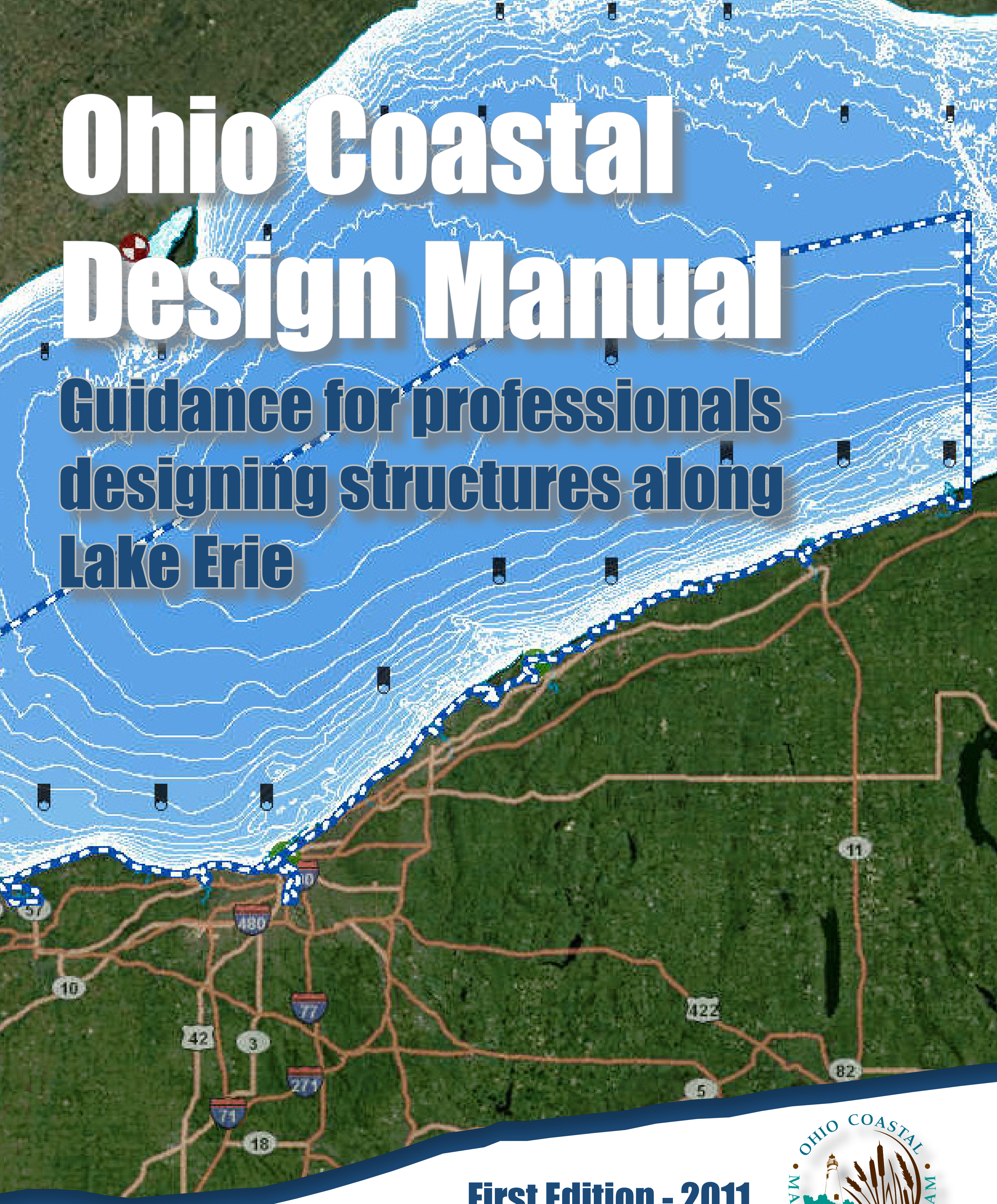
Ohio Coastal Design Manual

Guidance for professionals designing structures along Lake Erie



First Edition - 2011

Ohio Coastal Management Program

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About us:

To help balance the uses of Lake Erie's resources with sustaining a healthy environment, the Office of Coastal Management (OCM) administers the federally approved Ohio Coastal Management Program. OCM's responsibilities include education, outreach, resources management, grants administration and regulatory oversight in areas of the Ohio Coastal Management Program. These responsibilities are codified in Ohio Revised Code §1506 and Ohio Administrative Code §1501-6.

The Ohio Coastal Management Program Document and the OCM annual review can be downloaded from the Office of Coastal Management website.

Learn more:

www.ohiodnr.com/coastal

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Coastal Design Manual Online:
www.ohiodnr.com/tabid/23074/default.aspx

Ohio Department of Natural Resources
Office of Coastal Management
105 West Shoreline Drive
Sandusky, OH 44870
419.626.7980
coastal@dnr.state.oh.us

Mission: Achieve a balance between use and preservation of Lake Erie's coastal resources, in collaboration with our partners, by effectively administering the Ohio Coastal Management Program.

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Ohio Coastal Design Manual Introduction

Our Goal:

Promote better projects along the coast that balance the use of Lake Erie as a shared natural resource along with property owners' need for lakefront erosion protection and the benefit of access to the lake.

Introduction

The Ohio Department of Natural Resources (ODNR) Office of Coastal Management (OCM) has prepared this design manual to promote better projects along the Ohio shore of Lake Erie including Maumee Bay and Sandusky Bay. This manual demonstrates how structures along the shore of Lake Erie are designed and how coastal engineering principles are best applied to achieve a balance between landowners' needs for erosion control and lake access and the need to protect our lake's natural resources.

