Lake Erie Shore Erosion Management Plan

Bratenahl to Grand River: Reach 03

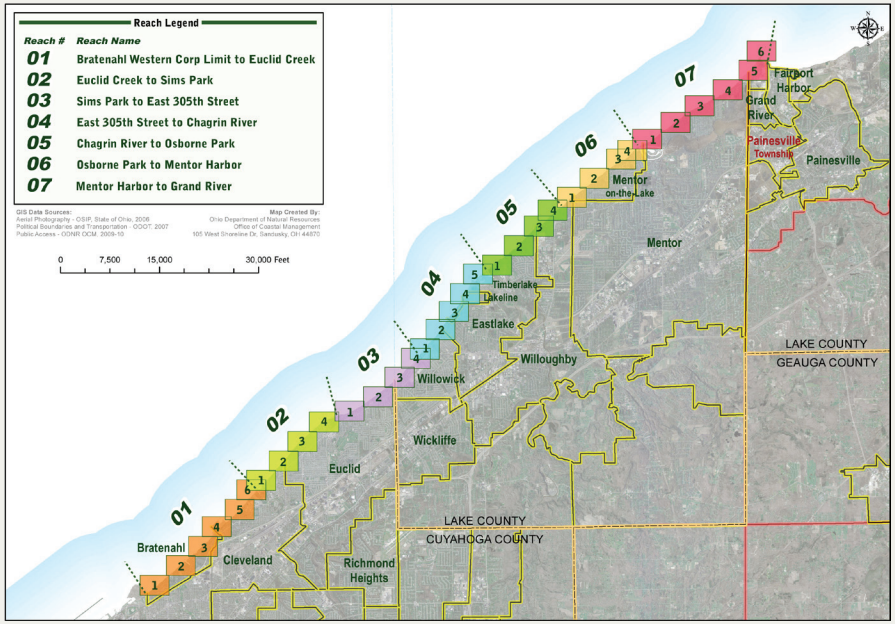
LESEMP

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 03 extends from the east end of Sims Park in Euclid to Willowick City Hall near the end of East 305th Street. This reach includes the lakefront residential communities in the eastern portion of the city of Euclid and in the western portion of the city of Willowick. This reach contains approximately 15,500 feet of shoreline and spans the Cuyahoga-Lake county line. The entire reach from the east end of Sims Park to East 305th Street is private property with the exception of the public access at Willowick City Hall at the east end of the reach.

This reach is oriented from southwest to northeast. The shore gradually curves toward the north on the east end of the broad headland near Sims Park known as Moss Point. The shore in this reach is fairly uneven as seen from above with alternating small headlands and embayments. Most irregularities are caused by man-made structures. The shore is generally characterized by 25 to 35-foot high glacial till bluffs. Shale is exposed along the toe of the bluff in the area of the broad headland at the west end of the reach and thin bands of laminated clay are present near the base of the bluffs to the east.

This reach is heavily armored with protective structures and occasionally fronted by narrow, transient beaches. The net direction of littoral drift along the shore is typically from southwest to northeast as westerly winds produce waves that reach the shore at an angle. The nearshore in this reach is composed of shale covered with a thin layer of sand along the shore. Sand deposits in the area are variable but generally increase from west to east. Sand deposits at the west end of the reach are typically less than 0.5 feet thick but increase to nearly 3 feet at the east end of the reach. Sand accumulation is greatest where trapped updrift of shore-perpendicular structures or in shallow embayments between headlands created by nearby structures. The shale nearshore is generally sloped at an angle of less than 1 degree. Nearshore slopes are greatest within the first 50 to 100 feet of shore and gradually flatten offshore.

At the west end of the reach approximately 1,750 feet of shore is fronted by a narrow beach covered with concrete rubble and other debris. Several large stones and concrete modules can also be seen in the nearshore. The 30-foot

The shore to the east of the Sims Park Pier consists of natural bluffs fronted by a narrow beach covered with concrete rubble and other debris (top). Great Lakes Erosion Control (GLEC) modules are common throughout the reach. Although GLEC modules have helped stabilize the shore in some areas, their functionality is often limited due to issues with uneven settling, cracking and excessive splashing and overspray (bottom).

bluffs in this area are generally left in a natural state and are well-vegetated. Near the northern terminus of Lake Edge Drive, a small concrete seawall has been constructed. Several large concrete blocks are also visible lakeward of the seawall. Along approximately 350 feet of shore to the east the entire bluff slope is covered in concrete rubble. The concrete rubble covers the toe of the bluff and nearshore. Bluff heights in this area decrease from 30 feet to about 20 feet. This area extends to the east as far as East 242nd Street.

