Lake Erie Shore Erosion Management Plan

Bratenahl to Grand River: Reach 04

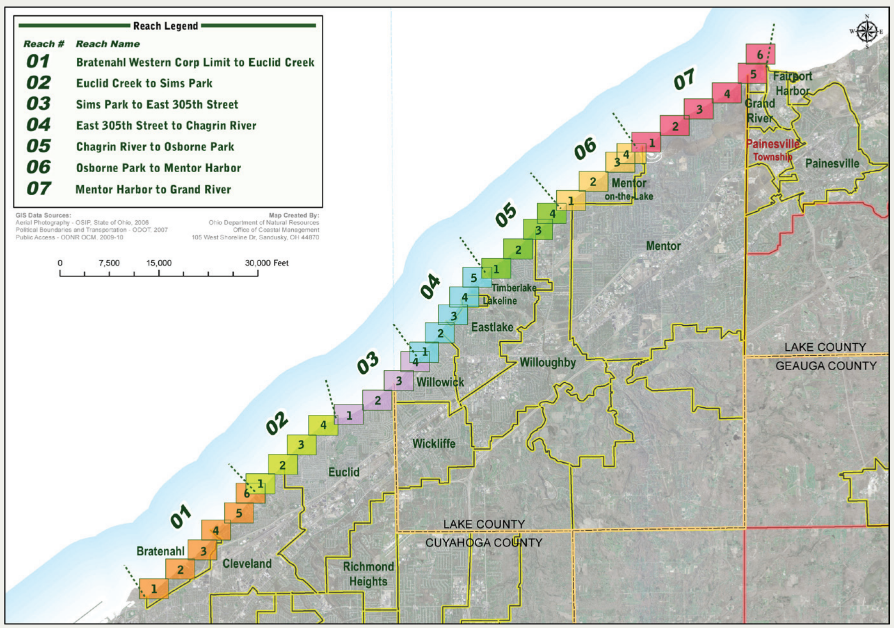
LESEMP

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 04 extends from the Willowick City Hall at the end of East 305th Street to the mouth of the Chagrin River. This reach includes the lakefront residential communities of the cities of Willowick and Eastlake and the villages of Lakeline and Timberlake. This reach contains approximately 17,500 feet of shoreline near the western end of Lake County. Most of the reach is private property with the exception of the Willowick Lakefront Park, Quentin Road Park and the Eastlake Seawall.

The shore of this reach is oriented from southwest to northeast. The most prominent feature along this reach is the large headland created by the shore-perpendicular structures at the Eastlake Power Plant. Because the net direction of littoral drift in the reach is from west to east, a wide beach has accumulated to the west (updrift) of the power plant. The shore steps approximately 400 feet landward downdrift of the shore structures at the power plant. The rest of the reach contains alternating small headlands and embayments breaking up long sections of fairly regular shoreline. Most irregularities are caused by man-made structures. The shore is generally characterized by 30 to 50-foot high bluffs, but the relief of the upland declines near the Chagrin River. The bluffs are primarily composed of glacial till with thin bands of laminated clay present near the base of the bluffs and at the top of the bluff in the eastern portions of the reach.

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 Eastlake Power Plant. A wide beach extends up to 3,500 feet to the west of the power plant breakwaters. The nearshore in this reach is composed of shale or till covered with a three to six-foot layer of sand along the shore. Sand deposits in the area are variable but generally increase from west to east due to sand accumulation updrift of the power plant. Nearshore slopes are greatest within the first 50 to 100 feet from shore and gradually flatten to approximately 1 degree farther offshore. Nearshore slopes become more variable between Stevens Boulevard and the Eastlake Power Plant due to the occasional formation of sand bars in the nearshore.

At the west end of the reach the bluff is re-graded and vegetated along the shore of the Willowick Lakefront Park. The toe of the re-graded bluff is also protected with stacked concrete blocks. A row of offset concrete Campbell module 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 module and perched beach span nearly 600 feet of shore lakeward of the Willowick City Hall (at the east end of Reach 03) and Willowick Lakefront Park (at the west end of Reach 04). The remains of several relict groins are also present in the nearshore near the west end of the reach.

East of Willowick Lakefront Park, approximately 100 feet of shore is protected with an armor stone revetment. The next 500 feet of shore relies on concrete rubble placed along the bluff face or at the toe of the bluff as shore protection. To the east the shore steps about 40 feet lakeward for approximately 400 feet as a revetment and concrete headwall protect the Shoregate Towers Apartments.

After approximately 100 feet of concrete rubble along the shore, the next 1,000 feet of shore is protected with a sloped block revetment. Above the revetment, the bluff has been re-graded to create a terraced path at the base of a stable, vegetated slope. Approximately 600 feet along the revetment the structure extends 30 to 40 feet lakeward to protect a small ramp for accessing the lake. To the east of the revetment approximately 600 feet of shore is covered in concrete rubble. Large concrete modules or slabs are also visible in the nearshore in this area.

A row of Campbell modules helps support a perched beach at Willowick Lakefront Park.