The focus of the manual is the types of structures most commonly constructed in Ohio; therefore the guidance only applies to Ohio's unique coastal environment. The companion to this design manual is the Lake Erie Shore Erosion Management Plan (LESEMP) which addresses how the conditions along Lake Erie vary, and which types of erosion control are best suited for specific locations and conditions along the lake. The LESEMP is available online at: *www.ohiodnr.com/tabid/20501/default.aspx*. The connection is the LESEMP identifies the types of structures or controls that would function best along a section of the shore and this design manual shows how those structures should be designed and constructed.

The purpose of this manual is to illustrate the engineering and surveying processes needed to develop safe, sound and successful erosion control and lake access projects along Ohio's Lake Erie shore. Engineers, surveyors and contractors should find the manual a valuable resource for planning projects and working with landowners. For the lakefront property owner, this manual can be a means of better understanding the design, surveying and construction processes.

The policies and guidelines included in the Ohio Coastal Management Program Document and the Ohio Revised and Administrative codes pertaining to design of coastal structures, along with the application and guidance on the application process for shore structure permits and submerged lands leases, are all available on the Office Coastal Management website: *www.ohiodnr.com/coastal*. The importance of meeting these requirements as well as those of all federal, state and local agencies involved in authorizing projects on Lake Erie cannot be overstated.

Why an engineer and surveyor should be part of the design process

Since 1994, plans and specifications submitted to the ODNR for Shore Structure Permits must be prepared and sealed by a professional engineer licensed by the state of Ohio (Ohio Revised Code Section 1506.40). Documents (metes and bounds descriptions and plats) required to enter into a Submerged Lands Lease with the state of Ohio must be prepared and sealed by a professional surveyor licensed by the state of Ohio.

Professional engineers (PE) and professional surveyors (PS) are licensed by the state of Ohio only after demonstrating technical knowledge and actual engineering/surveying experience. The act of signing and sealing a design drawing by an engineer or surveyor is a statement certifying that the work has been prepared with direct supervisory control and according to the best professional standards. It is an assurance to both the property owner and to the agency that receives the drawings that the work has adhered to appropriate design standards, is protective of the public welfare, and safeguards life, health and property.

Many property owners are familiar with building houses and other structures on land, where contractors "pull" permits from the local building authority without the need for sealed plans from a professional engineer. This process is supported by a system of very protective and conservative building codes and inspections that ensure buildings are both well designed and constructed with appropriate setbacks from property boundaries. No similar system of codes and inspections exists for structures built along the shore of Lake Erie.

The design of coastal structures is not always as straight-forward as complying with plumbing or electrical codes. Many sites have complex geology, drainage issues, structural conditions, and/or wave climates that require careful consideration, planning and design. Failure of an erosion control structure, even over a period of years, may result in loss of additional upland, may threaten existing buildings, and can result in damage to adjacent properties. The repair of a failed structure may be as expensive as the original construction.

The planning of a project also requires a field survey. The surveyor is best suited to provide the critical site information needed by the PE for design. This includes existing site contours, the location, dimensions and elevations of structures, and the offshore bathymetry. A surveyor is needed to determine the boundary of the upland parcel and the partition lines for littoral rights extending into the lake. If a submerged lands lease is needed, a PS prepares a metes and bounds description and plat. These products can only be prepared by an Ohio registered professional surveyor.

References, resources and other design manuals

In most cases, important references are noted as part of the discussion in a given Chapter. Design equations, charts and tables included in this manual have been drawn from numerous sources and reflect OCM's understanding of the state of the art of coastal engineering as it applies to structures along Lake Erie.

The "Reference of References" for coastal engineering is the US Army Corps of Engineers' (USACE) "Coastal Engineering Manual" or CEM (EM 1110-2-1100, published August 2008, available as multiple "pdf" files from the USACE website). The CEM is a valuable synthesis and repository of the understanding of coastal processes, the design and performance of structures and forms the basis of design for USACE's coastal projects.

Engineering Resources

- Phase I Revised Report on Great Lakes Open Coast Flood Levels USACE, Detroit, April 1988.
- Design Water Level Determination on the Great Lakes, USACE, Detroit District September 1993.
- ODNR Division of Geological Survey Coastal Erosion Area maps and tabulated datasheets for recession rates.
- USACE "WIS Report 22, Hindcast Wave Information for the Great Lakes: Lake Erie," October 1991.
- USACE, EM 1110-2-1614 "Design of Coastal Revetments, Seawalls and Bulkheads" June 1995.
- Pennsylvania Coastal Zone Management Program, "Vegetative Best Management Practices – A Manual for Pennsylvania /Lake Erie Bluff Landowners" 2007.
- Coastal Engineering Design & Analysis System, ACES (Automated Coastal Engineering System) module. This is a computer-based calculation tool that includes many of the most commonly used equations for performing coastal engineering calculations. Developed by USACE and now marketed through a private vendor.
- On-line maps and aerial photography. Resources such as Google Earth, Bing Map and the GIS products available from most county auditors are useful tools for visualizing existing conditions along the shore and evaluating potential effects of projects.

There are two preceding engineering design manuals that deserve note and are inspirations for this document.

"Coastal Processes Manual," University of Wisconsin Sea Grant Institute, WIS-SG-87-430, Second Edition, 1998.

"Help Yourself" a general information pamphlet by the USACE (1978), now out of print.

Surveying Resources

- Manual of Instruction for the Survey of Public Lands of the United States, Bureau of Land Management, 2009.
- Brown's "Boundary Control and Legal Principles."
- Simpson's "River & Lake Boundaries."
- Wattles' "Writing Legal Descriptions."