To the east, the bluff face transitions from concrete rubble to a more natural slope along the shore of the Harbor Crest Apartments. However, the Harbor Crest Apartments and the shore for about 400 feet to the east still rely on concrete rubble along the toe of the bluff for shore protection.

The next 350 feet to the east is protected with a steel sheet pile bulkhead fronted by an armor stone revetment. Bluff heights gradually increase in this area. To the east, approximately 125 feet of v-shaped concrete Great Lakes Erosion Control (GLEC) modules lead up to approximately 750 feet of armor stone revetment spanning several properties at the end of East 252nd Street and the west end of Edgecliff Drive. The revetment is wavelike as seen from above, creating an uneven shoreline. A steel sheet pile pier is present near the east end of the revetment. The bluffs in this area are also re-graded and vegetated.

The next 275 feet to the east is protected with v-shaped GLEC modules. The modules were placed approximately 50 feet into the nearshore and support a perched beach landward. A 150-foot long revetment has also been constructed at the toe of the re-graded bluffs near the east end of the GLEC modules. The beach along the GLEC modules continues for about 400 feet east to the east along Edgecliff Drive. A few properties in this area are also protected by armor stone at the toe of the bluff. The next 500 feet of shore is protected with an armor stone revetment with five armor stone groins extending approximately 70 feet into the lake. The groins are evenly spaced every 100 feet and support a narrow beach lakeward of the revetment.

Great Lakes Erosion Control (GLEC) modules are common throughout the reach. Although GLEC modules have helped stabilize the shore in some areas, their functionality is often limited due to issues with uneven settling, cracking and excessive splashing and overspray.

Just east of East 260th Street, a narrow beach is supported by a shore-parallel row of concrete modules. The next 750 feet of shore to the east (lakeward of the Riviera and North Pointe Apartments) is partially protected with approximately 200 feet of concrete seawall and 100 feet of concrete modules.

The remaining shore in the area is unarmored and fronted by a narrow beach. The next 250 feet of shore to the east is protected by a steel sheet pile bulkhead fronted by stacked concrete modules and large concrete blocks. East of a small concrete pier a narrow beach spans approximately 1,000 feet of shore between East 265th and East 270th streets. The bluff in this area is generally at a natural slope and well vegetated. Several properties have constructed concrete seawalls or steel sheet pile bulkheads as toe protection landward of the beach. Large concrete modules along the beach and nearshore are also common in this area.

The next 550 feet of shore (leading up to the storm sewer outfall at the end of Lloyd Road) primarily relies on concrete rubble for shore protection. The shoreline in this area is irregular due to a small headland just east of East 272nd Street. The storm sewer outfall at the end of Lloyd Road includes a large concrete structure along the toe of the bluff and two stone groins placed in the nearshore.

The next 2,300 feet of shore is primarily naturally sloped, vegetated bluffs fronted by a narrow beach. The beach spans the Cuyahoga-Lake county line. The west 350 feet of beach is covered with concrete rubble and includes a row of concrete modules. The next 900 feet of beach is supported by small concrete groins and often includes a small concrete seawall or randomly placed concrete rubble at the toe of the bluff. The remaining beach is occasionally supported by small concrete groins and by the storm sewer outfalls near the end of East 280th and 284th Streets.

To the east approximately 775 feet of shore is protected with a continuous series of concrete seawalls along the shore of several properties on Cresthaven Drive. Several small groin and pier structures have been constructed lakeward of the seawall. The east end of the seawall gradually curves landward and transitions to a series of steel sheet pile bulkheads to create a shallow embayment and narrow beach. The nearly 600-foot long beach is also supported by a 50-foot concrete groin near the east end.

To the east an armor stone revetment extends the shore approximately 50 feet lakeward to create a small headland along approximately 350 feet of shore. The headland is protected by a steel sheet pile bulkhead fronted with concrete rubble. East of the headland a narrow beach spans the next 1,200 feet of shore. A wide variety of structures have been constructed landward of the beach to protect the toe of the bluff in this area. The structures range from concrete rubble dumped along the bluff to well constructed seawalls and revetments. The beach is often supported by small concrete groins or concrete modules placed in the nearshore. Several shore-parallel rows of concrete modules can be seen in the nearshore near the east end of the beach.