The shore to the east curves approximately 60 feet lakeward around a 250-foot wide headland near East 320th Street. The headland is created by a stacked block revetment at the west end and a concrete seawall along the east end. The concrete seawall extends approximately 250 feet to the east to create a shallow embayment. A small stream enters the lake near the center of approximately 200 feet of sand beach in the embayment. The beach is supported by a small steel sheet pile groin to the east. With the exception of approximately 50 feet of steel sheet pile bulkhead, the next 400 feet of shore to the east is primarily protected with concrete rubble placed along the toe of the bluff.

Between East 324th and East 325thstreets, approximately 150 feet of shore is protected with an armor stone revetment. The revetment design includes a splash apron of smaller stone at the crest to prevent damage to the bluff from wave run-up. The bluff above the revetment has been re-graded to a stable slope and vegetated. The next 1,500 feet to the east relies on concrete rubble placed along the face or at the toe of the bluff for shore protection. A few properties also have large concrete modules near the toe of the bluff or in the nearshore. Residential development in this area is set back at least 60 feet from the top of the bluff because Shoreham Drive previously extended between the residential development and the lake.

The next nearly 300 feet of shore to the east is protected with concrete Great Lakes Erosion Control (GLEC) modules. The bluff landward of the modules has been re-graded to a stable slope and is vegetated. The GLEC modules lead up to a large stacked concrete block seawall. The seawall is approximately 30 feet wide and extends along about 250 feet of shore. Additional concrete blocks have been stacked to terrace the bluff face. The shore to the east includes approximately 125 feet of narrow beach covered with concrete rubble, 50 feet of steel sheet pile bulkhead, 125 feet of armor stone revetment and 50 feet of beach. The beach has accumulated updrift of a row of approximately 250 feet of Campbell module placed approximately 30 feet lakeward of the toe of the bluff. The staggered row of Campbell module supports a small perched beach fronting a concrete headwall at the toe of the bluff. To the east, steel sheet pile jetties protect the storm sewer outfall at Quentin Road Park to the east.

East of Quentin Road, the next 650 feet of shore is primarily protected by concrete rubble or large concrete blocks placed at the toe of the bluff. A few properties also have concrete structures extending into the nearshore. The 40 to 50-foot bluffs in the area are generally vegetated, although a few properties have concrete rubble placed along the bluff face. A narrow transient beach often forms lakeward of the concrete rubble at the toe of the bluff east of Woodstock Road at the west end of the village of Lakeline.

The next 1,100 feet of shore is protected by alternating steel sheet pile bulkheads and stone or concrete module revetments. The first 300 feet is protected by a consistent steel sheet pile bulkhead. The bulkhead continues for an additional 100 feet to the east after an approximately 80-foot gap in the structure. The next 300 feet of shore to the east is protected with a revetment at the toe of a re-graded and vegetated bluff. An additional 175 feet of sheet pile bulkhead protects the shore just west of the sewer outfall at the end of Stevens Road. The sheet pile bulkhead continues an additional 100 feet east of the steel sheet pile jetties stabilizing the storm sewer outfall. A narrow beach occasionally accumulates lakeward of the bulkhead updrift of the storm sewer outfall at the end of Stevens Road.

East of Stevens Road, approximately 700 feet of shore is protected with one continuous revetment. The revetment is constructed with a combination of armor stone and concrete rubble. The bluff in this area is re-graded to a stable slope and vegetated. To the east a small pier and boat lift extend approximately 100 feet lakeward from the toe of the bluff. The next 1,000 feet of shore to the east is protected with variety of concrete structures. Most properties have concrete seawalls, Campbell module or GLEC modules placed near the toe of the bluff. Several properties also have concrete groins extending into the lake or concrete blocks placed in the nearshore, particularly in the western portion of this stretch. To the east the shore is primarily protected with Campbell module and concrete rubble placed near the toe of the bluff.

Near the intersection of Lake Shore Boulevard and East Shore Boulevard approximately 200 feet of shore is protected with three stacked concrete seawalls. Each seawall is about 50 feet long spaced with 25-foot gaps. A stacked concrete retaining wall is used to terrace an access path into the bluff face. East of the seawalls the toe of the bluff is covered with armor stone or concrete rubble for the next 600 feet of shore. Narrow beaches occasionally form lakeward of the shore protection at the toe of the bluff. This area is at the west end of the beach that has accumulated updrift of the Eastlake Power Plant.

The next 3,500 feet of shore to the east is sand beach accumulated updrift of the large shore-perpendicular structures at the Eastlake Power Plant. The beach spans the east end Lakeline Village and the entire Timberlake Village. At the west end of this area beach widths are typically narrow but beach width gradually increases to over 600 feet wide directly updrift

The shore-perpendicular structures at the Eastlake Power Plant have caused a wide beach to accrete along the updrift shore to the east of the revetment shown in the left photo. The shore-perpendicular water intake structures of the power plant are shown in both photos. The right photo is taken from the seawall looking west.

of the breakwaters at the power plant. A few properties in this area have constructed small seawalls near the toe of the bluff or groins on the beach or nearshore. However, most properties in the area rely on the beach for shore protection. Sand bars occasionally form within 500 feet of shore updrift of the power plant breakwaters.

