Lake Erie Shore Erosion Management Plan

Bratenahl to Grand River: Reach 01

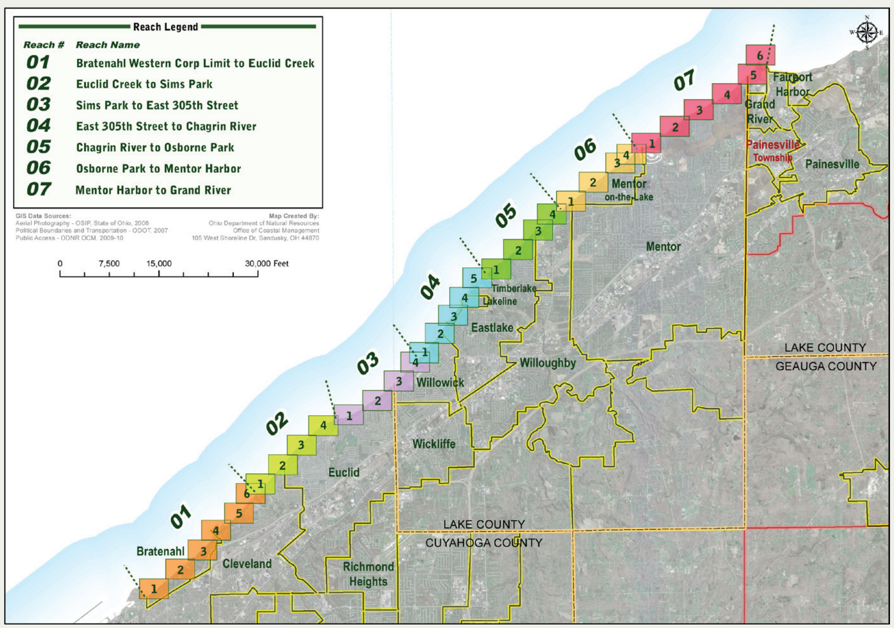
LESEMP

About the Program

In an on-going effort to assist property owners along Ohio's Lake Erie coast by providing free technical assistance, the *Lake Erie Shore Erosion Management Plan* (*LESEMP*) is being developed by the Ohio Department of Natural Resources through a partnership between the Office of Coastal Management, Division of Wildlife and Division of Geological Survey.

The *LESEMP* identifies the causes of erosion in specific areas called reaches which are stretches of shore with similar site conditions. The *LESEMP* then outlines the most likely means of successful erosion control based on reach-specific erosion issues, geology and habitat. The objective of the reach-based approach to erosion control is to simplify the decision process while enhancing the effectiveness of solutions to erosion related issues.

The *LESEMP* does not contain any regulatory oversight provisions.



The LESEMP is being developed by the project partners, Ohio Department of Natural Resources Office of Coastal Management, Division of Geological Survey and Division of Wildlife. Federal grant funding for this project is provided by the National Oceanic and Atmospheric Administration.

Description

The LESEMP Bratenahl to Grand River Region Reach 01 extends from the east terminus of the Cleveland Lakefront Nature Preserve at Dike 14 property in Cleveland to the mouth of Euclid Creek which bisects the Villa Angela and Wildwood areas of the Cleveland Lakefront State Park system. This reach contains approximately 25,000 feet of shoreline including residential lakefront communities in the village of Bratenahl and the east side of the Cleveland. Most of the reach is private property with the exceptions of the Easterly Wastewater Treatment Plant owned by the Northeast Ohio Regional Sewer District and Cleveland Lakefront State Park's Euclid Beach and Villa Angela Area at the east end of the reach.

The shore of this reach is oriented from southwest to northeast along Lake Erie's Central Basin. The net direction of littoral drift is typically from west to east. On a large scale, the shore is fairly uniform with no significant natural headlands or embayments. On a more localized scale, man-made structures have caused small irregularities in the form of the shore. The shore is generally characterized by 30 to 40-foot high bluffs, primarily composed of glacial till. The shore in this reach is heavily armored with protective structures and occasionally fronted by narrow, transient beaches. Beaches are most prominent updrift of the large shore perpendicular structures at the Easterly Wastewater Treatment Plant (formerly known as the White City Sewer Treatment Plant) and the structures at Euclid Beach and Villa Angela.

The nearshore in this reach is typically composed of till covered with a thin band of sand (generally less than 1-foot deep) along the shore. Sand accumulation is generally greatest near the Easterly Wastewater Treatment Plant and at the east end of the reach near the mouth of Euclid Creek. Nearshore slopes are slightly steeper than 1 degree for the first 1,000 feet and smooth to approximately 1 degree farther offshore.

At the west end of the reach the shore is protected by large armor stone and concrete blocks at the landward base of Dike 14. The next 650 feet to the east is protected with stone and concrete rubble. The 1,200 feet of shore to the east is protected by two 600-foot long armor stone revetments creating a consistent stretch of shore. The shore protection is less consistent for the next approximately 1,800 feet to the east. The shore in this area is protected by concrete blocks, concrete Great Lakes Erosion Control Modules, steel sheet pile bulkhead, armor stone and concrete rubble. Many properties in this area have large concrete modules placed in the nearshore approximately 20 to 30 feet lakeward of a structure at the toe of the bluff. The next 500 feet west of Bratenahl Road is protected by an armor stone bisected by a small pier structure for lake access near the center.