The next 1,400 feet of shore to the east is protected by the armor stone revetment constructed by Willowick Partners LLC. The revetment is divided by a small stream fed by a storm sewer outfall near the west end. The revetment curves landward at the stream creating a small embayment. The revetment is often fronted by a narrow beach, particularly in the embayment where the stream enters the lake. The bluffs above the revetment have been re-graded to create a stable bluff for residential development. The next 500 feet of shore to the east relies on concrete rubble for shore protection. Near the east end of this area the concrete rubble along the bluff is supported by concrete Campbell modules at the toe.

From the shore lakeward of the Willowick City Hall looking west, much of the approximately 15,500 feet of shoreline in the Sims Park to East 305th Street (Willowick Lakefront Park) can be viewed. This reach is heavily armored with protective structures and occasionally fronted by narrow, transient beaches.

The shore lakeward of the Willowick City Hall includes a perched beach above a row of concrete Campbell modules. The toe of the re-graded and vegetated bluff is also protected with a stacked concrete block seawall. The photos are taken looking west from the top of bluff (top) from the beach (middle) and from the beach looking at the toe of the bluff (bottom).

At the east end of the reach the bluff is re-graded and vegetated along the shore of the Willowick City Hall. The toe of the re-graded bluff is also protected with stacked concrete blocks. A row of offset concrete Campbell modules has been placed approximately 35 to 50 feet lakeward of the toe of the bluff to create a perched beach along the shore. The re-graded bluff, concrete toe protection, Campbell modules and perched beach span nearly 600 feet of shore lakeward of the Willowick City Hall and Willowick Lakefront Park (at the west end of Reach 04). Together the Willowick City Hall and Lakefront Park provide about 600 feet of continuous public access. The remains of several relict groins are also present in the nearshore at the east end of the reach.

Recession/Erosion

The ODNR Division of Geological Survey has evaluated the recession of Ohio's Lake Erie shore over three time periods: 1876 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 average recession rates typically less than 3 feet per year. Recession was typically greatest in unarmored areas downdrift of shore-perpendicular structures. Overall, average recession rates decreased as the shore was progressively developed and protected with shore structures.

From 1973 to 1990, average recession rates ranged from 0 feet per year to 6.5 feet per year. Recession was greatest in the area now protected by the revetment constructed by Willowick Partners, LLC. Recession rates also reached 4.9 feet per year on the unarmored bluff at the end of Edgecliff Drive (just west of the Riviera Apartments). This area has been structurally protected by a revetment and series of five stone groins. Recession rates greater than 1-foot per year occasionally occurred in other areas of the reach such as just east of the North Point Apartments and along the unarmored portion of shore along Gilchrist Drive. Larger recession rates were primarily measured in areas without shore structures or that rely on concrete rubble for shore protection.

From 1990 to 2004 most of this reach experienced little to no recession. Average recession rates ranged from 0 feet per year to 2.0 feet per year. Recession was greatest in the unarmored portion of beach along Gilchrist Road. Recession greater than 1-foot per year also occurred in the area now protected by the revetment constructed by Willowick Partners LLC, the

shore just east of the Harbor Crest Apartments, and the shore just east of Sims Park. During this time period, recession was also typically greatest in areas without shore structures or areas relying on concrete rubble for shore protection. Most of the reach experienced little to no recession as the shore is heavily armored with protective structures.

Beaches/Sand Supply

Sand resources are limited near the west end of the reach and steadily increase to the east. In 1876 a narrow beach fronted most of the shore of this reach. The only area without a beach was just east of the broad headland (now Sims Park) at the west end of the reach. During a period of low lake levels in 1938 nearly the entire reach was fronted by a continuous beach.

As the shore was developed a wide variety of structures were constructed to prevent erosion and protect upland property. The large scale hardening of Lake Erie's shores prevents sand from entering the littoral system as bluffs erode. Additionally, the structures at and near Cleveland Harbor, and the practice of dredging Cuyahoga River sediments and placing them in CDFs, may impact the amount of sand in the littoral system. Wave reflection off hardened structures also increased wave energy along the shore and often contributed to erosion in the nearshore. In many cases 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.

