Lake Erie Shore Erosion Management Plan

Bratenahl to Grand River: Reach 02

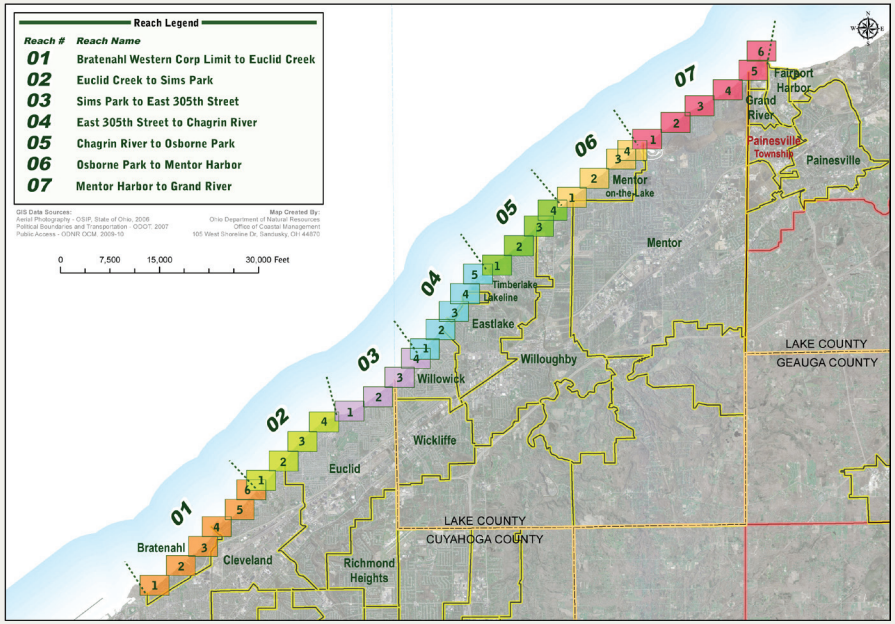
LESEMP

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 02 extends from the mouth of Euclid Creek on the west side of the Wildwood Area of the Cleveland Lakefront State Park system to the east side of Sims Park in Euclid. This reach includes the lakefront residential communities at the east end of the Cleveland and the west portion of Euclid. This reach contains approximately 17,000 feet of shoreline. Most of the reach is private parcels with the exception of the Wildwood Area at the west end of the reach, and Euclid and Sims parks 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 shore curves slightly to the east around a broad headland known as Moss Point which extends from Euclid Park to Sims Park near the east end of the reach. The net direction of littoral drift is typically from west to east. On a large scale, the shore is fairly uniform; but on a more local scale, man-made structures have caused small irregularities in the shore form.

The shore is generally characterized by 25 to 40-foot high bluffs. The bluffs are primarily composed of glacial till although shale is exposed along the toe of the bluff in the area of Moss Point. The shore in this reach is heavily armored with protective structures and occasionally fronted by narrow, transient beaches. The widest beach is supported by nearshore breakwaters at Sims Park, but narrow beaches also accumulate updrift of large shore perpendicular structures such as the jetties of the sewer outfall at Euclid Park.

The nearshore in this reach is composed of till gradually transitioning to shale near the east end of the reach. The till and shale are often covered with a thin band of sand along the shore, although sand deposits in this area are typically less than 0.5 feet thick. Sand accumulation is greatest where trapped landward of nearshore breakwaters or updrift of large shore-perpendicular structures. In the western areas of this reach, nearshore slopes are slightly steeper than 1 degree for the first 1,000 feet and smooth to approximately 1 degree farther offshore. As the nearshore lakebed transitions to shale, slopes are reduced to less than 1 degree.

The 650-foot long jetty stabilizing the east bank of Euclid Creek is at the west end of the reach (top). The marina and boat launch at the Wildwood Area of Cleveland Lakefront State Park is protected by the breakwater just east of Euclid Creek (bottom).