East of Bratenahl Road approximately 1,000 feet of shore is protected with a consistent revetment lakeward of the residences along Lakehurst Drive and Lake Harbor Court. The next 900 feet of shore to the east is protected by a row of concrete modules lakeward of concrete rubble placed along the bluff slope. These structures lead up to an approximately 100-foot long jetty at the mouth of Green Creek.

East of Green Creek approximately 800 feet of shore is protected by large concrete modules and slabs lakeward of Bratenahl Place. The next 600 feet is protected with an armor stone revetment leading up to the mouth of Dugway Creek. The marina at the Shoreby Club has been constructed at the mouth of Dugway Creek. The marina entrance is protected by a pair of armor stone breakwaters. A small breakwater extends approximately 150 feet offshore then 150 feet to the northeast at the west side of the entrance

Portions of the LESEMP Bratenahl to Grand River Region Reach 01 are protected by Great Lakes Erosion Control Modules like those pictured above.

channel. A second breakwater extends approximately 250 feet offshore then 500 feet to the southeast from the east side of the channel. An approximately 150-foot long pier extends into the lake about 75 feet east of the marina breakwaters. The next 300 feet of shore to the east is protected by an armor stone revetment leading up to a 150-foot long concrete block jetty at the mouth of Ninemile Creek. Approximately 450 feet of shore to the east of Ninemile Creek is protected by an armor stone revetment that curves lakeward to form a small breakwater at the east end of the creek.

The bluff heights in this area steadily decrease from 30 to 40 feet near the west end of the reach to 10 to 20 feet near the mouths of Green, Dugway and Ninemile creeks. The bluffs in this area and near the west end of the reach are often re-graded to a stable slope and vegetated.

The next approximately 4,000 feet spans the properties along Lake Shore Boulevard between Ninemile Creek and the Easterly Wastewater Treatment Plant. The shore in this area is heavily armored with protective structures. The first 600 feet just east of Colony Drive is primarily protected with large concrete blocks at the toe of the bluff. The steep 20 to 30-foot bluffs in the area are covered with concrete rubble. Approximately 500 feet of shore to the east is protected by a curved seawall creating a shallow embayment along the shore. The next 500 feet is armored with a series of stepped concrete seawalls, although additional concrete blocks appear to have been placed lakeward of the structures. Concrete block structures armor the shore for the next seven parcels to the east, spanning approximately 1,200 feet of shore. The structures are of similar construction but in some cases are not placed consistently along the toe of the bluff causing a shallow embayment of the shore near the center. A stepped concrete seawall extending approximately 450 feet spans the next three parcels. Sand accumulation in this area gradually increases to the east and narrow, transient beaches occasionally form during periods of low water.

Beaches front the next 1,500 feet of shore to the east as sand accumulates updrift of the Easterly Wastewater Treatment Plant. At the west end of this area beach width is minimal but beach width gradually increases to approximately 200 feet directly updrift of the breakwater at the water treatment plant. A few properties at the west end of the beach are protected by seawalls which gradually transition into low headwalls upland of the beach to the east.

At the west end of the Easterly Wastewater Treatment plant a steel sheet pile groin extends approximately 325 feet to the northwest perpendicular to shore. An armor stone breakwater continues an additional 600 feet offshore after an approximately 30 foot gap between the structures. The lakeward end of the breakwater bends to the north for an additional 200 feet. After a 150-foot gap, the breakwater surrounding the water treatment plant continues approximately 2,200 feet to the northeast. The west end of the breakwater is split with 150 and 200-foot sections extending to the west and southwest. The northeast end of the breakwater bends to extend an additional 300 feet to the east. The bend in the breakwater creates a protected entrance for the Northeast Yacht Club marina at the northeast end of the water treatment plant. After an approximately 80-foot wide marina entrance the water treatment plant breakwater continues an additional 800 feet to shore.

East of the breakwater a narrow beach has accumulated along approximately 600 feet of shore. The beach is widest at the base of the breakwater and narrows to the east. The beach is likely formed by sand accumulation during periods when winds from the northeast cause a reversal of the dominant west-to-east littoral currents. The beach is also supported by the wave shadow created by the water treatment plant. The breakwaters at the water treatment plant extend over 1,000 feet into the lake and provide protection from waves from the west and northwest. As the beach narrows the shore lakeward of Bonniewood Drive is protected by a series of concrete blocks and rubble leading up to a concrete block seawall. A few properties also have small concrete piers extending to the lake. To the east an approximately 200-foot long armor stone revetment leads up to a concrete block seawall and pier near the end of Overlook Park Drive.

Along approximately 1,200 feet of shore lakeward of Shore Acres Drive most parcels are only about 50 feet wide with individual property owners having constructed a wide variety of shore protection. Structures range from armor stone revetments and concrete block seawalls to randomly placed concrete modules along the shore. Many parcels in this area have a small concrete seawall at the toe of the bluff fronted by a row of large concrete blocks. The shore and bluff slope are covered with concrete rubble along much of this area.

East of Shore Acres Drive approximately 450 feet of shore is covered with concrete rubble leading up to a 300-foot long armor stone revetment constructed with a small embayment near the center. The shore is covered with concrete rubble for the next 1,600 feet to the east with large concrete sewer outfalls intersecting the lake near the ends of Lakeside Avenue and East 156th Street. The upland in this area transitions from individual lakefront homes to large condominium and apartment development.