By 1973 beaches narrow beaches were primarily present updrift of shore perpendicular structures or in shallow embayments between structures. Today narrow beaches front much of the eastern half of the reach. Beaches are most common updrift of shore-perpendicular structure or in shallow embayments along the shore. Sand accumulation at the west end of the reach is limited by an overall lack of sand resources and the large shore structures at Sims Park impeding littoral currents.

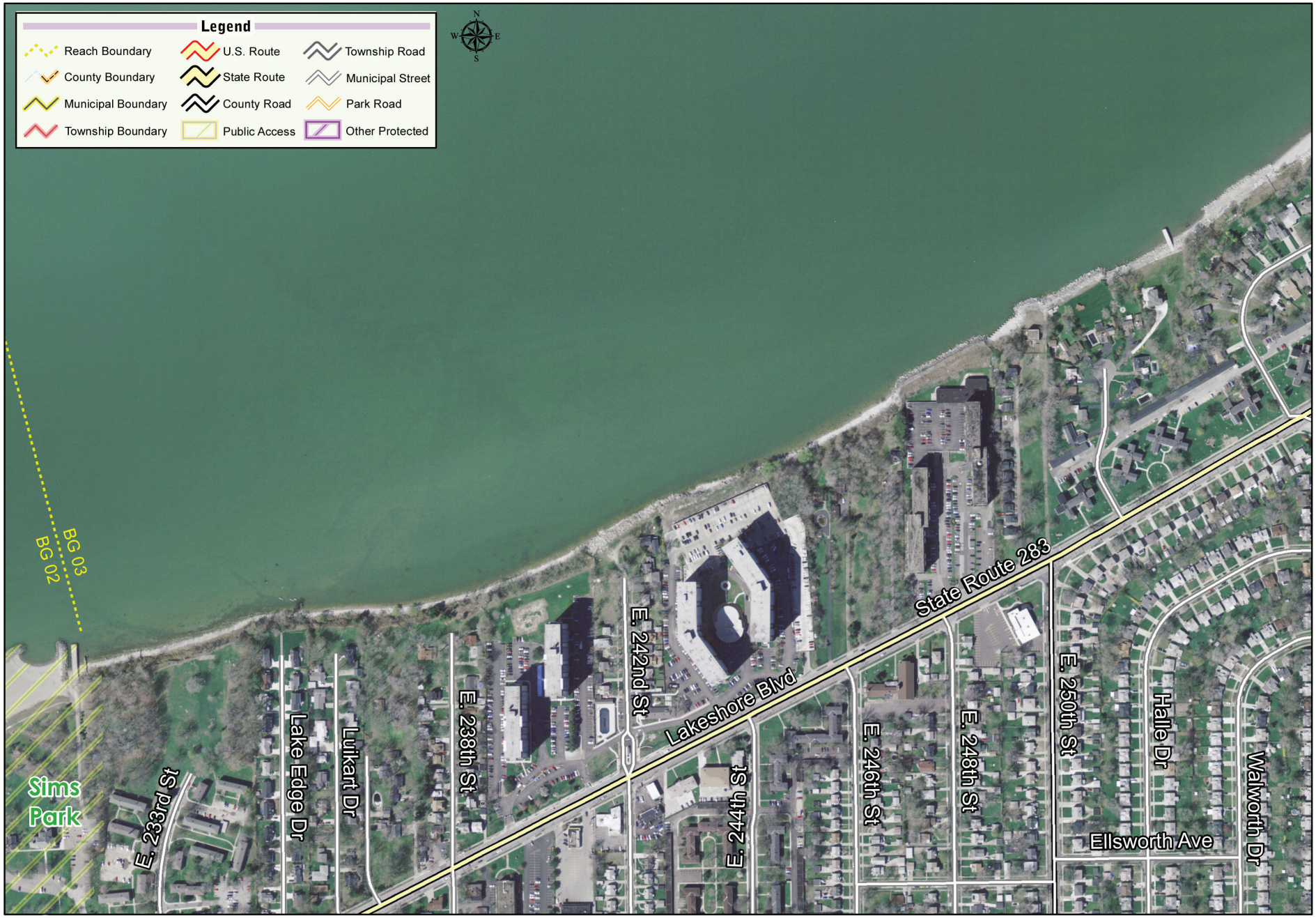
Use of Shore Structures

Much of the shore from Sims Park to East 305th Street is protected by some form of shore structure. The shore in this reach includes individual residential properties as well as some larger apartment and condominium properties, but each property owner is responsible for his or her own shore protection. This has led 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. Long, fairly continuous revetments span numerous areas including: approximately 750 feet of shore near East 252nd Street, 500 feet just west of the Riviera Apartments, and 1,400 feet along the shore of Willowick Partners LLC. Concrete seawalls are also common throughout the reach, particularly along Cresthaven Drive.