The relief of the upland gradually decreases in the area of the Eastlake Power Plant which is approximately 2,400 feet west of the mouth of the Chagrin River. The water intake and outlet at the power plant are protected with breakwaters constructed with 25-foot diameter cylindrical steel sheet pile cells filled with stone and capped with concrete. The west breakwater extends approximately 1,000 feet to the northwest. In typical conditions the breakwater extends approximately 400 feet lakeward of the beach accumulated updrift of the structures. The second breakwater also extends 1,000 feet to the northwest then curves back around the first breakwater at a 375-foot diameter. The third breakwater extends approximately 475 feet north from the base of the second breakwater before bending about 250 feet to the northeast, parallel to shore. A small beach has accumulated at the angle between the intake and outlet breakwaters.

The shore between the Eastlake Power Plant and Chagrin River is protected by a steel sheet pile bulkhead (bottom) which wraps around an "L" shaped turn to an armor stone revetment farther east (top). Approximately 500 feet of the bulkhead is accessible to the public.

East of the breakwaters, the next 1,575 feet of shore is protected with a steel sheet pile bulkhead. The bulkhead extends to the north approximately 350 feet then to the northeast 175 feet to parallel the easternmost breakwater. To the east, the bulkhead steps about 250 feet back to shore for approximately 700 feet along the Eastlake Seawall public access. The bulkhead extends an additional 100 feet landward adjacent to an armor stone revetment that spans approximately 750 feet to the east. At the east end of the reach the jetties at the mouth of the Chagrin River extend approximately 200 feet to the northwest. The west jetty is constructed with steel sheet pile and armor stone. The western jetty supports about 150 feet of sand beach leading up to the mouth of the river.

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 average recession rates less than 3 feet per year over most of the reach. 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 most of this reach experienced average recession rates less than 2.2 feet per year. Recession was greatest in the former location of Shoreham Drive between East 325th Street and East 332nd Street. Average recession rates also reached 1.6 feet per year near the end of Woodstock Road and 1.5 feet per year near the end of East 324th Street. Average recession rates greater than 1 foot per year also occurred near the east end of Lakeline Village. Overall, recession was typically greatest in areas without shore structures and areas relying on concrete rubble for shore protection.

From 1990 to 2004 average recession rates ranged from 0 feet per year to 2.5 feet per year but most of the reach experienced little to no recession. Recession was greatest in the unarmored area where a small stream enters the lake near the end of East 322nd Street. Average recession rates also reached 1.5 feet per year between East 332nd Street and Waverly Road and in a small stretch along Lake Shore Boulevard near the east end of Lakeline Village. Average recession rates were otherwise less than 1 foot per year throughout the reach. In general, larger recession rates were measured in areas without shore structures or areas relying on concrete rubble for shore protection.

At the east end of the reach, where the floodplain of the Chagrin River meets the shore, properties may also be subject to flood damage from the Chagrin River, as well as flood and erosion damage from Lake Erie.

Beaches/Sand Supply

There is sand available in the littoral system throughout the reach from East 305th Street to the Chagrin River. A three to six-foot layer of sand covers the nearshore zone along most of the reach. In 1876 a narrow beach fronted the entire reach. 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 shore has prevented sand from entering the littoral system from eroding bluffs, resulting in an overall reduction of beach material.

The breakwaters at the Eastlake Power Plant were constructed in the early 1950s and have gradually accreted a beach extending about 3,500 feet to the southwest. By impeding the flow of littoral material along the shore, the breakwaters have significantly decreased sand resources at the east end of this reach and the western portions of Reach BG05. By 1973 beaches fronted about 70 percent of the reach. Along most of the reach, beaches were supported by small groins, many of which are still visible in the nearshore.

Today, sand resources generally increase from west to east as sand has accumulated updrift of the breakwaters at the Eastlake Power Plant. In the western portions of the reach beaches are primarily present updrift of shore perpendicular structures or in shallow embayments between structures. Narrow beaches are also present at the toe of the bluff along most of the reach but are often covered with concrete rubble.