The shore to the east is occupied by Euclid Beach Park and Villa Angela Park leading up to the mouth of Euclid Creek. The shore is protected by a series of five detached breakwaters with a T-shaped groin at the west end. The breakwaters range from 150 to 200 feet long and are relatively evenly spaced at approximately 130 feet apart. The breakwaters were constructed

Detached breakwaters support a nearly 1,600-foot long beach updrift of the jetties at Euclid Creek. Beach areas at Euclid Beach (left photo) and Villa Angela Area of the the Cleveland Lakefront Park system are pictured above.

with the toe of the structure approximately 220 feet from shore creating slight salient beach formations, particularly near the west breakwaters. The salient beach formations landward of a few of the west breakwaters are supported by small stone groins. The breakwaters support a 100 to 200-foot wide beach for approximately 1,600 feet leading up to the jetty at the mouth of Euclid Creek.

Recession/Erosion

The ODNR Division of Geological Survey has evaluated the recession of Ohio's Lake Erie shore over three time periods: 1876-77 to 1973, 1973 to 1990 and 1990 to 2004. Changes in the rates measured during each of the time periods are generally attributed to development along the coast and natural factors such as lake level changes.

From 1876 to 1973, this reach generally experienced slow recession with an average recession rate of 0.5 feet per year. Overall average recession rates from 1876 to 1973 ranged from 0.0 feet per year to 1.8 feet per year. Recession was slightly greater early in the time period and decreased as the shore was developed and structural shore protection was added. Average recession rates reached 0.9 feet per year from 1876 to 1938 and reduced to 0.2 feet per year from 1938 to 1973. Early in this time period, recession was typically greatest at the west end of the reach, however recession in this area reduced as the shore was armored.

From 1973 to 1990, the recession rates ranged from 0 feet per year to 1.1 feet per year. Recession was greatest along the shore at the east end of Gordon Park, immediately downdrift of Dike 14. The shore in this area is covered in concrete rubble. Recession also reached an average of 1.0 feet per year approximately 700 feet east of the Easterly Wastewater Treatment Plant between Bonniewood and Overlook Park drives. Most of the reach experienced slow recession with rates rarely greater than 0.3 feet per year.

From 1990 to 2004, most of this reach experienced little to no recession. Average recession rates ranged from 0 feet per year to 1.3 feet per year. Recession was greatest in areas at the east end of the reach relying on concrete rubble for shore protection. Average recession rates reached 1.3 feet per year just east of Villa Beach Drive and 1.2 feet per year near the sewer outfall at the end of Lakeside Avenue. Overall recession was typically less than 0.3 feet per year throughout the reach.

Flooding

Due to the 30 to 40-foot high bluffs along most of this reach flooding is not a concern. Flooding is limited to lower areas at the mouths of Ninemile, Green and Euclid creeks. Flooding can generally be attributed to a combination of high lake levels and flooding of the creeks due to upland runoff.

Euclid Creek bisects the Villa Angela and Wildwood areas of the Cleveland Lakefront State Park System flowing north into Lake Erie. The left photo above is looking north and the right photo is looking south at the creek.

Beaches/Sand Supply

The few areas with stable beaches along this reach demonstrate the overall lack of sand available in the area. In 1876 a narrow beach fronted most of the shore of this reach. By 1938 beaches were primarily present updrift of shore perpendicular structures near Ninemile Creek, the Easterly Wastewater Treatment Plant and Euclid Creek. As beaches eroded, the shore was protected with a variety of structures. Wave reflection off hardened structures increases wave energy along the shore and often increases erosion in the nearshore. In many cases, the shore protection was also constructed in the area previously occupied by the eroded beach. This effectively increased water depths along the shore further decreasing the potential for sand accumulation in the area. Today the only significant beaches in this reach are near the large shore-perpendicular breakwaters at the Easterly Water Treatment Plant and where the beach is stabilized by detached breakwaters just west of Euclid Creek. Decreases in beach width are generally attributed to the overall reduction of sand supply to the area due to the large scale hardening of Lake Erie's shore. To a lesser degree, port structures and harbor dredging also contribute to the reduction of sand supply to the area.

Use of Shore Structures

Nearly the entire shore of the Bratenahl to Euclid Creek reach is protected by some form of shore structure. The only areas not armored are where wide beaches are present immediately east and west of the Easterly Wastewater Treatment Plant. Shore structures in this reach range from ineffective concrete rubble along the shore to well constructed seawalls and revetments.