Summary

The reach from Sims Park to East 305th Street primarily consists of residential development with 25 to 40-foot high bluffs along the shore. The shore is divided between individual residential properties and large apartment or condominium properties. Much of the shore of this reach is armored with protective structures. Shore protection in this reach ranges from well-constructed revetments and seawalls to less-effective measures such as placing concrete rubble along the shore. Sand resources are limited near the west end of the reach but gradually increase to the east. Narrow beaches are present updrift of the large shore-perpendicular structures and in shallow embayments, particularly in the east half of the reach. This reach has historically experienced slow recession rates although moderate recession often occurs on properties without shore structures or properties relying on concrete rubble for shore protection.

Narrow beaches are visible along the shore to the west of Willowick City Hall.



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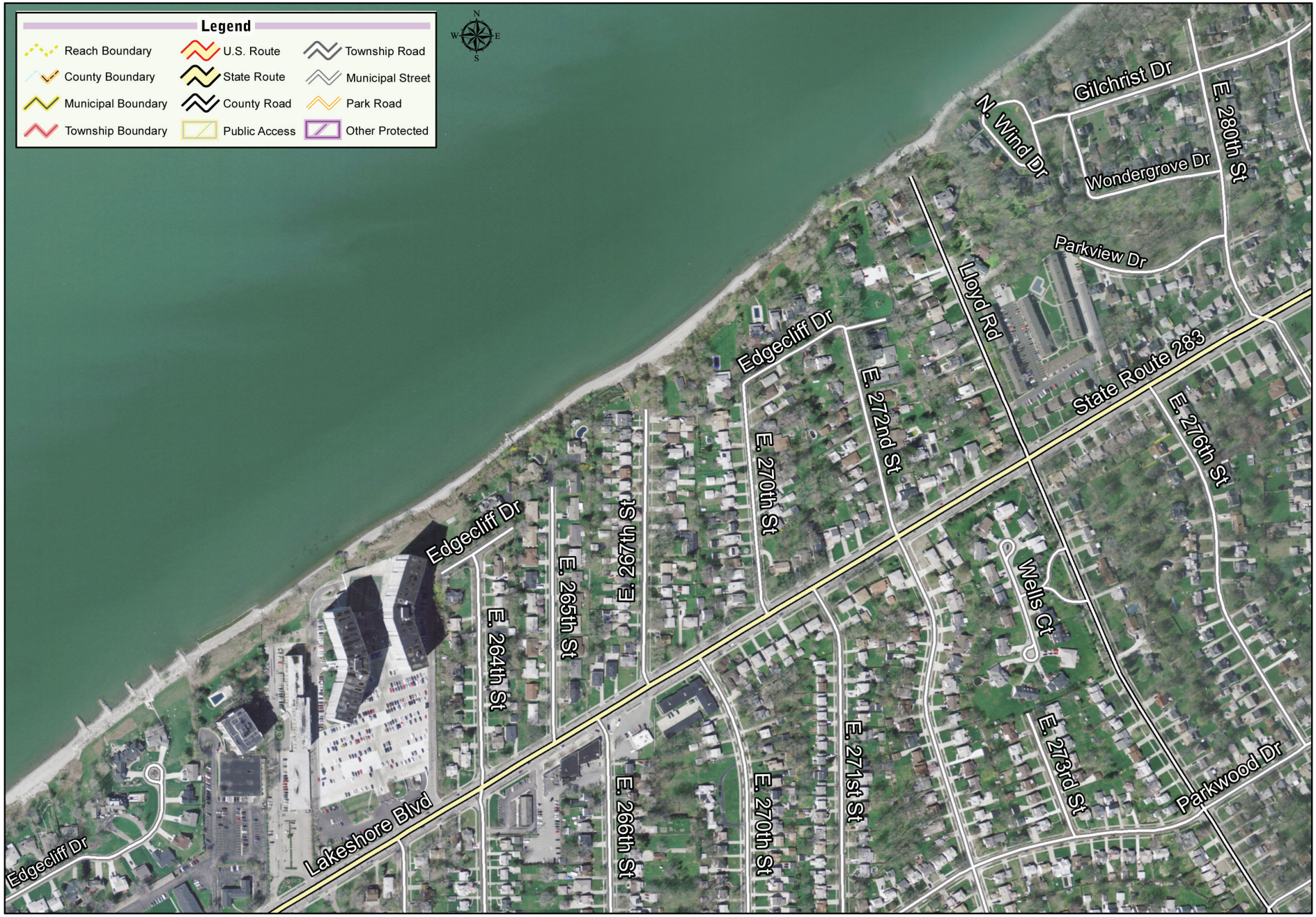
Map Created By:
Ohio Department of Natural Resources
Office of Coastal Management
105 West Shoreline Dr, Sandusky, OH 44870