For definitions of terminology used in the surveying profession, see the American Congress of Surveying and Mapping's (ACSM) "Definitions of Surveying and Associated Terms."

The limited design discussions presented in this manual should in no way suggest that more detailed engineering analysis of a structure's expected performance is not desired or of great value. In many cases larger or more complex projects, such as those proposed for commercial facilities, by municipalities, or the USACE may require evaluations using computer and/or physical models.

Organization of the Ohio Coastal Design Manual

Chapters 1 and 2 describe the information needed to support the design process including the requirements for site surveying. Chapter 3 presents the elements of coastal engineering design common to nearly all projects. Chapter 4 presents the design processes for typical erosion control structures and includes detailed design examples. OCM expects future chapters in later editions of the manual to present design processes and examples for groins, detached breakwaters, piers and access structures.

- Site Information (Chapter 1)
- Site Surveying Principles (Chapter 2)
- Design Fundamentals (Chapter 3)
- Erosion Control Structures (Chapter 4)

Coastal Design Manual Online

www.ohiodnr.com/tabid/23074/default.aspx

The Office of Coastal Management is part of the Ohio Coastal Training Program which conducts research, provides education programs and delivers science-based training to professionals throughout the Lake Erie watershed. This picture was taken at a training for coastal design professionals.

Chapter 1. Site Information

This chapter describes the types of site-specific information that are usually needed by the engineer or surveyor in the development of a successful design for a project along the Lake Erie shore. Most of the information described here would be incorporated into design drawings and submittals to the regulatory agencies that issue authorizations. Most of the information is readily available from county recorder's and auditor's offices, on-line sources, site inspections, the property owner and, in some cases, the ODNR Office of Coastal Management (OCM). The following sections note why each type of information is important to the planning and design of a project and highlights conditions at a site that may impact the success of a design.

General vicinity map

A map showing the general location of the project is needed by the regulatory agencies and the public so that the project can be easily located. It also provides a larger frame of reference for the project and is used as a means of identifying nearby areas that may impact or be impacted by the project. Maps from on-line resources or maps from county auditor web sites are usually sufficient. It has also been common to use copies of a United States Geological Survey 7.5-minute topographical map, also known as a "quad" map.

Identification of adjoining and nearby property owners

The agencies that authorize projects along Ohio's Lake Erie coast are required to notify the property owners adjacent to the proposed work, and to request comments on the project. The names and addresses (both property and mailing) of all owners of properties that abut, adjoin or are adjacent to the project property along the lake shore must be identified.

Each county auditor maintains this information and it is available through their web sites. In some cases, there may be multiple owners, or ownership associations that hold adjacent property. Subdivision plats, parcel deeds and association agreements should also be obtained and reviewed to identify the names and addresses of those with an interest in the property. All persons with an ownership or non-possessing interest, (such as an easement or a reservation of rights of way) in an adjacent property must be identified so that regulatory agencies can provide notice of the project.

Information

History of the site

Historical information allows the designer or the surveyor to visualize how and why the shore at the project site has changed over time. Aerial and site photos from past years as well as recent photos may be available from sources such as online mapping services, county auditors and the OCM. A property owner may also have photos and information about when human-made site features were constructed.

Regulatory agencies may have information related to project sites that have previously applied for or obtained authorizations. Site information that may be available includes authorization application forms, existing and proposed plans and section drawings, design assumptions and calculations, subdivision plats, parcel deeds, metes and bounds descriptions, submerged lands lease agreements and authorized permits. In some cases design information from adjacent properties may be available and may contain appropriate information for developing plans for a proposed project.

Site conditions and existing structures

The engineer should coordinate with a surveyor to conduct a field survey of the project area. All existing structures along the shore should be properly defined in location, elevation and dimension including retaining walls, decks and other upland structures at least up to the elevation where no erosion is present or anticipated. Survey the features that may affect design choices. Particular attention should be paid to rubble material located offshore and to adjacent structures. These may influence the wave climate and movement of littoral material, or interfere with watercraft access at the project site.

Development of a field survey by a PS is further discussed in Chapter 2.

A site plan, field notes and photographs documenting the current condition and composition of site features will aid development of the engineering design and drawings, as well as facilitate the permitting process.

Aerial photographs such as this one from 1957, are helpful in determining a site's history including when human-made structures were built.

The OCM maintains a database of historic photos.

The Coastal Erosion Area designation and erosion at the site

The ODNR Division of Geological Survey delineates the boundary of Ohio's Coastal Erosion Area (CEA). The mapping program produces maps and tabulated datasets for Ohio's entire Lake Erie shore. For these maps, erosion is measured at transects located approximately every 100 feet and a CEA boundary line is determined. The CEA boundary line represents the estimated location of the edge of the bluff or recession feature after 30 years. The maps and datasets, available from OCM upon request, are useful in establishing the historical rate of erosion at a project site and offer some indication of a site's history.

The original CEA mapping, completed in 1998, was based on changes from 1973 to 1990 as determined from aerial photography. The CEA designation is periodically updated with the most recent designation released in 2010. This delineation was based on the changes from 1990 to 2004. Additional information about the CEA is available online:
www.ohiodnr.com/CEAm (maps)
www.ohiodnr.com/tabid/9290/default.aspx

Geology of the upland

Identifying the specific geology at a project site is critical. The type of materials present at the bluff face and beneath the surface is the single most important upland site condition. In general, most of the bluffs along the shore are comprised of bedrock overlain by one or more layers of a glacial till or glacial lake deposit, over which is usually a fill or top soil. In some areas the bedrock is exposed above lake level, as is the case along much of Cuyahoga County into eastern Lorain County where shale bluffs dominate. In other areas, the bedrock is below lake level, and the exposed bluffs are comprised of glacial tills and lake deposits.