At the west end of the reach a 650-foot long jetty extends northwest into the lake at Euclid Creek. The jetty makes up the west side of the basin for the marina and boat launch at Wildwood Area of the Cleveland Lakefront State Park system. The east and north sides of the marina basin are protected by a breakwater that extends approximately 375 feet to the northwest before bending about 225 feet farther west. The breakwater bends parallel to shore an additional 400 feet. The west end of the breakwater splits to extend about 250 feet to the east to protect the marina entrance channel. The marina entrance is also protected by two 60-foot diameter steel caissons filled with armor stone and large concrete blocks. Additional armor stone and concrete blocks have been added to each side of the caissons to extend the breakwater

East of the Wildwood Area, the bluffs have been covered in concrete for the first 400 feet along East Park Drive. The remains of several relict groins can be seen submerged in the nearshore in this area. The next 1,000 feet of shore to the east consists of low till bluffs covered with concrete rubble along the east end of East Park Drive and along Dorchester Drive. At the east end of Dorchester Drive a single property is protected by a 125-foot concrete block seawall.

The next 1,600 feet of shore spanning the Coronado Beach Association and Beachland Park Association is similar to the area to the west with low till bluffs covered with concrete rubble. Partially submerged groins can be seen along the shore of the Beachland Park Association. Approximately 100 feet of shore in this area is protected with steel sheet pile near a sewer outfall at the end of Windward Road. Approximately 300 feet of shore along Dorchester Drive at the end of Maplecliff Road is protected with a series of seawalls with large concrete modules placed just lakeward. In some areas concrete rubble is present at the toe of the seawall.

To the east, the Hospice of the Western Reserve spans the next 1,900 feet of shore. The first 625 feet of shore is protected with a steel sheet pile bulkhead fronted by a low revetment constructed as toe protection lakeward of the bulkhead. The next 1,275 feet of shore is consistently protected with an armor stone revetment extending to East 185th Street. The next 700 feet of shore to the east is protected by a steel sheet pile bulkhead along the Euclid Hospital. An armor stone revetment has been constructed to dissipate wave energy and provide toe protection lakeward of the bulkhead. The revetments along this stretch create a continuous structure spanning nearly 2,600 feet of shore. Landward of the shore structures the 30 to 40-foot bluffs at the Hospice of the Western Reserve and Euclid Hospital have been re-graded to a stable slope. Sand resources in this area are minimal.

East of the Euclid Hospital the upland transitions back into residential property. Individual properties in this area are often just 40 to 50 feet wide and are protected by a variety of shore structures. The first 175 feet of shore is split between an unarmored bluff face with concrete rubble and small groins at the toe and approximately 100 feet of armor stone revetment. To the east a concrete module breakwater spans several parcels over the next 650 feet of shore. The breakwater was constructed 30 to 50 feet from the toe of the bluff, lakeward of a variety of revetments and seawalls in the area. Several parcels also have concrete rubble covering the toe of the bluff in this area.

Sand accumulation along the shore begins to increase near the end of East 196th Street. A narrow, transient beach comprised of sand mixed with cobble and scattered concrete rubble spans approximately 1,200 feet of shore along Edgecliff Drive. Several parcels have concrete groins to stabilize the narrow beach. The 30-foot high bluffs in this area are typically re-graded and several properties have seawalls as toe protection. The seawalls vary in construction but were constructed in a similar location along the toe of the bluff resulting in a fairly consistent shore. Several parcels include deck, boat house or lake access structures along the bluff.

The beach gradually widens to nearly 70 feet along approximately 600 feet of shore to the east as sand accumulates updrift of a storm sewer outfall along the shore of the Arcadia Club. The unarmored bluffs lakeward of East 201st Street and East 202nd Street gradually decrease in height as the beach widens to the east.