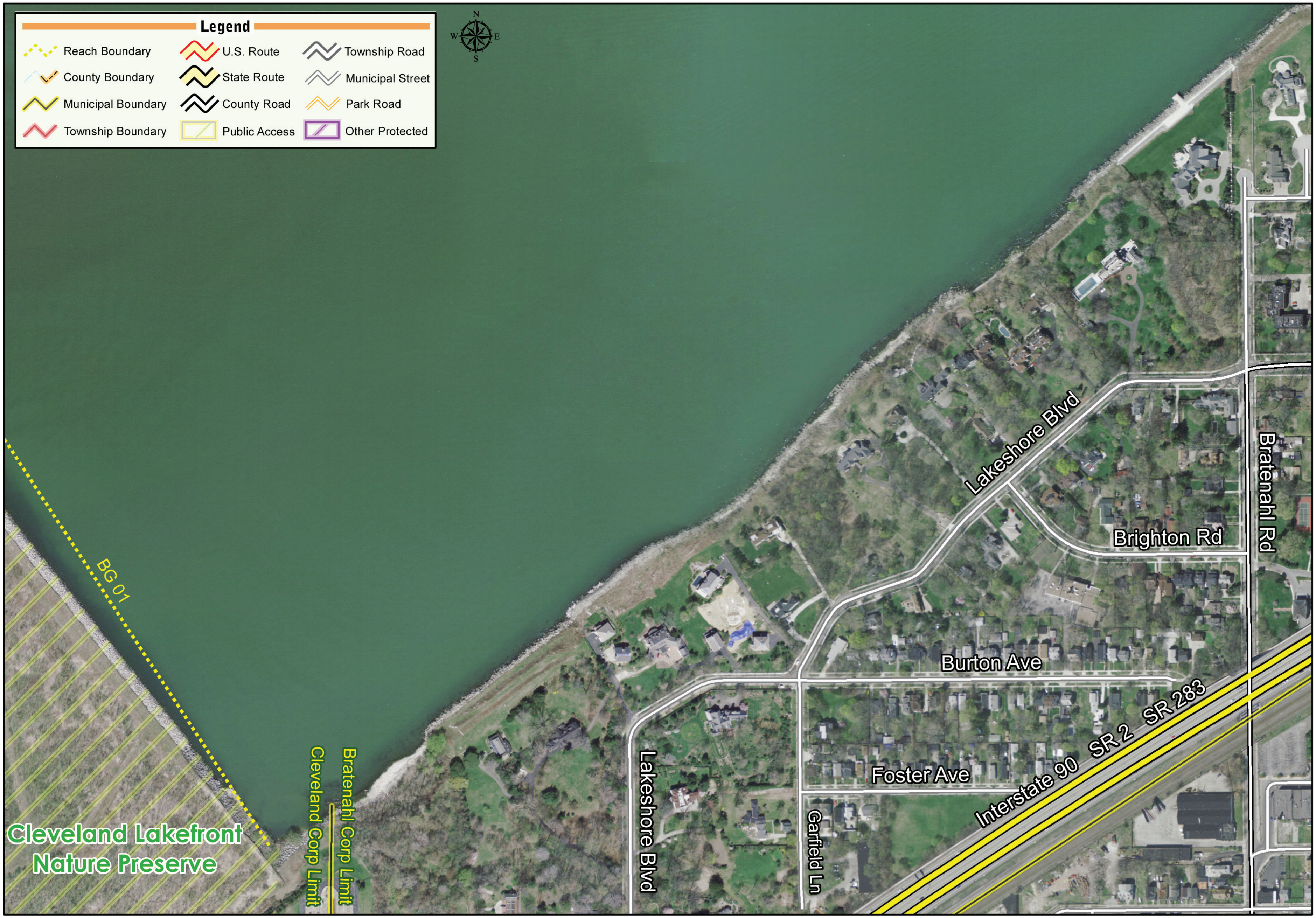
The largest shore structures in this reach are the breakwaters surrounding the Easterly Wastewater Treatment Plant. The breakwaters were originally constructed in 1915 and have accumulated enough sand to sustain beaches for approximately 1,500 feet west and 600 east of the structures. Detached breakwaters are also effectively used to sustain the beach just west of Euclid Creek at Euclid Beach and Villa Angela Area parks.

Revetments are the most common shore protection in this reach. Concrete block seawalls are also common near the center of the reach. Many properties are protected by large concrete blocks placed lakeward of revetments or seawalls at the toe of the bluff.

Summary

The reach from the east end of the Cleveland Lakefront Nature Preserve at Dike 14 to the mouth of Euclid Creek primarily consists of residential development with 30 to 40-foot high bluffs along the shore. The shore in this reach is almost completely armored with protective structures. The only areas without structural protection are adjacent to the Easterly Wastewater Treatment Plant and have stable beaches. Sand supply is limited throughout the reach and the only significant beaches are near the large shore-perpendicular structures at the water treatment plant and where the beach is stabilized by detached breakwaters at Euclid Beach and Villa Angela Parks. Shore protection in this reach ranges from ineffective concrete rubble placed along the shore to well constructed revetments and seawalls. This reach has historically experienced slow recession rates although moderate recession often occurs on properties relying on concrete rubble for shore protection.

Large shore-perpendicular structures to the west of the Bratenahl to Grand River Region, such as the structure that created the former confined disposal facility of Dike 14 (now Cleveland Lakefront Nature Preserve) pictured above, help contribute to the lack of sand at the west end of the Cleveland Lakefront Nature Preserve/Dike 14 to Euclid Creek Reach.



GIS Data Sources:
Aerial Photography - OSIP, State of Ohio, 2006
Political Boundaries - ODOT, 2007
Public Access - ODNR OCM, 2009-10
Transportation - LBRS, Erie County and State of Ohio, 2005-07

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Ohio Department of Natural Resources
Office of Coastal Management
105 West Shoreline Dr, Sandusky, OH 44870