The bedrock from Erie County east to Ashtabula County is shale, which is exposed along the shore of many reaches, most notably west of downtown Cleveland. The bedrock west of Sandusky is limestone, most visible along the west side of Catawba and the Erie Islands. West of Catawba, the shore is low-lying and composed mostly of recent sediment, sand and fill.

The glacial tills and lake deposits that overlay the bedrock are highly variable both in profile at a site and within short distances (even within 100 feet) along reaches of the shore. Glacial tills can range from very dense and nearly impermeable (the typical grey tills usually above the bedrock) to lighter clay-silt material with pockets of gravel. Lake deposit materials are also highly variable, ranging from clay-silts to very permeable sandy clays, the latter of which is a common upper stratum in much of Ashtabula County.

There are stretches (or reaches) along the shore that may appear to have consistent bedrock and overlying tills that can also include buried river beds or former stream channels. In these locations the bedrock, even offshore, may have eroded to elevations much deeper than the nearby area. These areas generally have less steep slopes along the lake and may contain existing streams and outlets to the lake.

The type of materials present at the bluff face and beneath the surface is the single most important upland site condition.

The elevations of geologic strata boundaries should be identified. This is important if groundwater seeps are present along the bluff or if geotechnical engineering analysis is required to design a foundation or slope stabilization structure. The geological materials (or fill) should be defined so that they can be shown on a cross-sectional view of the existing bluff or slope with the associated elevations of each stratum.

There can be a number of distinct layers within each shale, limestone or glacial till unit along the shore with different physical and engineering properties.

The engineer should evaluate whether the different properties within a bedrock or till have an impact on the design.

Examples of the importance of identifying and evaluating differences in the upland geology include:

- Sites with sandy, porous soils lying over dense glacial till are especially subject to upland slope failures caused by groundwater seepage weakening the resistance to slipping at the boundary between the two strata. Sites with this condition are found in Ashtabula County and parts of Lake County.
- Sites without exposed bedrock that have glacial till bluffs to the lake water level can experience high rates of wave-based erosion of the toe of the bluff. Following loss of a portion of the toe, the upland will be subject to slumping failures. This condition occurs in parts of Erie, Lorain and Lake counties and much of Ashtabula County.
- Sites with bedrock at the bluff face and above the elevation of the shore generally are less susceptible to wave-based erosion. This occurs in Cuyahoga and eastern Lorain County and the Lake Erie Islands area.

Identification of the geology and the engineering properties of the geologic strata present at the site are also critical in evaluating foundation loads, slope stability and the calculation of lateral earth pressures for any proposed structure near or on a bluff or bank.

Site drainage

The lake would seem a natural sink for the storm water collected from roofs and paved areas. Nearly all lakefront property slopes toward the lake due to thousands of years of erosion.

In many of the geological settings along the lake, surface drainage and subsurface groundwater flow are the dominant forces influencing erosion of the upland. Existing surface drainage features that may need to be modified or re-routed as part of a shore structure project should be included in the design plan.

During site inspections, any visible indications of surface water run-off or groundwater problems should be located and described. Surface water run-off and groundwater seepage can cause erosion of the fill or existing bluff/bank material behind an erosion control structure which creates voids that may result in partial collapse of a section of the structure. Site conditions that indicate potential surface water or groundwater problems include:

- Gullies running down the bluff slope sides.
- Evidence of slumps along the bluff face.
- Ponded surface water on the flat upland.
- Areas of subsidence.
- Seeps along the bluff.
- Drain pipes extending over the bluff edge.
- Algae or wetlands vegetation along the bluff slope above the elevation of wave action.
- Channeling under soils, vegetation or fill material on the slope.

Characteristics of the shore

In order to understand how a project may impact adjoining and nearby properties, the characteristics of the shore along the area of the project site should be documented. Many features can be identified during site investigations including:

- The approximate width of the beach area.
- Approximate slope or profile of the beach and presence of terraced areas or wind-borne sand.
- Structures within the beach (pre-cast concrete modules, rubble, etc.).
- The size of the beach materials (sand, gravel, cobbles).
- The shape of the beach.
- Length of the beach overall as it extends over adjacent properties.

Taking samples of the existing beach material during site investigations to be used for particle size analysis is strongly recommended.

The above information will represent the shore characteristics only at a single point in time. In many cases the property owner will have good anecdotal evidence and photographs of how the shore has changed over seasons and years.

Historical aerial photography can also be used to gain an understanding of how and why the shore has changed over time. When interpreting multiple aerial photos of a site, the designer needs to consider the differences in the lake's water level elevation from one photo to another. NOAAs Tides and Currents website at *www.tidesandcurrents.noaa.gov/station_retrieve* provides historical water level elevation data for a number of locations on Lake Erie.

Types of coastal habitats

Structures placed along the shore have impacts on the habitat available for flora and fauna. There are three general habitats present: nearshore, beach and upland.

Nearshore Habitat

The nearshore habitat extends from where the water meets the land (the swash zone) lakeward until the water is deep enough to be less affected by wave action. On Lake Erie, this would nominally be deeper than 20 feet. The nearshore area along the entire Ohio Lake Erie shore is vital to a healthy sport and commercial fishery, providing spawning, nursery and feeding areas for forage fish as well as for steelhead, bass, perch and walleye. The nearshore area is generally more productive than deeper areas of the lake, supporting significant populations of both phytoplankton and zooplankton which form the base of the lake's food web. The nearshore habitat is differentiated by the type of material present along the bottom (the substrate). Rocky nearshore areas are favored by different species of fish and invertebrates than muddy or sandy areas. Nearshore habitats that support submerged aquatic vegetation (eel grass, for example) are rare in areas with deeper water or that are subject to significant wave action.