The next approximately 1,900 feet of shore along Edgecliff Drive between East 206th Street and East 212th Street is protected by a variety of shore structures. Residential parcels in this area are typically only 50 to 100 feet wide. Concrete block seawalls and armor stone revetments are the most common structures in this area. Several parcels also have concrete groins extending into the lake to stabilize the narrow, transient beaches in the area. Sand accumulation generally increases to the east as the beach is stabilized by a long concrete storm sewer outfall extending approximately 100 feet into the lake near the Edgecliff Club. A few parcels have a row of concrete modules 30 to 50 feet lakeward of the toe of the bluff. In some instances the modules have been effective at trapping a perched beach along the shore. In most cases, however, sand accumulation near the modules is minimal.

East of the sewer outfall at the Edgecliff Club approximately 500 feet of shore is protected with concrete Great Lakes Erosion Control Modules spanning several parcels. To the east, the next 700 feet of shore along Edgecliff Drive is protected with a variety of structures. The area between East 216th Street and East 219th Street is primarily protected with seawalls placed at the toe of the bluff. Several parcels also have concrete groins or piers extending into the lake. A few parcels also have Great Lakes Erosion Control Modules or other concrete modules placed along the shore. East of

The toe of the bluff at Euclid Park in Euclid is protected by an armor stone revetment at the back of the beach (left). The beach at Euclid Park is supported by stone jetties along the storm sewer outfall at the east end of the park (right).

219th Street the shore transitions to unarmored bluffs with a narrow beach stabilized with concrete groins. Shale bedrock is exposed near the toe of the bluff along the broad headland in this area.

The beach gradually widens to the east as sand accumulates updrift of the jetties along the storm sewer outfall at Euclid Park. The shore lakeward of East 220th Street and East 221st Street is generally unarmored, although several concrete modules can be seen along the beach and in the nearshore. At Euclid Park the bluff has been re-graded to a stable slope and an armor stone revetment has been constructed for toe protection.

East of Euclid Park approximately 450 feet of shore is protected with an armor stone revetment lakeward of a steel sheet pile bulkhead along the shore of Edgecliff Drive. The revetment curves landward into an embayment along a 100-foot unprotected gap between structures near the end of East 225th Street. The next 1,000 feet of shore to the east is protected with a variety of structures. Approximately 150 feet of shore is protected with Great Lakes Erosion Control Modules covered with concrete rubble.

The next several parcels are protected with a concrete seawall at the toe of the bluff and concrete modules placed in the nearshore. Groins are present at the ends of each parcel. The nearshore concrete modules are placed in a variety of configurations. Narrow, transient beaches occasionally accumulate landward of the nearshore concrete modules. Overall sand accumulation in this area is minimal until the east end of this stretch as sand collects updrift of the terminal groin and detached breakwaters at Sims Park.

At the east end of the reach 1,000 feet of shore is protected by three nearshore breakwaters and terminal groins at the east and west ends of Sims Park. The west terminal groin extends 120 feet from the toe of the bluff. The three 175-foot long breakwaters begin approximately 40 feet east of the terminal groin and are evenly spaced about 110 feet apart. The east terminal groin extends approximately 150 feet into the lake and is spaced about 100 feet east of the east breakwater. A concrete pier covers a storm sewer outfall just east of the east terminal groin. The design of the structures and large amount of sand placed at the site have caused large tombolos to form landward of the breakwaters at Sims Park. A tombolo is an extension of beach projecting lakeward from the shore and connecting to an offshore breakwater or island.

The breakwaters were constructed with the toe of the structures approximately 200 feet lakeward of the bluff. The long breakwaters placed relatively close to shore with short gaps and long terminal groins has resulted in tombolo sand formations as sand as accumulated all the way

Much of the shore of Reach 02 is protected with armor stone or pre-cast concrete modules (left). The shore along Edgecliff Drive east of Euclid Park is protected with an armor stone revetment and steel sheet pile bulkhead at the toe of the re-graded, vegetated bluff (right).

out to the structures. Beach accumulation was assisted with large amounts of sand pre-fill placed landward of the breakwaters during construction. Ideally most nearshore breakwaters would be detached and separated from shore with small salient sand formations along the beach. This allows littoral currents to transport material between the breakwaters and shore. Once tombolos form and the detached breakwaters become connected to shore they function similar to groins, trapping littoral material updrift or along the project beach. Because of the scarce sand resources in the area the breakwaters at Sims Park were designed to create tombolos to contain the sand added to the area.