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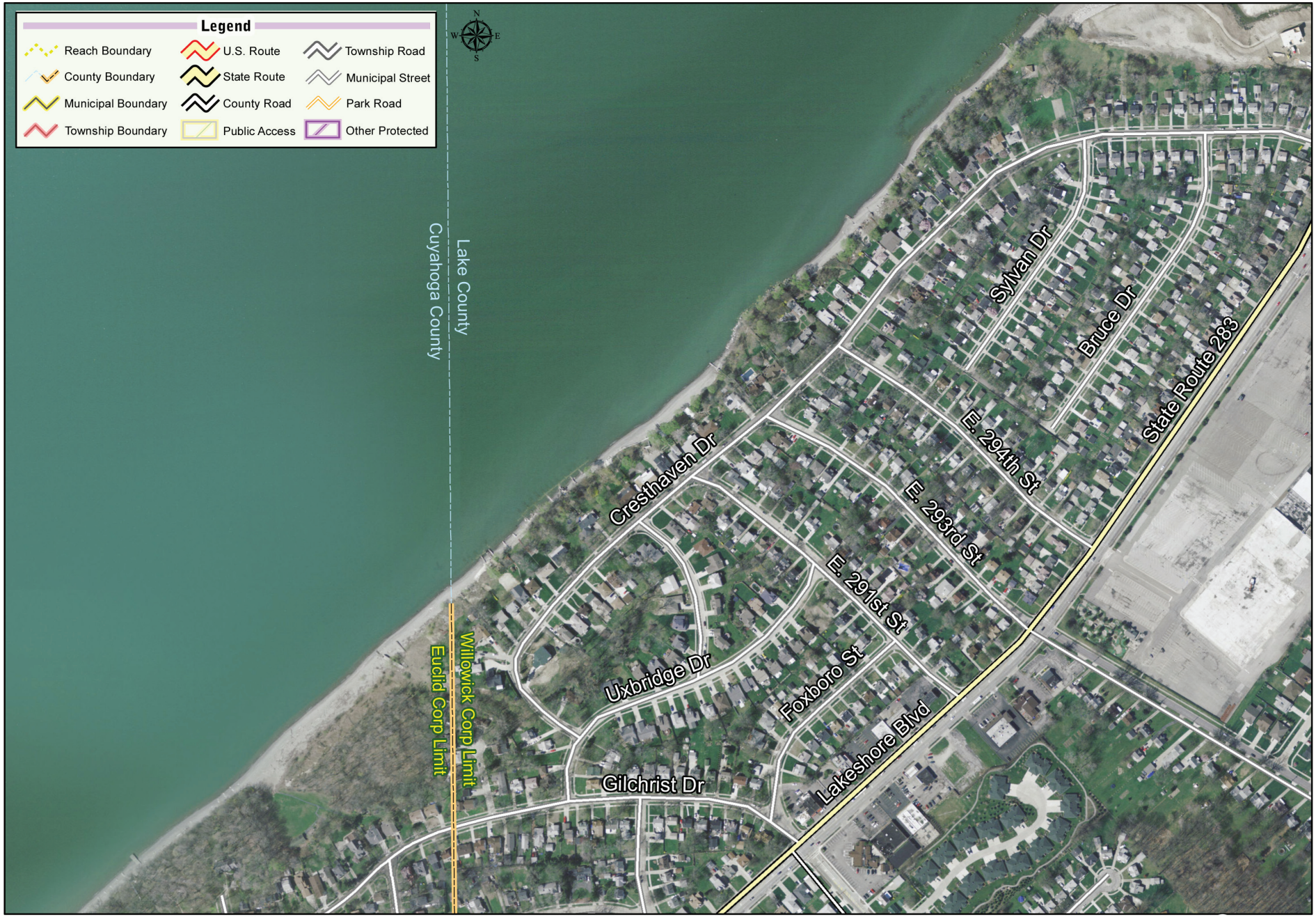