The coastal habitat at Cullen Park (Lucas County) includes shallow nearshore waters, a diverse beach ranging from sand to cobble and an upland of mixed low wetlands and forest.

Beach Habitat

The beach habitat is landward of the water and is comprised mostly of material that is transported onto and off of the beach by wave action or wind. The lake's beach habitats support distinct plant populations, some of which are rare. The beach also serves as a nexus where the food material generated by the lake can be accessed by birds and other land-based fauna. The beach habitat is highly valued and frequently visited by people.

Upland Habitat

The upland habitat varies considerably along the Lake Erie shore from high bluffs to low wetlands all of which are distinct in their characteristics and the diversity of life they support. Although the Lake Erie shore is highly developed, even thin margins of bluff between the beach and the more level upper land can support diverse populations of plants and animals. Vegetation along bluffs, especially native trees and shrubs, provides critical habitat and food for resident and migratory birds.

Habitat considerations

The effects of losing portions of one or more of the coastal habitats from one project at one property are apparently small, but the cumulative effect of structures along 80 percent of Ohio's Lake Erie coast have been significant, though not yet fully appreciated or documented.

Coastal habitat-related issues that may have a direct impact on the design and construction of shore structures include:

- A prohibition on in-water construction at all locations, typically from April 15 thru June 30 to allow undisturbed fish spawning along the nearshore.
- All construction along or near the shores of Ohio's Lake Erie Islands must be conducted after the hibernation period of the Lake Erie Water Snake has ended in the spring and before it begins in the fall. Work must be monitored and performed according to plans developed by the U.S. Fish & Wildlife Service.
- Projects adjacent to bald eagle nesting sites may have time periods during the hatching and fledging season when no construction can be performed.

Information about habitats and known locations of rare, threatened or endangered species is available from a number of sources including the online Ohio Biodiversity Database (formerly known as the Natural Heritage Database) maintained by the ODNR at *www.ohiodnr.com/tabid/2010/Default.aspx*. An endangered species review is performed by ODNR and the U.S. Fish and Wildlife Service as part of all Lake Erie projects that require authorizations from the U.S. Army Corps of Engineers and Ohio EPA.

Sites that have existing and stable beaches and diverse, well-vegetated, stable bluffs that support both nearshore fauna and coastal flora are among the most fortunate of all. To minimize impacts to coastal habitats, a "low-impact" design that leaves most of the existing beach and slope intact and still reduces long term erosion and provides access is an appropriate design choice.

Other site habitat information that might impact the design of a project can often be identified by the engineer or property owner during a site visit.

Nearshore bathymetry

Nearshore lake bottom elevations should be field-surveyed for all projects. The nearshore bathymetry (the measurement of water depths) is required to:

- Calculate the slope of the near-shore area.
- Establish the design depth of water at the proposed structures.
- Evaluate the wave climate (wave heights and directions).
- Evaluate the water depths and identify potential obstructions for watercraft use.
- Evaluate the potential changes to the movement of sand and gravel in the littoral system.

In most cases, measurement should begin at the crest of the beach and extend at least 100 feet from the anticipated location of the lakeward extent of the project. Bathymetric surveys are typically performed from the beach and by means of small watercraft. Common practice is to establish multiple transect lines along the shore and record elevations using land-based survey instruments. Bathymetric elevations should be referenced to the International Great Lakes Datum 1985 (IGLD 1985) which is discussed in Chapter 2. Using best surveying practices, elevations recorded at an accuracy of ± 0.2 foot are sufficient, given the changing nature of the water surface and the near-shore bottom.

It is also possible to obtain suitable bathymetric elevations by measuring the depth of water under calm conditions. The measured water depth can be referenced to the recorded water level data from the nearest NOAA water level gauge station. Water level stations in Ohio are at Toledo, Marblehead, Cleveland and Fairport Harbor. Data can be accessed for these locations online at: *www.glakesonline.nos.noaa.gov/geographic.html*.

The water level data from these gauges is reported relative to IGLD 1985. This method has the benefit of not requiring an on-land survey instrument beyond establishing the location of transect starting points and bearings.

Hand-held GPS units can be used to establish coordinates for the depth measurements, but care must be taken to incorporate the varying range of accuracy these units typically provide into final survey information. Due to the low level of precision and accuracy of hand-held GPS units, elevation readings obtained from this type of equipment are not suitable for bathymetric surveys.

The field survey should identify the substrates (bedrock, cobbles, sand, mud, etc.) present and any submerged off-shore structure such as stone, rubble, relict groins and piers. This information should be included on design drawings.

Navigation charts can be very helpful in understanding the larger scale, off-shore bathymetry and the effect on wave development. However, such charts are typically limited to 6-foot contour intervals with a few intermediate point depth measurements. These charts are not considered sufficiently accurate in depth or location along the shore to be used for design of shore structures.

Performance of nearby structures

Existing structures adjacent to and near the project site can influence how a design performs and in turn can be affected by the proposed structure. During site investigations, the condition of nearby structures should be documented. For example:

- Does stone or rubble appear displaced? If so, what size is it?
- Are vertical seawalls or sheet pile structures leaning lakeward, undercut or washed out?
- Are crib structures dislocated, bending or emptying of rock fill?
- Are there major cracks in concrete structures?

Shore-perpendicular structures such as groins and piers will generally have a greater accumulation of littoral material (sand and gravel) on one side or the other. This is usually a good indication of the predominant direction of the movement of littoral material along a specific reach.