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 0.4 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 0.6 feet per year from 1876 to 1938 and reduced to 0.2 feet per year from 1938 to 1973.

The design of the structures and large amount of sand placed at the site have caused large tombolos to form landward of the breakwaters at Sims Park in Euclid. A tombolo is an extension of beach projecting lakeward from the shore and connecting to an offshore breakwater or island.

From 1973 to 1990 the recession rates ranged from 0 feet per year to 4.4 feet per year. Recession was greatest along the beach at Sims Park which was unprotected prior to construction of the breakwaters in 1991. Recession also reached an average of 3.4 feet per year west of East 185th Street along the shore now occupied by the Hospice of the Western Reserve. 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 0.9 feet per year. Recession was typically greatest in areas relying on concrete rubble for shore protection. The maximum average recession rates during this time period occurred near the end of Canterbury Drive where the bluff is unarmored and the shore is covered in concrete rubble. Overall recession was typically less than 0.3 feet per year throughout the reach.

Beaches/Sand Supply

The few areas with stable beaches along this reach demonstrate the overall lack of available sand in the area. In 1876 a narrow beach fronted most of the shore of this reach. During a period of low lake levels in 1938 nearly the entire reach was fronted by a continuous beach. By 1973 beaches were primarily present updrift of shore perpendicular structures. As beaches eroded the shore was protected with a variety of structures. Wave reflection off hardened structures increased wave energy along the shore and often increased erosion in the nearshore. In many cases shore protection was 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 stabilized by shore structures. Narrow beaches have accumulated updrift of large shore-perpendicular structures at the Arcadia Club and Euclid Park. A wide beach is also stabilized by the breakwaters at Sims Park. 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.

Use of Shore Structures

Much of the shore of the Euclid Creek to Sims Park reach is protected by some form of shore structure. In most cases individual property owners constructed shore protection as area beaches eroded. This has lead to a wide-variety of shore structures ranging from well constructed seawalls and revetments to less effective measures such as dumping concrete rubble along the shore. Revetments are the most common shore protection in this reach. A fairly continuous revetment spans nearly 2,600 feet of shore along the Hospice of the Western Reserve and Euclid Hospital. Revetments are also common along individual properties throughout the reach. Concrete block seawalls are also common throughout the reach. Many properties are protected by large concrete blocks placed lakeward of revetments or seawalls at the toe of the bluff, particularly at the east end of the reach.