Use of Shore Structures

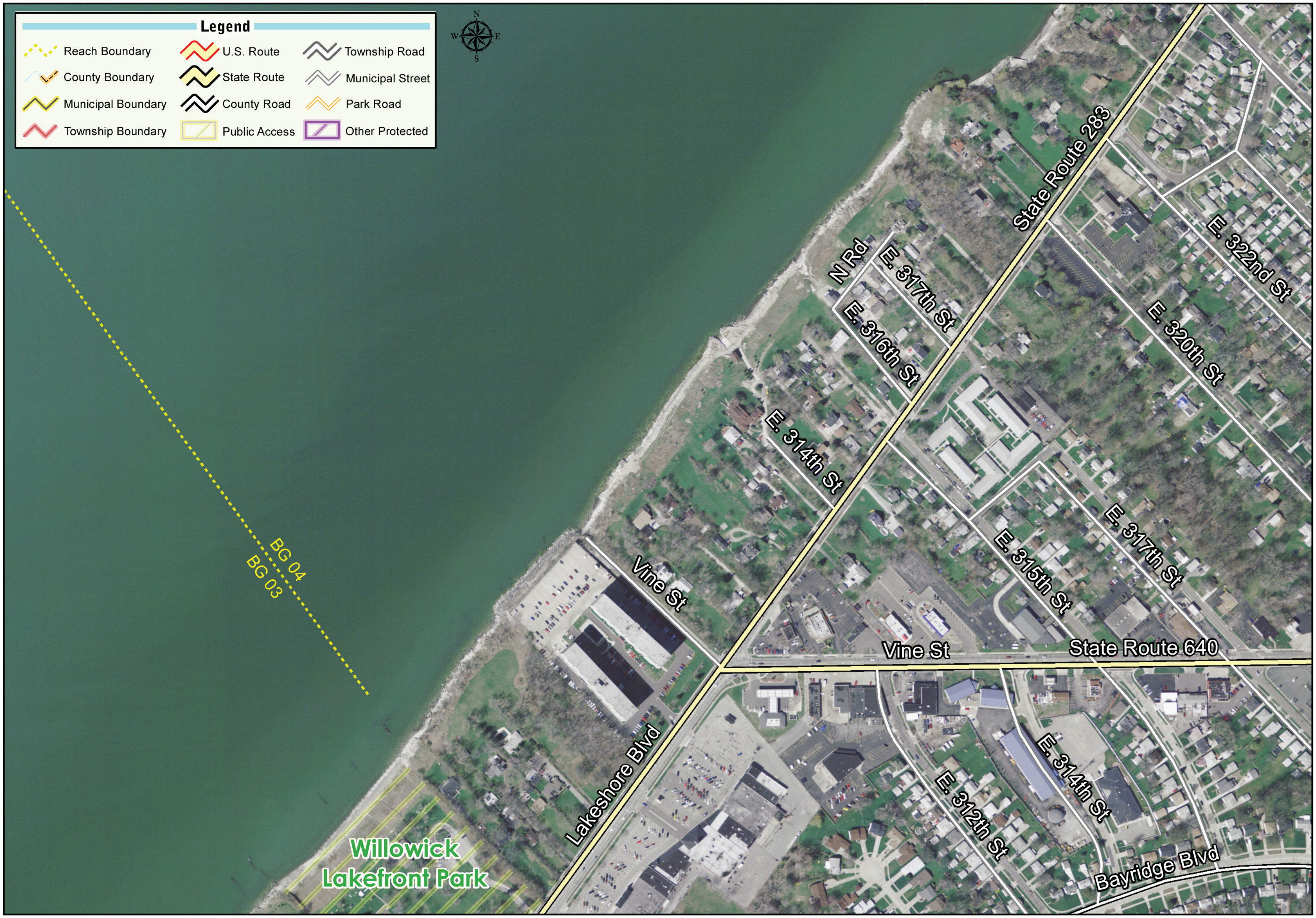
The most significant shore structures in this reach are the breakwaters at the Eastlake Power Plant. The breakwaters have caused a beach to accumulate for approximately 3,500 feet updrift of the structures.

Much of the shore of the shore from East 305th Street to the Chagrin River is protected by some form of shore structure. West of the Eastlake Power Plant the shore in this reach is primarily individual residential properties with each property owner responsible for their own shore protection. This has lead to a wide variety of shore structures ranging from well-constructed seawalls and revetments to less effective measures such as dumped concrete rubble along the shore.

Although ineffective as shore protection, the most common structure in this reach is concrete rubble placed along the bluff face or at the toe of the bluff. Concrete rubble is primarily relied on for shore protection from around East 325th Street to East 330th Street and is found on most properties throughout the reach. In many cases the concrete rubble has also been displaced by wave action and is dispersed throughout the nearshore. The placement of pre-cast concrete modules at the toe of the bluff or in the nearshore is also common.

Summary

The reach from East 305th Street to the mouth of the Chagrin River consists of residential development with the exception of the Eastlake Power Plant near the east end of the reach. Although bluff height decreases near the mouth of the Chagrin River, most of the reach is fronted by 30 to 50-foot bluffs. Sand resources generally increase from west to east in this reach and as sand accumulates updrift of the breakwaters at the power plant. A wide beach, extending nearly 3,500 feet to the southwest, has accumulated updrift of the water intake breakwaters at the power plant. To the west, much of the shore is armored with some form of protective structure. Although ineffective as shore protection, concrete rubble is commonly found along the shore of this reach. In some areas more effective structures such as revetments and seawalls are also present. Narrow beaches are present updrift of the small shore-perpendicular structures or in shallow embayments throughout the reach. In many areas the beaches have been covered with concrete rubble. 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.