The condition of adjacent and nearby upland slopes should be noted. If adjacent property is receding, and erosion appears recent and ongoing, the edge of an erosion control structure at the project site may eventually be washed out or flanked if the design and arrangement of the structure does not adequately tie back into the slope.

Site wave climate

The wave climate refers to the hourly, daily, seasonal or annual changes in wave height, period and direction. More generally, the wave climate is the expected range of winds and storms and their abilities to create elevated water levels and waves along the shore. Some project sites will be sheltered from waves from certain directions by nearby structures or the orientation of the shore. Other sites, especially around the islands and Sandusky Bay, may have a limited distance (or fetch) over which wind from a given direction can generate waves, limiting the wave height.

Many sites will experience full exposure to waves from winds and storms from the dominant southwest direction as well as the less frequent, but usually stronger, northeast storms.

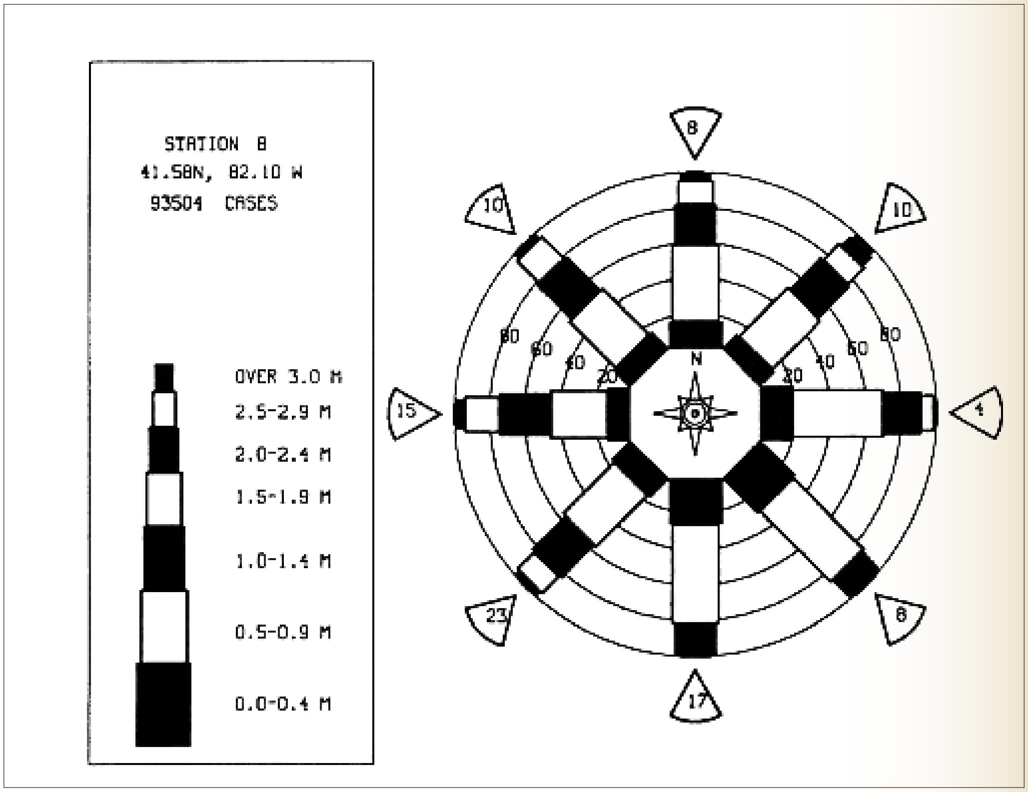
Much the same as a wind rose, wave roses, as seen on this page, are used to evaluate the probability of wave height and direction and to assess the wave conditions that structures should be designed to withstand. The assessment of design wave heights for structures is discussed in detail in *Chapter 3.*

Observations at a project site under storm or high wind conditions can also be very helpful in developing a more visual understanding of the potential wave climate. It is useful to record the weather conditions and water level at the time of observation. Wind direction and velocity data are available online from sites including the NOAA Tides and Currents, NOAA Great Lakes Environmental Research Laboratory, the NOAA National Weather Service, and the nearest NOAA station on Lake Erie.

Example Wave Rose

Station E008, NW of Avon Point. From the U.S. Army Corps of Engineers "WIS Report 22, Hindcast Wave Information for the Great Lakes: Lake Erie," October 1991.

The numerical values at the end of each directional point are the percent of time waves will originate from that direction. The wave heights (in meters) are on a percent scale from the center of the rose. Looking at the SW direction, waves would come from the SW 23% of the time and of that, about 60% of those would be less than 1 meter in height. Note that this rose is for OFF-SHORE waves. Potential waves heights in the nearshore can be calculated using this information (See Chapter 3).



Chapter 2. Site Surveying Requirements

This chapter describes the unique conditions of performing topographic and boundary surveys along Ohio's Lake Erie coast for projects that require authorizations from the Ohio Department of Natural Resources (ODNR). The purpose of this chapter is to assist the professional surveyor in establishing accurate site control, the collection of field data, the research of public records and the preparation of application submittals for projects proposing to occupy portions of the Public Trust Territory of Lake Erie, including the waters of Maumee Bay and Sandusky Bay.

Horizontal and vertical datums

A horizontal control network establishes horizontal positions, or plane coordinate values, on each station or point for a variety of surveys. Topographic surveys determine the configuration of the earth's surface and location of natural and artificial features, while cadastral surveys retrace property lines. A traverse is a method by which lengths and directions of lines between points on the earth are observed from field measurements to determine positions of those stations. The design of a horizontal control network for preliminary topographic and/or cadastral surveys should include a traverse that surrounds the entire site. A closed traverse is a convenient, rapid method for establishing horizontal control and is particularly useful in densely built up areas along the Lake Erie coast and in heavily forested regions where lengths of sight are short.