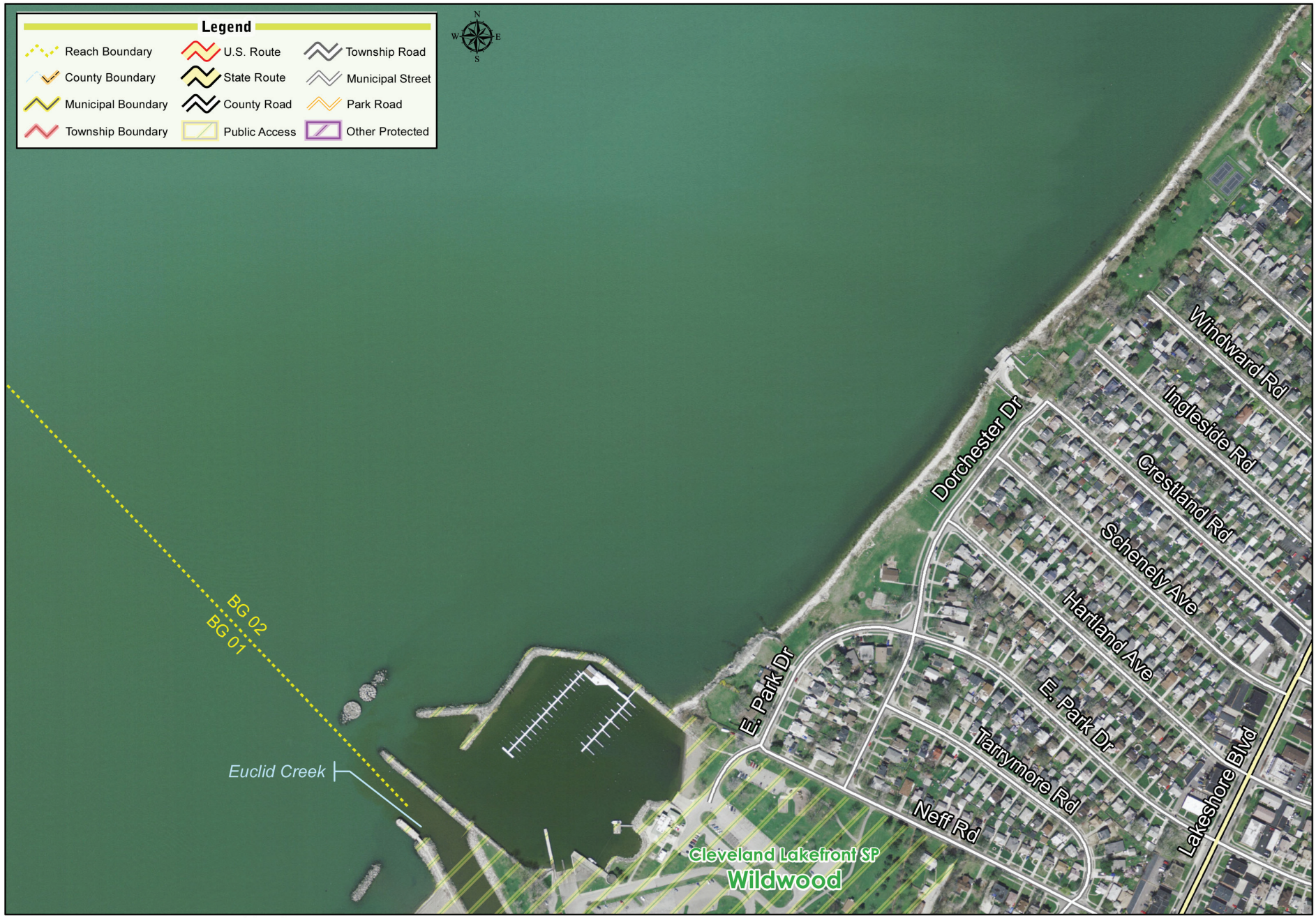
The largest shore structures in this reach are the breakwaters surrounding the marina and boat launch facilities at the Wildwood Area of the Cleveland Lakefront State Park system. The structures were originally constructed in the late 1940s and have contributed to sand accumulation in the Euclid Beach and Villa Angela areas which are at the east end of Reach BG 01. This has limited the amount of sand available east of Wildwood Area.

The detached breakwaters at Sims Park are another significant structure in the Euclid Creek to Sims Park reach. The breakwaters were designed to effectively contain a wide beach at the park.

Summary

The reach from the Euclid Creek to Sims Park primarily consists of residential development with 25 to 40-foot high bluffs along the shore. Much of the shore of this reach is armored with protective structures. Shore protection in this reach ranges from ineffective concrete rubble placed along the shore to well constructed revetments and seawalls. Sand supply is limited throughout the reach and the only significant beaches are stabilized by shore structures. Narrow beaches are present updrift of the large shore-perpendicular structures at the Arcadia Club near East 204th Street and Euclid Park just east of East 221st Street. A wide beach is also present landward of the breakwaters at Sims Park. This reach has historically experienced slow recession rates; however, moderate recession often occurs on properties relying on concrete rubble for shore protection.