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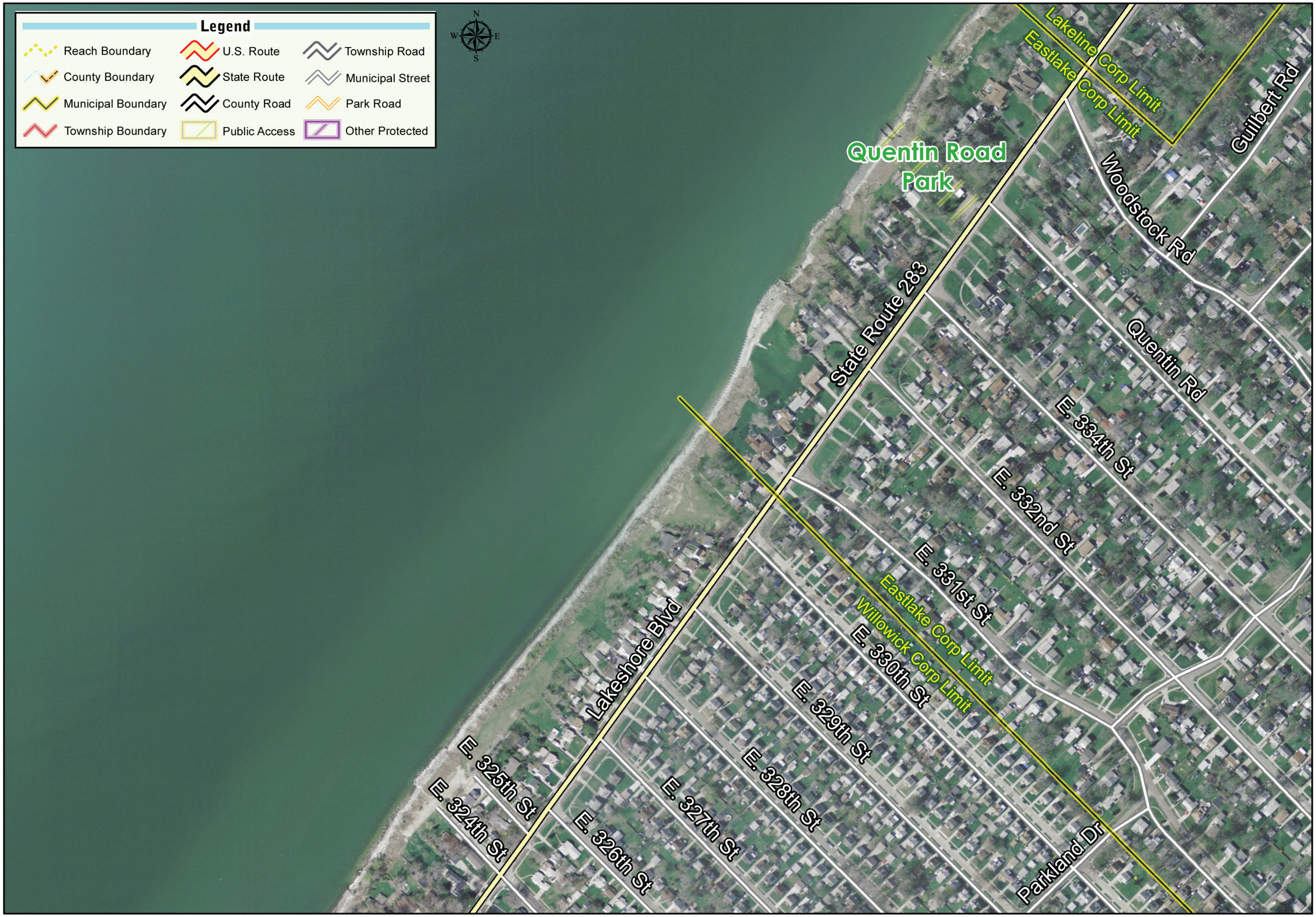
Ohio Department of Natural Resources
Office of Coastal Management
105 West Shoreline Dr, Sandusky, OH 44870