Alternatively, control surveys using the Global Positioning System (GPS) may prove to be the best solution, especially for open areas where there are no physical obstructions. Consideration must be given to errors in positional accuracy created by multipath issues when collecting data near the waters of Lake Erie. Multipath errors occur when buildings or other obstacles block the direct path of the satellite signal to the GPS receiver and there is a time delay of the reflected signal to the receiver. Dilution of Precision (DOP) values are an indicator of the quality of the satellite arrangement. Increased values in the DOP that introduce error to the control or topographic survey can be observed when collecting data near the vertical bluff face and tree canopy.

Datums define the shape and size of the earth, or a portion of it, based upon an origin and direction of the coordinate systems. Datums available to the surveyor performing horizontal control surveys include several local datums created for small geographic areas and geodetic datums that define the spherical model of the earth such as the North American Datums of 1927 and 1983, and the World Geodetic System (WGS).

Surveying Principles

Coordinate systems that define points in space by distance and direction based upon either a local or a geodetic datum have been established by municipalities in each of the eight coastal counties. Referencing coordinates to the wrong datum can result in positional errors when performing or positioning field surveys. Although there is no requirement for field surveys to be based upon a specific horizontal datum and coordinate system, it is beneficial to utilize the Ohio State Plane Coordinate System North Zone (SPC3401) which is based upon North American Datum of 1983 (NSRS 2007). The benefits of using a common datum include digital data sharing by regulatory agencies, consultants and county administrators; accessibility to published monumentation by the National Geodetic Survey (NGS); and maintaining coordinate integrity for multiple project sites.

Although there is no requirement for field surveys to be based on a specific horizontal datum and coordinate system, it is beneficial to utilize the Ohio State Plane Coordinate System North Zone (SPC3401) which is based upon North American Datum of 1983 (NSRS 2007).

Land parcel data provides geographically referenced information associated with the real property and generally forms a structure of polygons within a defined area. The OCM uses parcel data generated and maintained by each county auditor's office as a framework for locating specific sites and alignments of rights of way. Survey products produced, reviewed and distributed by OCM are referenced to parcel data obtained from the corresponding county auditor's office. OCM recognizes that these boundaries and alignments are not survey accurate. Although this dataset is based upon SPC3401, OCM does not routinely field-verify the locations of intersecting centerlines for rights of way or parcel corners. Coastal permit and lease application submittals that identify coordinate values for subdivision corners or intersecting centerlines based upon SPC3401 or WGS 1984 are incorporated into OCM's Geographic Information System (GIS).

A vertical control network establishes vertical positions, or elevations, on each station or point for surveys that relate a vertical distance from a datum. A closed level circuit is the preferred procedure for determining the elevations as this method provides the surveyor the ability to adjust observations based upon lengths of the sights between each station. Although this method may not be as convenient as control surveys using the GPS, the results may be more accurate.

Datums available to the surveyor performing vertical control surveys include several local datums, and resultant benchmark systems established by municipalities in each of the eight coastal counties and geodetic datums such as National Geodetic Vertical Datum of 1929 (NGVD 29), North American Vertical Datum of 1988 (NAVD 88) and International Great Lakes Datum of 1985 (IGLD 1985).

For project sites that are within the regulatory jurisdiction of the United States Army Corps of Engineers (USACE), Ohio Environmental Protection Agency (OEPA) and ODNR, application submittals must provide a reference to the most current International Great Lakes Datum (IGLD).

The vertical distance from the point on the earth's surface to the geoid model, NAVD 88 for example, is a true orthometric height. IGLD 1985 is reported as a dynamic height that is calculated from the orthometric height and a value of the geopotential related to gravity. Therefore, there is not a single conversion factor between these datums. A calculated conversion from a relative, reference or local vertical datum to IGLD 85 must be provided if the field survey was not based upon IGLD 1985. NGS' website: http://vdatum.noaa.gov provides tools to convert between various vertical datums.

OCM has included survey monumentation as a thematic layer within the Lake Erie Ohio Coastal Atlas Project's Interactive Map Viewer. Located on OCM's website: *ohiodnr.com/tabid/23320/default.aspx* this tool allows the consultant to identify all First or Second Order monuments, (those that have a high level of accuracy and precision for the vertical component) within a certain radius of a specific location within Ohio's eight coastal counties. A link to the current NGS datasheet is included.

Existing site conditions and structures

Adjusted horizontal and vertical control networks allow the surveyor to locate the natural and human-made features on the site. These features may provide reference points to the location of the water's edge and/or top of bluff as depicted on historic plats and aerial photography. Site features may also be used to identify impacts upon the rights of the littoral property owner such as adverse possession claims and prescriptive easements that can influence design choices or construction methods.

The location of all fills and structures along the shore should be referenced to the upland parcel boundaries so that inconsistencies between boundary lines described in the title and the claimed possession by the occupation of human-made structures can be identified. The surveyor should coordinate with the design engineer for the project to assure that all features within the project area are defined in location, elevation and dimension. This includes adjacent structures along, near and/or offshore that may affect the upland owner's ability to exercise their littoral rights, potentially affect littoral transport or influence design choices.

Sufficient topographic and bathymetric data should be collected to build a digital elevation model (DEM) of the bare-earth, to generate contours and to accurately represent the elevation surface. Digital terrain models (DTM) may include the surface of buildings, water and tree canopy.