The jetties along the sewer outfall at the east end of Euclid Park help support a beach at the park (right).



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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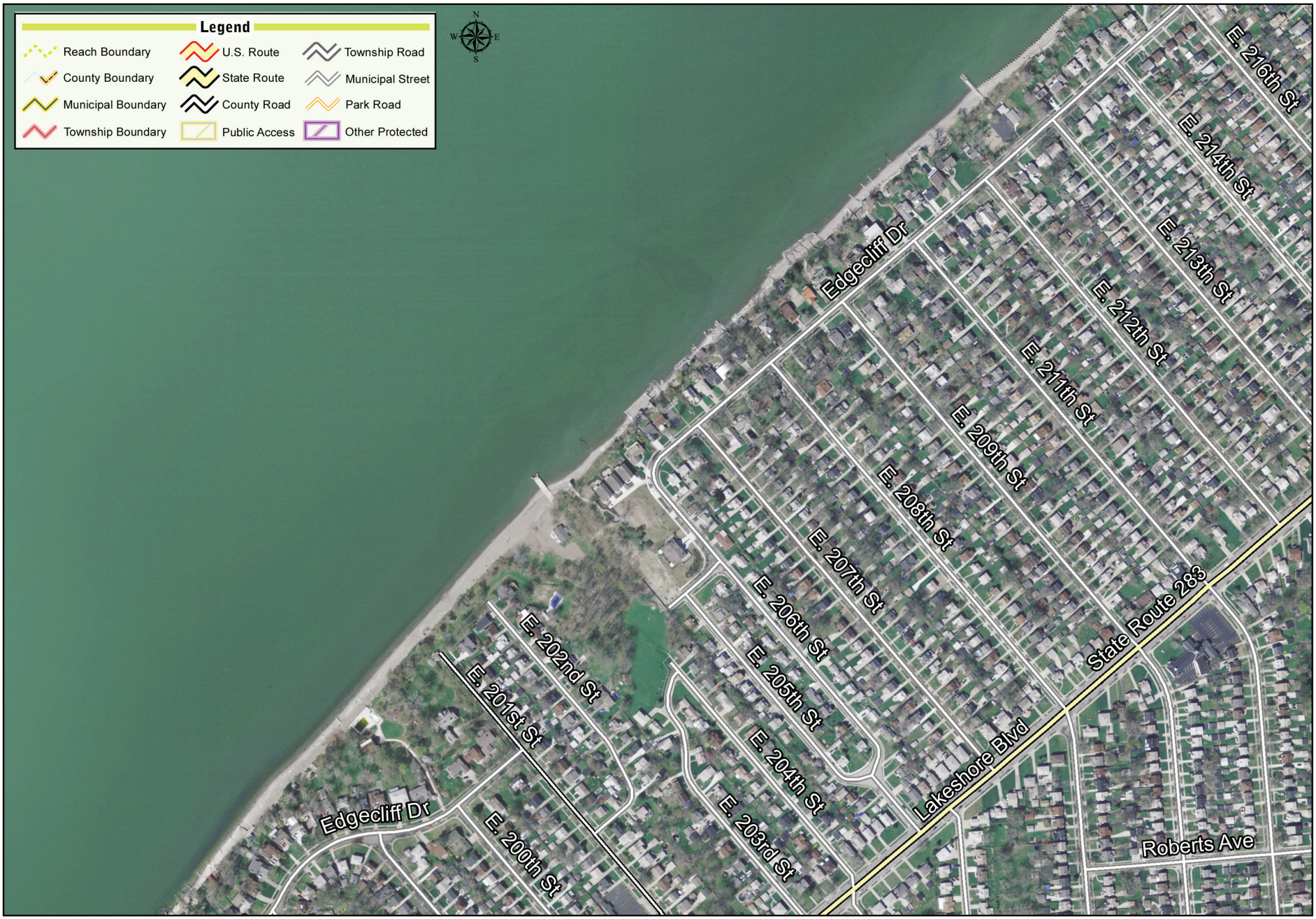