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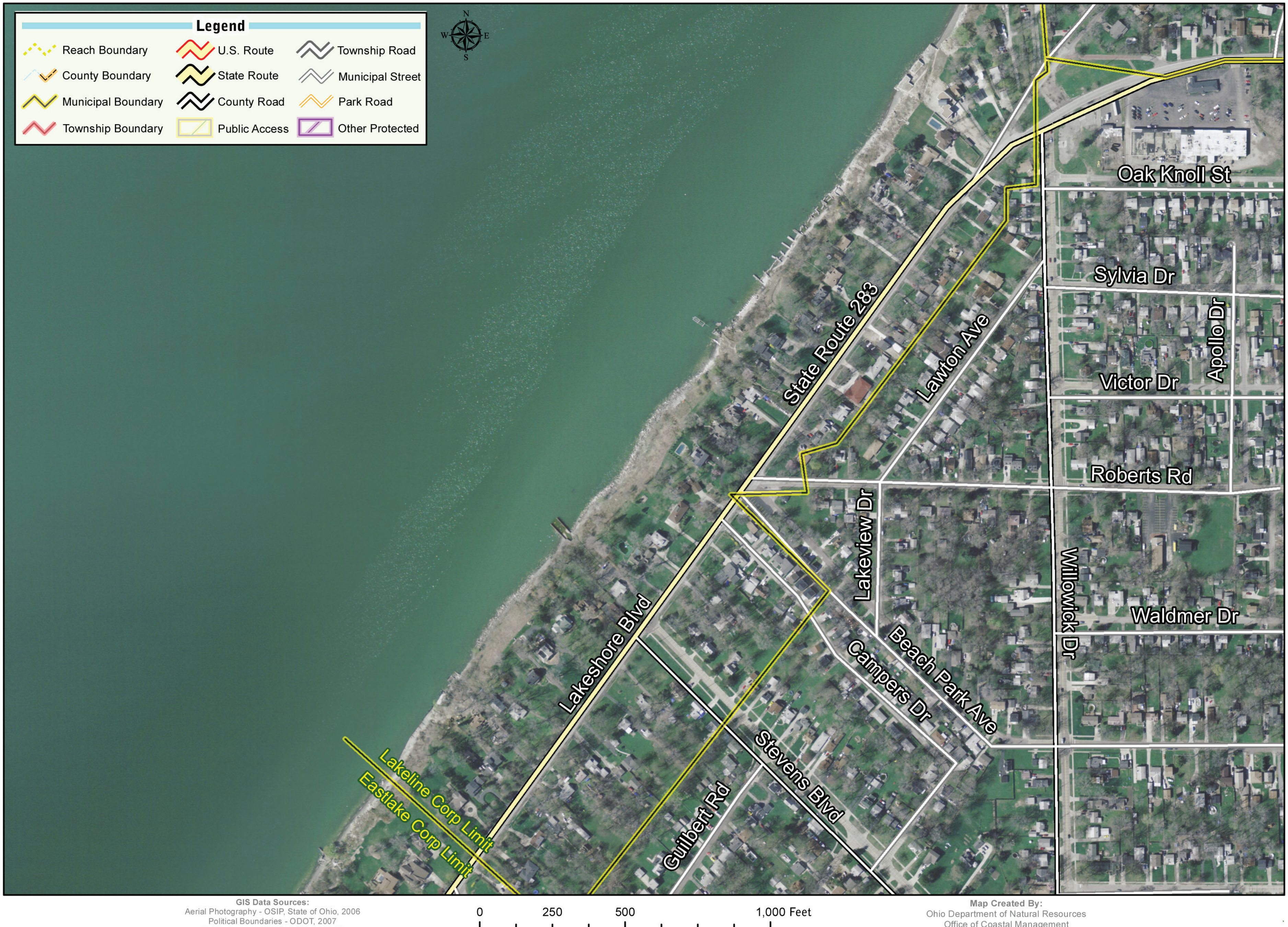

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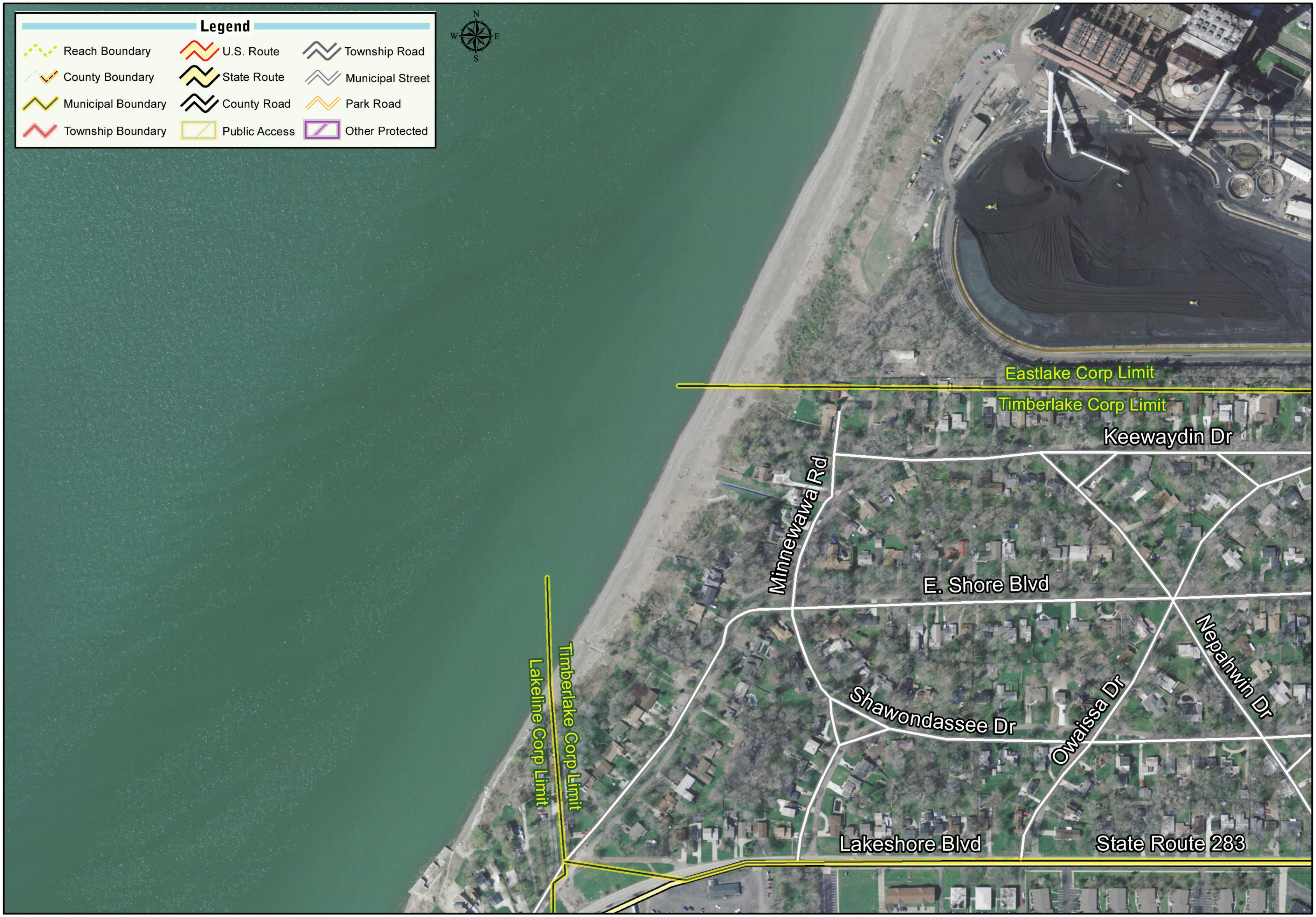