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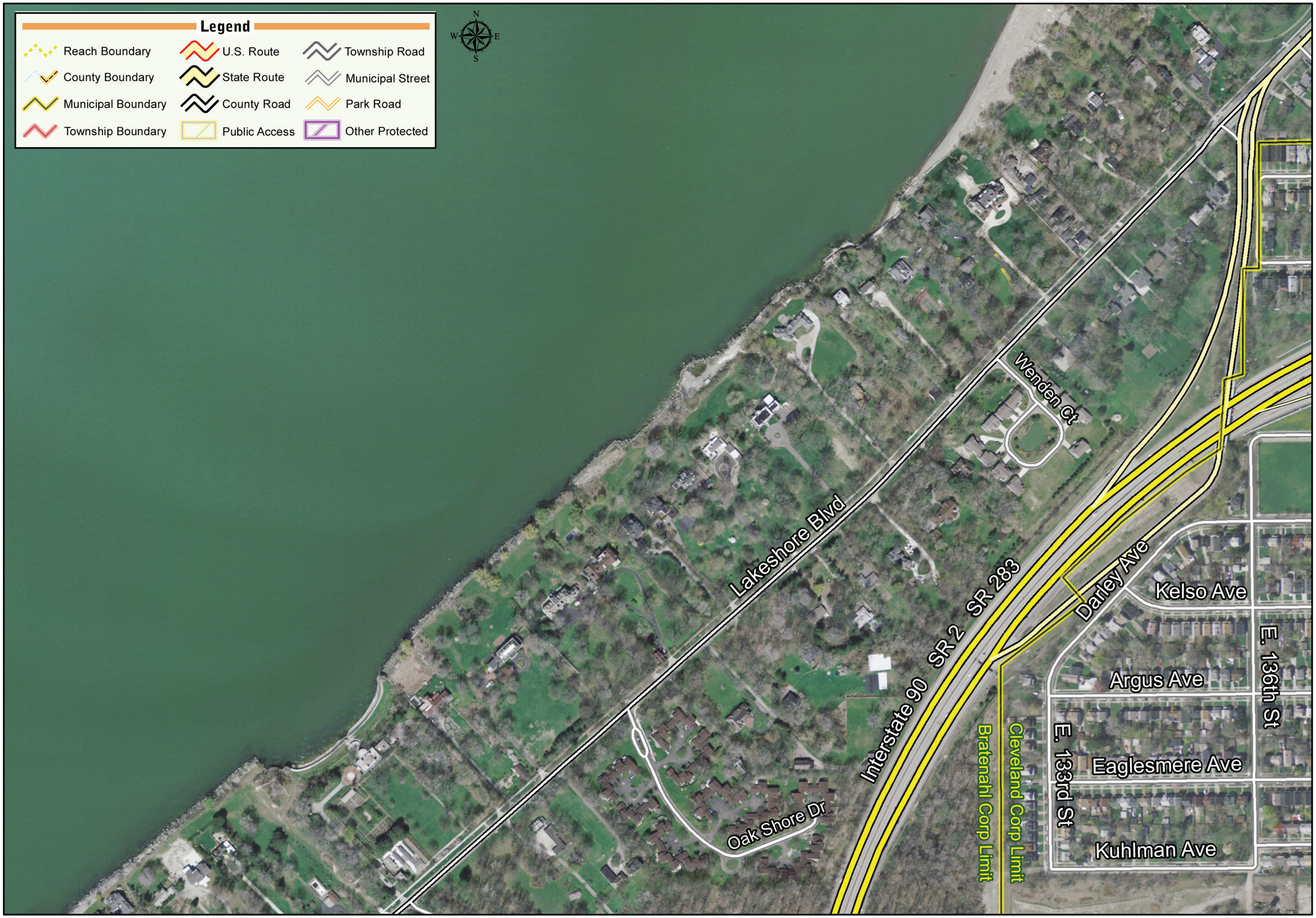

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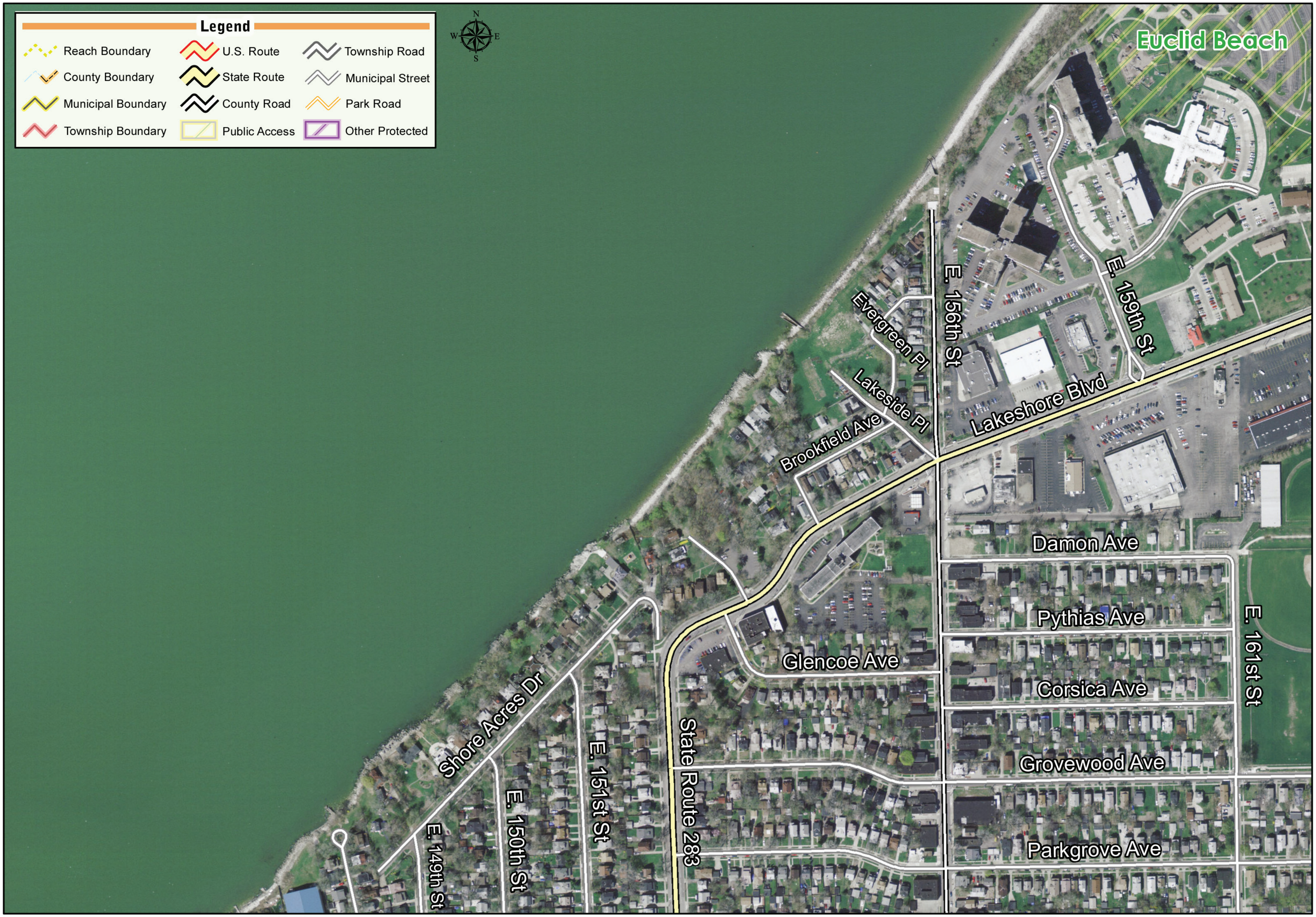