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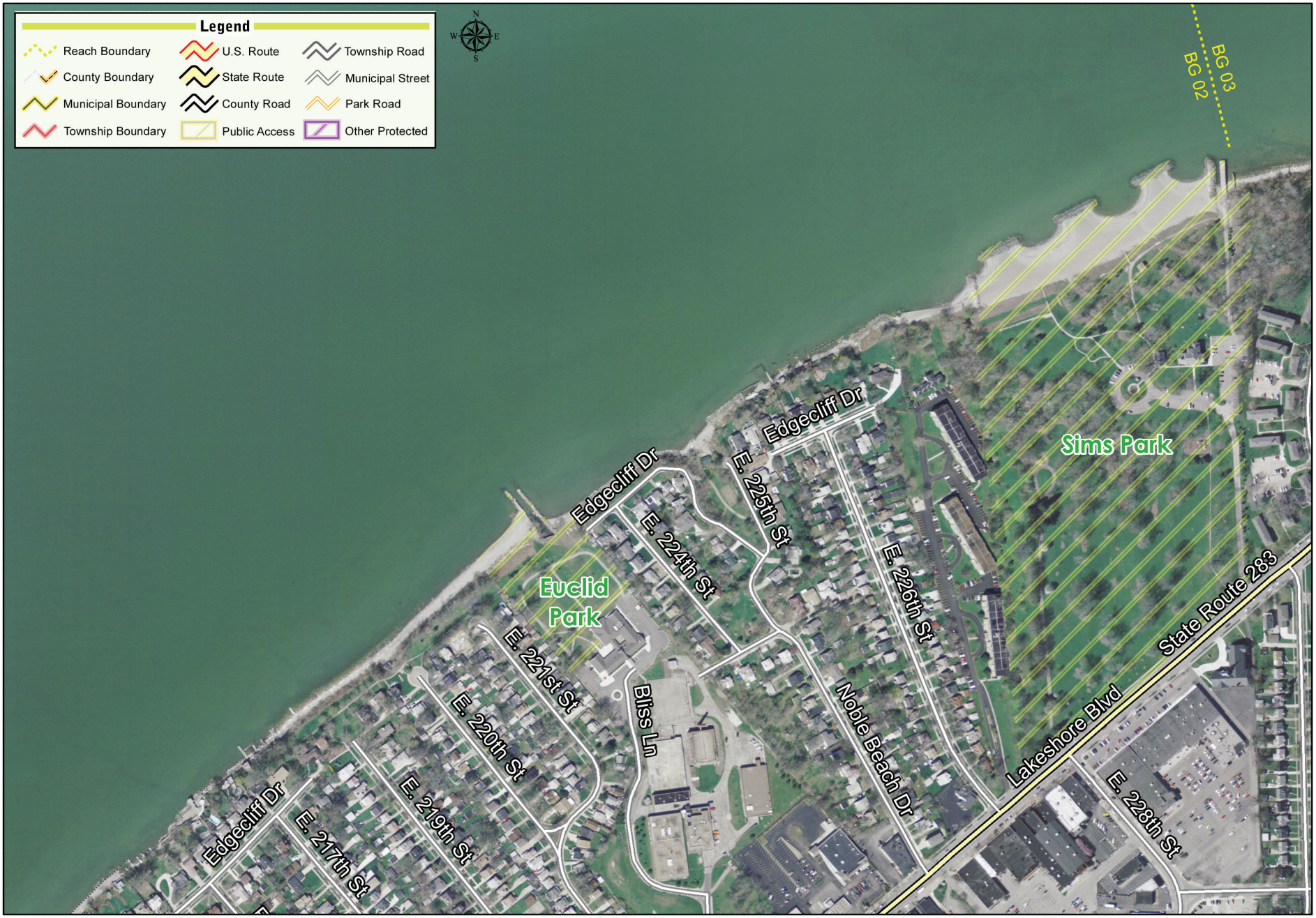

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Recommendations

The recommendations included below are options that may be applicable within this reach and should only be used for planning purposes. Based on the physical characteristics of the reach, the following recommendations are suggested for the area between Euclid Creek and Sims Park. 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 LESEMP's Erosion Control Methods Appendix.