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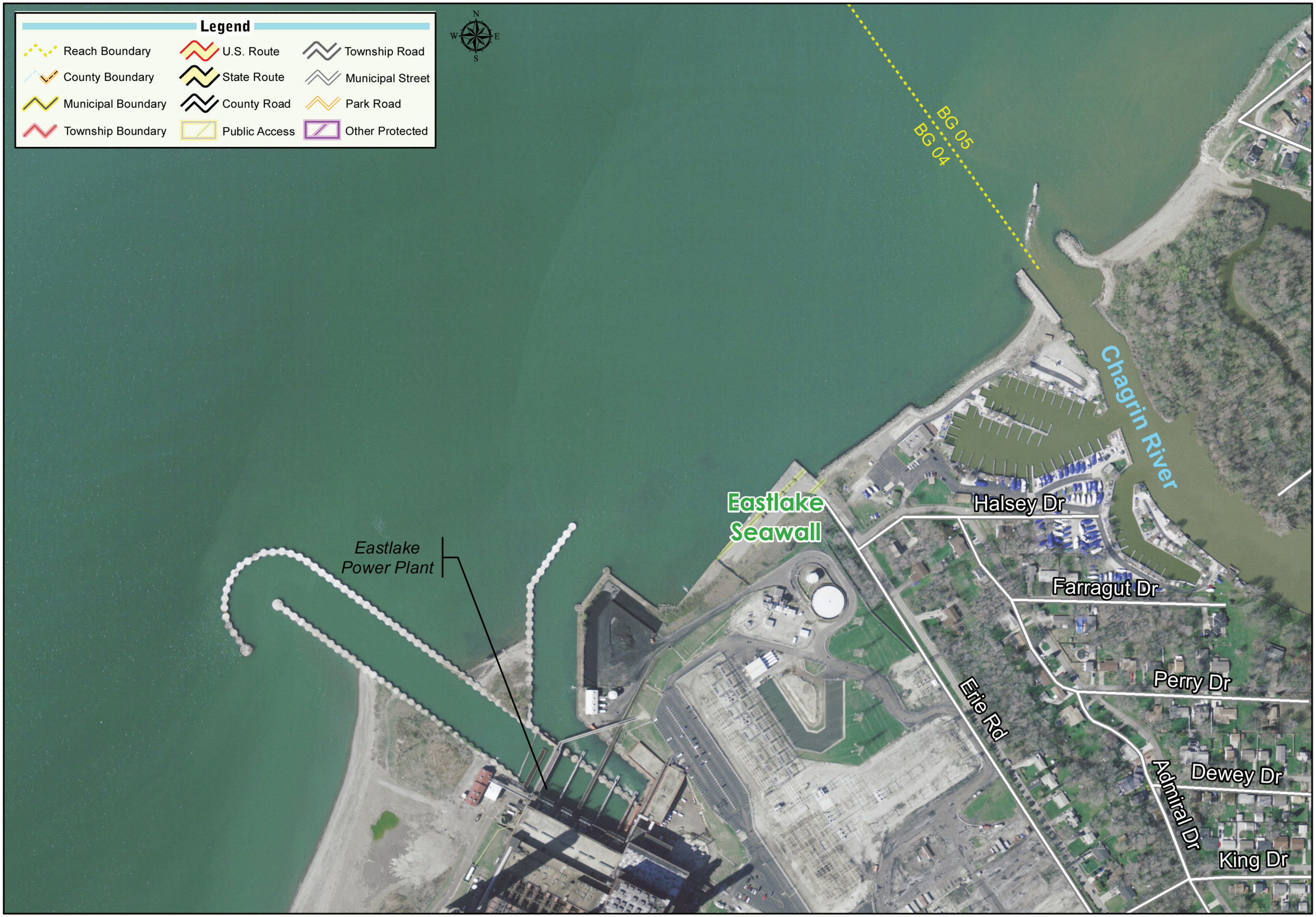

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Recommendations

The recommendations included 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 reach between East 305th Street and the Chagrin River. 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 on Erosion Control Methods.