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Recommendations

The recommendations included below are options that may be applicable within this reach and should only be used for planning purposes. Based upon the physical characteristics of this reach, the following recommendations are suggested for the reach between the east end of Cleveland Lakefront Nature Preserve at Dike 14 and the mouth of Euclid Creek. Each recommendation includes a brief overview of the solution prior to addressing areas within the reach where the recommendation is best suited. For more information on any of the items listed below, please refer to the LESEMP Glossary and Erosion Control Methods Appendix.

In addition to the recommendations listed below a "do nothing" alternative should also be considered. This may be a viable, and even favorable, alternative for much of Ohio's Lake Erie shore. The area from Cleveland Lakefront Nature Preseve to Euclid Creek is almost completely protected with existing structures and has relatively low erosion rates. In areas where the shore is protected with effective structures additional protection might not be necessary. In these areas attention should be focused on monitoring and maintaining the structures. In other areas, particularly those with a natural shoreline and low erosion rates, the best option may be to hold development back from the shore and allow natural erosion/accretion processes to occur. This option should be considered on the unarmored beaches near the Easterly Wastewater Treatment Plant.

Sand Management:

1. <u>Conserve Sand Resources</u>: Conserve sand resources within the shore and nearshore areas. Sand is a limited resource in constant fluctuation. Avoid removing sand from the system. Sand moved or excavated from along the shore during construction should be placed in the nearshore, not on the upland. The sand should also not be incorporated into the construction project.

Sand is a limited resource in the area from Cleveland Lakefront Nature Preserve to Euclid Creek and should be conserved throughout the reach. Several properties in the area surrounding the Easterly Wastewater Treatment Plant rely on beaches for shore protection. A decrease in sand resources would leave these properties vulnerable to erosion.

In areas without beaches, nearshore sand accumulation helps reduce water depths, causing waves to break farther offshore. A reduction of sand in the littoral system would cause a corresponding increase of wave energy along the shore and reduce the effectiveness of many protective structures. Sand accumulation in the nearshore can also help increase the design life of many of the aging structures in this reach.

2. <u>Vegetation</u>: Encourage growth of native vegetation on the back beach. Beach vegetation encourages the formation of a dune system by holding sand in place and providing protection from wind. It is also possible to simply allow the natural succession of native plant species to grow along the beach.

This recommendation is applicable on the beaches near the Easterly Wastewater Treatment Plant and near Euclid Creek. Native vegetation on the narrow beaches helps encourage sand accumulation and dune formation at the toe of the low bluffs in these areas. Dunes provide a natural sand reserve to restore beaches during periods of erosion due to storms or high water. Dune formation is particularly significant in areas that rely on the beach for shore protection such as those west of the power plant.

Native varieties of American beach grass, little bluestem, sand dropseed or beach pea are well suited for beach vegetation in this area.

Planting native vegetation on the beaches near the Easterly Wastewater Treatment Plant and Euclid Creek will help encourage sand accumulation and dune formation.

3. <u>Sand Bypassing</u>: Move sand from areas of excess accretion, usually up-drift of a shore perpendicular structure, to areas downdrift. By redistributing sand within the nearshore system, the littoral drift in the area will be more evenly dispersed.

Sand bypassing would be beneficial near the large shore-perpendicular structures at the Easterly Wastewater Treatment Plant. The breakwaters surrounding the water treatment plant have impeded the flow of littoral material, trapping sand on up-drift beaches. This has limited the amount of sand available downdrift. Bypassing future accretion will help reduce erosion at downdrift properties.

Allowing native vegetation to grow on the natural bluff face and on re-graded slopes above seawalls, revetments and other shore structures provides shore habitat for resident and migratory birds and helps stabilize the bluff (top). Additional detached breakwaters could be used to extend the beaches updrift (west) of Euclid Creek (bottom).