In addition to these recommendations, a "do nothing" alternative should also be considered. This may be a viable, and even a favorable alternative for much of Ohio's Lake Erie shore. The area from Euclid Creek to Sims Park 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 may be considered on the unarmored beaches between East 201st Street and the Arcadia Club.

Vegetation at the landward end of the beach helps encourage dune formation near the toe of the re-graded bluff at Sims Park.

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 Euclid Creek to Sims Park and should be conserved throughout the reach. Several properties near East 201st Street and East 221st Street rely on narrow beaches to protect the bluffs. A decrease in sand resources would leave these parcels vulnerable to excessive 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, and the corresponding reduction in wave energy reaching the shore, 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 Arcadia Club and at Sims Park. Native vegetation on the narrow beaches helps encourage sand accumulation and dune formation at the toe of the bluff. Dunes provide a natural sand reserve to restore beaches during periods of erosion due to storms or high water. Native varieties of American beach grass, little bluestem, sand dropseed or beach pea are well suited for beach vegetation in this area.

3. <u>Dredging</u>: 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

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

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 entrance to the marina at Wildwood Area requires maintenance dredging, nearshore placement of the dredged material should be considered. If the dredge material is suitable for the nearshore environment, nearshore placement will beneficially nourish downdrift beaches.

Toe Protection:

*4. **Revetments**: 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 and 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:

*5. **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 the 25 to 40-foot high bluffs is common throughout this reach. The upper portions of the bluffs are primarily composed of till and glaciolacustrine deposits. These materials are highly susceptible to slumping if the toe of the bluff is eroded by wave action. Except for the 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. Terracing should be considered in areas where upland structures are very close to shore. Re-grading or terracing is typically done in conjunction with the construction of a revetment to provide a stable slope above the structure.

6. 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 as a means of intercepting and diverting 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.

An access trail is included in the re-graded bluff at Euclid Park (left). Vegetation is re-planted along the bluff face after the construction of an access path at Sims Park (photo).

The re-routing of surface water should occur throughout the Euclid Creek to Sims Park 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.

7. <u>Vegetation</u>: 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 area from Euclid Creek to Sims Park. 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 would 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.

Routinely monitoring shore structures provides an opportunity to detect and resolve potential issues before large scale failures occur. Typical monitoring should include a visual inspection of the structures and should be documented with photographs.

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 common 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:

8. <u>Bank-Top Management</u>: 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 25 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.

9. <u>Coordination of Projects</u>: 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 utilized over large areas of the shore.

This recommendation is applicable throughout this reach. In residential areas, shoreline property is often divided into parcels as small as 50 feet wide with each property owner responsible for their own shore protection. This is common along Edgecliff Drive in the eastern half of this reach and has led to the construction of a mix of shore protection structures of varying designs, construction quality and condition. Complex interaction between structures in certain wave conditions often limits their effectiveness and at times can cause increased erosion at the site or 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 parcels.

When structures can not be continued across multiple parcels, conditions at the ends of the structure should be carefully considered in the design. The structures should be designed to prevent intersections causing increased wave energy or gaps between structures where increased erosion is likely.

10. <u>Shore Structure Management-Monitoring</u>: Monitor and maintain shore structures. Routine monitoring of shore structures will allow for early detection of any 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. Should removal of an aged or deteriorating structure be 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 parcels. 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.

Routinely monitoring shore structures provides an opportunity to detect and resolve potential issues before large scale failures occur. Typical monitoring should include a visual inspection of the structures and should be documented with photographs.

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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