which lake activity affects the structure Inspections will be performed for evidence of moved or slipped material, flanking, scour, exposed filter fabric, or drainage problems. Each property owner is responsible for the inspection of the portion of the structure on his or her property unless other agreements are in place

3: Maintenance and Repairs (Permits may be needed)

Maintenance meeting the criteria of Part 505.2(bb), "Normal Maintenance," may be performed without a coastal erosion management permit. "Normal maintenance" means periodic replacement or repair of same-kind structural elements or protective coatings that do not change the size, design, or purpose of a functioning structure A functioning structure is one that is fully performing as originally designed at the time that normal maintenance is scheduled to begin. Any maintenance will be performed under the conditions defined in the original permit.

Any structural repair, rehabilitation, modification, restoration, or reconstruction will not be performed without first submitting a written request and receiving written approval from the Department of Environmental Conservation.

4: Degradable Materials and Vegetation

Degradable materials such as woven filter fabric will be maintained to ensure proper functioning of the structure

Vegetation planted as required as a condition of the permit shall be successfully established, replanted as needed, and maintained as a viable vegetated community for the lifespan of the project. Refer to sheet __ of the project drawings for planting and maintenance guidelines.

NO MOWING

Note that maintaining vegetation on the bluff face and top of bluff within the Natural Protective Feature Area in a natural state must include the practice of regular weeding to remove unwanted and invasive species. It may take years of diligent weeding to give the preferred native species time to establish and dominate the site Maintenance of vegetation shall not include the establishment of lawn down the slope from the new top of the bluff to the riprap and must extend to the landward limit of the Natural Protective Feature Area as identified on the Coastal Erosion Hazard Area mapping.

NO DUMPING

The dumping of organic materials such as lawn clippings, leaves, brush and branches onto a bluff increases erosion. Such materials hold water on the slope over the long term and will smother vegetation that could grow there, thus promoting greater erosion. Inorganic materials such as concrete rubble adds excessive weight to an already unstable bluff, increasing the chance of bluff failure

5: Removable Materials

Material such as limestone riprap rock or other moveable material shall be monitored and repaired as needed. Retrieval of material from the beach or nearshore area shall be undertaken periodically to return the structure to the original design configuration Department of Environmental Conservation Permits may be required.

If new material is required for structure maintenance and functionality, the Department of Environmental Conservation shall be contacted to obtain required permits or to determine if the activity is covered under "normal maintenance"

6: Structure Failure

The Department of Environmental Conservation will be notified immediately if a failure of the limestone rock riprap revetment occurs. Repair of the failed structure will be performed within one year from the time of failure

7: Transfer of Maintenance Agreement and Responsibility

Purchasers of this property shall be notified prior to sale that this maintenance responsibility will be transferred to them. A copy of the original Permit and this 30-Year Maintenance Plan Agreement shall be transferred by the seller to the new owner(s) when the property is sold. The seller will obtain a written agreement from the new owner as a condition of sale that the maintenance plan will be followed.

8: Names and Signatures

A signed copy of this plan shall be included with any Coastal Erosion Hazard Area permit application to the administering agency

Property owner (Print):________________________________

Signature: ________________________________

Date: ________________________________