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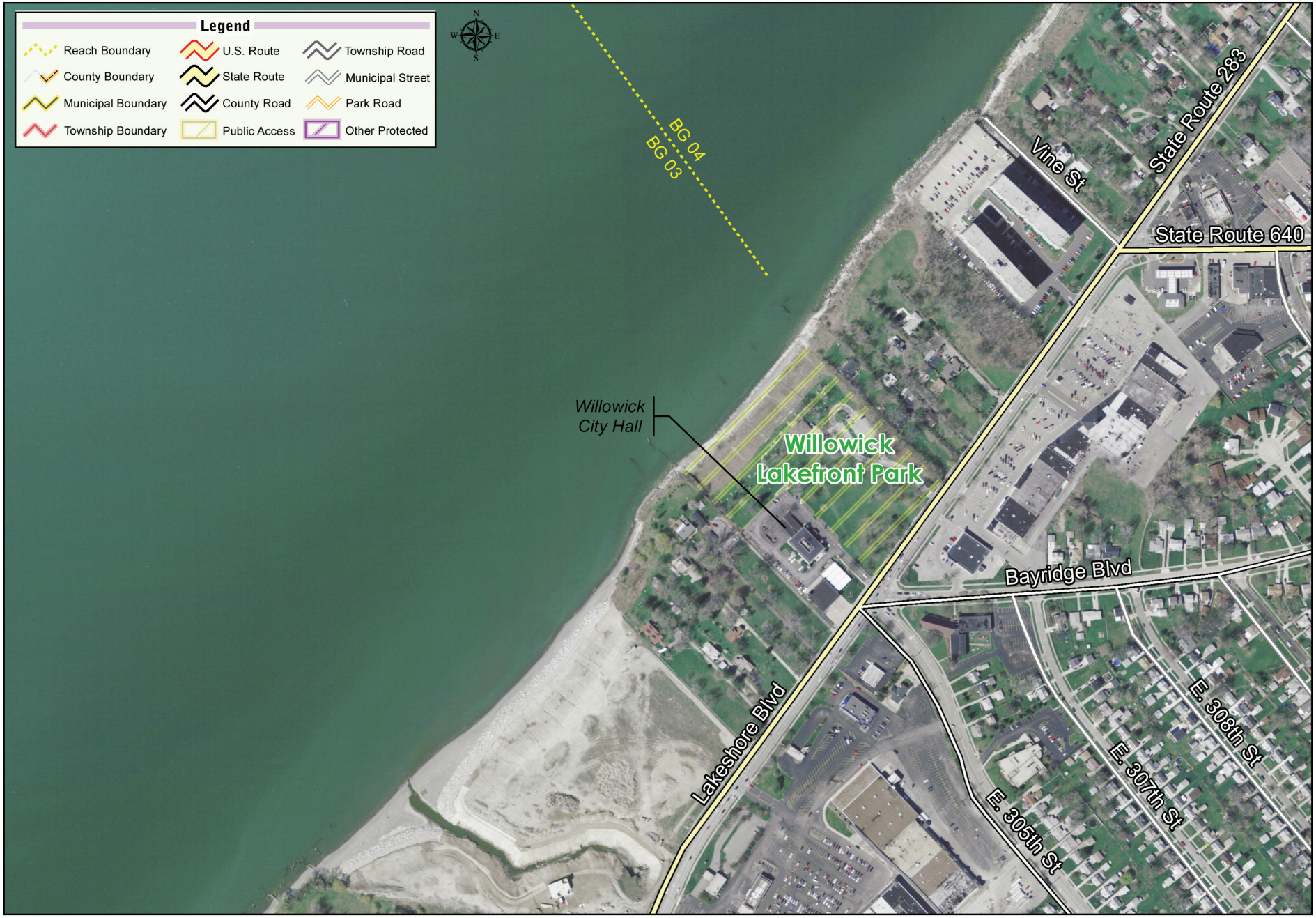

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Recommendations

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 the reach, the following recommendations are suggested for the reach between Sims Park and East 305th Street. 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 appendix for Erosion Control Methods.