4. Dredging: Dredge marinas and harbors on as frequent a basis as possible to add sand into the littoral system. Dredging of navigation channels at harbors and marinas enhances navigation for boaters and provides sand for downdrift areas when the sand is placed along the shore. When dredged material is disposed of on the upland or in offshore areas, the material is no longer a benefit to the littoral system. In-lake placement of sand is preferred as long as the sand meets the grain size and total organic carbon criteria. Uncontaminated dredge material that is composed of sand and gravel should be placed in the nearshore through sidecasting or placing downdrift. Placing sand in shallow water keeps the sand in the nearshore environment and the littoral system. Sand placed in deeper waters will likely be lost to the system and will not nourish downdrift beaches.

If the entrances to the marinas at the Shoreby Club or the Northeast Yacht Club require maintenance dredging, nearshore placement of the dredged material should be considered. If the dredge material is suitable for the nearshore environment, nearshore placement would nourish the beaches updrift of Euclid Creek at Euclid Beach Park and Villa Angela Park.

Toe Protection:

5. Detached Breakwaters: Detached breakwaters may be useful in areas where beaches are present or likely to form. Detached breakwaters aid in retaining a beach by limiting the wave energy reaching the shore causing sediment to settle out and be deposited along the shore. As opposed to groins which trap sand moving along the shore, properly designed and constructed detached breakwaters are intended to allow alongshore movement of sand. An initial beach nourishment and periodic re-nourishment will often be advantageous in creating and retaining a beach landward of a breakwater while limiting impacts to the neighboring shore. Some regulatory agencies may require an initial beach nourishment and periodic re-nourishment as one of the design components for a project that includes detached breakwaters. A plan should also be developed to monitor the condition of the beach and periodically by-pass sand if the breakwaters cause sand to accrete in addition to the initial nourishment.

While detached breakwaters effectively support the beaches updrift of Euclid Creek their application in this reach is limited. Detached breakwaters require specific conditions to effectively support stable beaches. For example, detached breakwaters are most effective in areas with a shallow nearshore and adequate sand resources to maintain a beach. Sand resources throughout this reach are limited. The effectiveness of detached breakwaters

Fractured concrete rubble provides little protection and is a significant hazard along the shoreline (top). Concrete rubble is too light to withstand wave forces along the shore and is easily transported by littoral currents (above).

The condition of existing shore structures should be closely monitored for displaced stone, cracks or uneven settling of the structure.

is also increased when multiple breakwaters are constructed over a long stretch of shore, making them a suitable design alternative for the larger lakefront properties, condominiums or homeowners associations.

Detached breakwaters would be most effective to extend the western end of the beach updrift (west) of the Easterly Wastewater Treatment Plant. Constructing additional detached breakwaters along the shore of the large condominium and apartment development west of Euclid Beach may also extend the beach in this area to the west. Beach nourishment or sand pre-fill should be included in the design of a detached breakwater to prevent the structure from trapping littoral material and increasing the risk of erosion on adjacent properties. Due to the limited sand resources in the area periodic re-nourishment may also be required.

6. <u>Revetments</u>: Revetments along the toe of a bank will aid in protecting against wave-based erosion. In areas without beaches, a structural measure may be necessary to protect the toe of the bank. The low-relief banks within this reach have relatively gradual slopes, which are ideal for revetment development. In essence, the revetments form a stable bank slope, providing protection to the soil underneath while breaking up wave attacks. Since material eroded off the bank is one source of beach-building sand, some regulatory agencies may require that one of the design components for a revetment be the inclusion of sand pre-filling in the amount equal to that which would have been added to the system over the life of the structure.

Revetments are the most common erosion control structures in this reach and have been effective at stabilizing the shoreline and minimizing erosion in the area. Revetments are intended to dissipate wave energy along the rough angular slope of the structure. Revetments should be constructed with armor stone large enough to be stable when impacted by significant wave forces. To provide long term shore protection, revetments are typically constructed with carefully placed limestone, sandstone or engineered concrete modules.

In many areas of this reach randomly placed or dumped concrete rubble is relied on for shore protection. Reviewing the areas in this reach with moderate recession rates demonstrates that concrete rubble does not provide adequate protection from wave action. In general, areas in this reach relying on concrete rubble for shore protection have the highest average recession rates. This is because concrete rubble is too light to withstand the wave forces along the shore and is easily displaced and transported by littoral currents. Rubble on the upper bluff will frequently slide down to the toe and increase the continuing recession of the bluff. Individual pieces of concrete typically weigh less than a few hundred pounds as compared to the several ton armor stone used in revetment construction.

Concrete rubble also fractures much more easily than the solid stone armor units used in properly constructed revetments. When concrete cracks it also crumbles more easily than limestone or sandstone resulting in very small pieces that are easily moved by waves. The small pieces provide little protection to the shore. Much of the concrete placed along the shore is in the form of slabs and broken pavement. Randomly placed concrete rubble often has large voids causing concrete slabs to be unevenly supported and easily fractured. In some cases concrete rubble can be used in the base layers of a revetment if covered by suitably sized armor stone.

Bluff/Bank Modifications:

7. Re-Grading/Terracing: Re-grade or terrace less stable bluffs/banks to a more gradual slope. By creating a lower (flatter) slope angle or terracing the slope to a series of steps, instability caused by gravity's forces on the upper bluff/bank is decreased. Re-grading is a non-structural approach to stabilize the bluff that leaves the shore relatively unaltered. When re-grading, also review the toe of the bluff/bank to determine if a structural (revetment) or non-structural (beach nourishment) solution would be preferable.