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. Much of the area from East 305th Street to the Chagrin River is already protected with existing shore 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 should be considered on the unarmored beaches updrift of the Eastlake Power Plant.

A reduction of sand resources in the area could cause an increase in water depths and a corresponding increase in wave energy reaching the shore.

Sand Management:

1. Conserve Sand Resources: 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.

While there is sand available in the littoral system, this recommendation should be considered throughout this reach. Several properties updrift of the Eastlake Power Plant rely on the beaches for shore protection. A decrease in sand resources would leave these properties vulnerable to excessive erosion, particularly as the beach narrows at the west end.

Narrow, transient beaches often form lakeward of shore structures placed at the toe of the bluff throughout the reach. 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.

2. Beach Nourishment: 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 west end of this reach is often fronted by narrow beaches that would benefit from nourishment. The addition of beach nourishment would be especially beneficial if added to sites with existing structures to stabilize the sand or as part of new construction of detached breakwaters.

Beach nourishment could also be used at the west end of East Shore Boulevard to supplement the beach updrift of the Eastlake Power Plant. This would be most beneficial as part of a larger project including shore structures to support a beach in this area. Beach nourishment could be used to extend the beach farther to the west.

3. Vegetation: 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 most applicable on wide beaches updrift of the Eastlake Power Plant but may also be beneficial at the small beach updrift of the Chagrin River jetties or on the perched beach at Willowick Lakefront Park. Native beach vegetation 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. Native varieties of American beach grass, little bluestem, sand dropseed or beach pea are well suited for beach vegetation in this area.

***4. Sand Bypassing**: 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 around the breakwaters at the Eastlake Power Plant. The shore-perpendicular breakwaters protecting the water intake at the power plant have impeded the flow of littoral material, trapping sand on up-drift beaches and preventing material from reaching the shore downdrift. Bypassing future accretion would reduce erosion downdrift.

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.

***5. 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 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 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. In order to nourish downdrift beaches, sand must be placed in water shallow enough to be influenced by littoral currents.*

If maintenance dredging is required at the mouth of the Chagrin River or near the power plant intake or outlet, the nearshore placement of dredge materials should be considered. If the dredge materials are suitable for the nearshore environment, nearshore placement would be beneficial to nourish the narrow beach just east of the Chagrin River jetties in Reach BG05.

Toe Protection:

***6. 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.*

Where constructed, revetments 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 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 concrete rubble can be used in the base layers of a revetment if covered by suitably sized armor stone.

7. <u>Detached Breakwaters</u>: 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. 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 (pre-fill) and periodic re-nourishment will often be advantageous to creating and retaining the beach landward of the breakwater while limiting impacts to neighboring shorelines. Some regulatory agencies may require pre-fill and periodic nourishment as one of the design components for a project that includes detached breakwaters.

Detached breakwaters could be used to extend the beach updrift of the breakwaters at the Eastlake Power Plant farther to the west. The area near the intersection of East Shore Boulevard and Lake Shore Boulevard has a shallow nearshore and sufficient sand resources to support a beach.

Detached breakwaters are most effective when constructed over a long stretch of shore. To be effective in this area, a project containing breakwaters may need to span the shore of several upland properties. Sand pre-fill and provisions for sand by-pass as well as potential beach re-nourishment 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.

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 is a significant hazard along the shoreline.

Bluff/Bank Modifications:

8. <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 of the 30 to 50-foot high bluffs is common throughout the reach from East 305th Street to the Chagrin River. The upper portion of the bluff in this reach is 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. Upland structures are set back from the bluff along much of this reach, particularly the area between East 325th Street and East 330th Street, formerly occupied by Shoreham Drive. Re-grading would be ideal for this area if slumping or erosion of the upper portion of the bluff is noticed. 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.

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.

9. <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 East 305th Street to Chagrin River 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.

10. <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. A thin layer of laminated clay is present near the base of the bluff and at the top of the bluff along most of the reach. 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.

11. <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 East 305th Street to the mouth of the Chagrin River. 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

The addition of a drainage system can help reduce erosion due to surface and ground water. Collected water should be drained as close to the toe of the bluff as possible (top). 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 (bottom).

vegetation also helps hold soil in place to prevent erosion from runoff and can protect the bluff face from weathering.

The till and clay 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:

12. Bank-Top Management: Keep heavy materials, equipment and 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 50-foot bluffs 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.

13. <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 throughout the reach from East 305th Street to the Chagrin River 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 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.

14. <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 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, 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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Issue date: 06222012