In addition to the recommendations listed below, a "do nothing" alternative should be considered. This may be a viable, and even favorable, alternative for much of Ohio's Lake Erie shore. The area from Sims Park to East 305th Street is heavily armored 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 relatively 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 along Gilchrist Drive where residential development is set back from the shore.

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 Sims Park to East 305th Street, particularly at the west end of the reach. Sand should be carefully conserved throughout the reach. Several properties, including the large North Point apartment buildings near East 264th Street, rely on narrow beaches to protect the bluffs. A decrease in sand resources would leave these properties vulnerable to excessive erosion. The narrow beaches are also relied on for shore protection near East 267th Street and along Gilchrist Drive.

Many properties at the east end of the reach also have shore protection at the toe of the bluff landward of narrow beaches. A reduction of sand in the littoral system may result in erosion of the beaches. Sand accumulation lakeward of the structures and in the nearshore helps to reduce water depths and causes 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 aging structures in this reach.

As sand resources vary, the perched beach lakeward of Willowick City Hall can extend lakeward of the Campbell Modules. During periods of higher lake levels or reduced sand supply the beach is limited to the area landward of the Campbell Modules. Varying widths are shown in April 2012 (left) and November 2009 (right).

2. <u>Beach Nourishment</u>: Supplement the current sand supply with beach nourishment, also known as beach fill or pre-fill. Beaches protected by groins and detached breakwaters will benefit from initial nourishment (pre-fill during or directly after construction) and periodic re-nourishment. The sand used in these projects should be acquired from an upland source.

The east end of this reach is often fronted by narrow beaches that would benefit from nourishment. The addition of beach nourishment would be especially beneficial at sites with existing structures to stabilize it such as the armor stone groins near the end of Edgecliff Drive or as part of a new construction project.

3. <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 & 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 natural beaches and unprotected bluffs along Gilchrist Drive. 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.

Planting native vegetation on the beach helps encourage sand accumulation and dune formation. Dunes provide a natural sand reserve to restore beaches during periods of erosion due to storms or high water.

Toe Protection:

4. <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 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 higher average recession rates than properties with well constructed revetments or seawalls. 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. 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, existing concrete rubble along the shore can be used in the base layers of a revetment if covered by suitably sized armor stone.

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

Bluff/Bank Modifications:

5. <u>Re-Grading/Terracing</u>: 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 35-foot high bluffs is common throughout this reach. The upper portions of the bluffs in this reach 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. In areas with upland structures very close to shore, terracing should be considered. Re-grading or terracing is typically done in conjunction with the construction of a revetment to provide a stable slope above the structure.

6. <u>Surface Water Management</u>: 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.

The re-routing of surface water should occur throughout the Sims Park to East 305th Street 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>Ground Water Management</u>: Remove ground water from within the bank. Drainage should be installed in areas with excess water in the bank, visible as seeps or springs in the middle of the bank. A subsurface drainage system should remove water from an upper layer within the bank (often a sandy layer), and should exit at the lake level to limit lower bank erosion. Sources of ground water include, but are not limited to leaking septic systems, underground pipes and swimming pools.

In areas of this reach with higher bluffs, ground water seepage can be a significant cause of erosion. In the eastern portions of this reach a thin layer of laminated clay is present near the base of the bluff. Ground water can cause slipping and slope failures along the layer of clay. A subsurface drainage system should be considered for properties prone to rotational slumps or with visible signs of ground water seepage. Drainage systems are often installed as a component of a re-grading or terracing project to create a stable slope.

8. <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.

This recommendation is applicable throughout the area from Sims Park to East 305th Street. 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 wind and 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 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:

9. <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 35-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

The addition of a drainage system can help reduce erosion due to surface and ground water. Any water collected should be drained as close to the toe of the bluff as possible (left). Allowing native vegetation to grow on the natural bluff face or on the re-graded slope above seawalls, revetments and other shore structures helps stabilize the bluff by reducing excess surface and ground water (right).

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.

10. 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 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 his or her own shore protection. This is common along Edgecliff Drive and Cresthaven Drive. This 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 properties.

When structures can not be continued across multiple properties, 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.

11. Shore Structure Management/Monitoring: 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. 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 a 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, a property owner may consider re-grading the bluff and constructing an armor stone revetment. 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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