Re-grading of the 30 to 40-foot high bluffs is common throughout this reach. Because the bluffs in this reach are composed of till and glaciolacustrine deposits they area highly susceptible to slumping if the toe of the bluff is eroded by wave action. Except for those areas where a building is too close to the bluff/bank edge, re-grading could be applied to any property within this reach that is experiencing active slumping or upper bluff/bank erosion. Re-grading or terracing is typically done in conjunction with the construction of a revetment to provide a stable slope above the structure.

8. Surface Water Management: Route surface water away from the face of the bluff/bank. In areas where gullies or rills are forming, surface water is slowly eroding the face of the bluff/bank. Where possible, re-route water away from the bluff/bank. Sometimes this may involve changing gutter or driveway drainage. Terracing of the bluff/bank can also be used to intercept and divert seeped ground water. Sources of surface water include, but are not limited to, roof gutter downspouts, runoff from driveways and sidewalks, precipitation, and sprinkler systems.

The re-routing of surface water should occur throughout the Cleveland Lakefront Nature Preserve to Euclid Creek reach. The till and glaciolacustrine deposits that make up the bluffs in this reach area highly erodible by surface water. Attention to the signs of surface water will allow for early action on limiting the affects of runoff.

9. Vegetation: Encourage growth of vegetation along the bank slope. Where possible plant vegetation, preferably native species, along the bank to remove excess ground water while retaining soil strength. It is also possible to simply allow the natural succession of native plant species to grow along the bank. Care should be taken to prevent damage to existing vegetation during any shore construction project.

This recommendation is applicable throughout the reach. Allowing native vegetation to grow on the natural bluff face or on the re-graded slope above the seawalls, revetments and other shore structures in this reach will reduce excess ground water and help stabilize the bluffs and low banks. Well rooted vegetation also helps hold soil in place to prevent erosion from runoff and can protect the bluff face from weathering.

The till and glaciolacustrine bluffs in this area are sloped, exposed to harsh weathering processes and are relatively low in nutrients. Native plants from a local source are best adapted to survive in these conditions. It is typically most effective to cultivate plants already growing along the shore or to survey established vegetation along nearby properties and plant similar varieties. In general, well rooted grasses, shrubs and small trees are most effective as they remove surface and ground water without adding excessive weight to the bluff face. Native varieties of Indian grass, big bluestem grass, mesic grapes, sumacs, gray dogwood, heartleaved willow and cottonwood trees are well adapted to survive along the till and glaciolacustrine bluffs in this area.

While beneficial along the bluff, vegetation growing on shore structures should be closely monitored. For example, vegetation growing on a rip-rap or armor stone revetment could damage the structure by causing stones to be broken or displaced.

Management and Monitoring:

***10. Bank-Top Management**: Keep heavy materials, equipment or structures well back from the edge of the bank-top. Any structure (concrete decks, stone walls) or heavy object (vehicles or construction equipment) placed near the bank edge will increase the stress within the soil and can lead to slope failure.*

This recommendation applies to the 30 to 40-foot bluffs and structure crests throughout this reach. Care should be taken when accessing the top of the bluff with heavy materials or machinery while maintaining existing shore structures to prevent sliding failures. This recommendation should also be carefully considered when planning new structures on the upland or along the shore.

This recommendation also applies to the placement of debris or yard waste near or over the edge of the bluff. Leaves and grass clippings can become saturated with water and greatly increase the weight on the bank's slope, directly causing slumping. Concrete rubble and construction debris should never be placed along or near the slope of the bluff.

***11. Coordination of Projects**: Continuation of similar erosion control measures along a stretch of shore will often yield more effective protection than the installation of multiple types of structures adjacent to one another. Most erosion control measures function better when used over large areas of the shore.*

This recommendation is applicable throughout this reach. In residential areas, coastal property is often divided into parcels as small as 50-feet wide with each property owner responsible for their own shore protection. This has led to the construction of a variety of shore protection structures within this reach. The interaction between structures can cause increased erosion on adjacent properties. This is best avoided by coordinating projects over a length of shore. In addition to creating more effective shore protection, coordinating projects limits the amount of time the littoral system is disturbed and can also allow some engineering and construction expenses to be spread over several properties.

***12. Shore Structure Management/Monitoring**: Monitor and maintain shore structures. Routine monitoring allows for early detection of potential failures. Smaller repairs performed more frequently will be less costly and can often increase how long the structure will be effective at controlling erosion. If removal of an aged or deteriorating structure is necessary, consider the above recommended items as potential future solutions.*

Many of the structures in this reach were constructed more than 30 years ago. The condition of the structures should be closely monitored and repairs should be made when necessary. Periodic monitoring of existing structures should include a visual inspection for displaced armor stone, cracked armor stone or concrete, uneven settling of the structure, slumping or gullies in the upland or bluff face and flanking at the ends of structures. Inspections should also include a review of sand resources or beach widths in the area and should note conditions on adjacent properties. If the base of the structure is visible during periods of low water inspections should also be made to check for scour and possible undermining of the structure.

If new erosion control measures are installed, the recommendations listed above should be considered. A combination of recommendations may be the most effective solution. For example, to effectively protect a steep bluff with concrete rubble placed at the toe, re-grading the bluff and constructing an armor stone revetment may be considered. In many cases the existing concrete rubble along the shore can be re-used in the base of the structure if covered with appropriately sized armor stone.

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