Joining datasets obtained from varying sources to generate any DEM requires an evaluation of the data collection techniques. These include the coordinate system utilized, its origin and accuracy and other characteristics included in the metadata. In order to determine the model grid spacing between field located points, the surveyor should evaluate the collection methods used, the datum and the desired type of surface (DEM/ DTM) needed to depict the data.

Grid spacing in bathymetric data collection is dependent upon the degree of elevation change, the geographic limits of the project site and the software application used in processing the dataset. Additional guidelines for bathymetric profiles are included in Chapter 3.

A grid arrangement comprised of asymmetrical points, referred to as a Triangulated Irregular Network (TIN), has an associated elevation at each vertex and can enable a more detailed depiction of elevation changes upon the surface model at strategic locations along significant features (i.e. water's edge), and less detailed depiction where there is a consistent grade.

A site plan prepared by the surveyor that depicts the existing conditions must be signed, sealed and dated by the Ohio registered professional surveyor. By affixing their seal to any document, the registrant certifies to the accuracy and completeness of the information contained in the sealed document, and by such action, assumes full responsibility thereof. (Site plans not expressly prepared for the depiction of legal boundaries may also be prepared, signed and sealed by an Ohio registered engineer referencing the plans and data prepared by the surveyor.) Site plans are included in the five design examples in Chapter 4.

Determination of the parcel boundaries for the site

Boundary surveys along Lake Erie's shoreline require that the surveyor collect and evaluate all available evidence or data required to make a determination on the location of the ambulatory boundary. This evidence should include, but should not be limited to:

- Historic aerial photography.
- Previous surveys of record.
- Previous conveyance instruments to discover the intent of the grantor.
- Water gauge data.
- Nautical chart data.
- Geomorphic features that define the earth's shape or surface collected by a field survey.
- Existing site conditions.

Visual inspection of the site for hydrologic, vegetative and geomorphic indicators provides information that can be evaluated and incorporated into the natural shoreline determination. Natural processes such as accretion, avulsion, reliction and erosion must be considered in any determination of the ambulatory boundary defined by the body of water. All evidence should be weighed accordingly.

When fill material has been artificially placed on the site, further examination of the evidence must be made to determine the location of the natural shoreline prior to that activity. Examples of such evidence include:

- Information obtained through soil borings.
- Search of regulatory agency records.
- Drawings that depict pre-construction site conditions.
- Inspection of historic aerial photography.
- Parol evidence taken at the site.

Historic aerial imagery can be examined to determine the location of the water's edge prior to the placement of fill and to establish an approximate period for that activity. Sources for historical aerial imagery datasets include ODNR, the Ohio Department of Transportation Office of Aerial Engineering, county engineer's and auditor's offices, county soil and water conservation districts, utility companies and historical societies. When aerial photography is used to compare and identify changes to the shoreline, either by naturally occurring processes or disruption due to manmade structures and fills, an examination of the impacts of coastal processes (i.e. erosion, accretion) on the adjacent shoreline must be performed.

The surveyor should seek advice from legal counsel on rulings from the court and the applicability to any specific site. Consideration of how Ohio courts have decided cases involving erosion, placement of artificial fill, and extinguishing of title (i.e. Beach Cliff Trustees v. Ferchill) must be factored into any determination.

Citation of all collected evidence and resulting conclusions should be documented in a surveyor's report that must be signed, sealed and dated by the Ohio registered professional surveyor. By affixing their seal to any document, the registrant certifies to the accuracy and completeness of the information contained in the sealed document, and by such action, assumes full responsibility thereof.

Depicting the littoral partitions between adjoiners for the site

Lakefront property owners have certain rights that are included in the "bundle of rights" held by the titleholder. Boundary lines of the upland parcel are projected into the waters from the natural shoreline and form a division line, or partition, between contacted owners and their respective littoral rights. It is the duty of the surveyor to make a determination of where one owner's boundaries begin and the neighbors' boundaries end including the limits of any littoral rights within the waters of Lake Erie.

There are multiple established methods for determining the littoral rights partition lines between parcels that are directly contacted (or "adjoined"). It is critical to examine the appropriate reach of shore when apportioning between several nearby or "adjacent" parcels that have a close proximity to the subject parcel. In some cases it may require the surveyor to extend the field location survey a significant distance from the project site.

Several elements should be considered in partitioning these rights within the waters of Lake Erie. Among these factors are the alignment of the reach of shoreline that is to be apportioned, the ambulatory nature of the water's edge and the location of the natural shoreline prior to any alteration caused by humans. The artificial placement of fill material within the waters of Lake Erie or along its shore, or the excavation of private lands to create marina basins does not change the location of the natural shoreline.

A general rule of procedure is to project partition lines perpendicular to the natural shoreline at the point where the upland parcel boundary intersects the natural shoreline. In cases where the natural shoreline alignment is concave, as in an embayment, or convex, as on a peninsula, a center point is calculated and these projection lines are drawn radial to that point.

There are instances in which the sidelines of the upland parcel boundary should be controlling and perpendicular and where radial projections should not be made. Examples of this circumstance include where the upland sideline has the same boundary without gap or overlap, (or is "coterminous"), with the fractional section or township due to the border with the water boundary or the adjoining survey district. Range lines or original Ohio land subdivision lines throughout Erie County and the Danbury Township portion of Ottawa County (also known as the Firelands) can create the same condition.

Due to the varying conditions along the 312 miles of Lake Erie shoreline within Ohio, it would not be practical to apply one single method. However, as a rule, the alignment of upland sidelines should not control the alignment of partition lines into the waters of Lake Erie. In some instances, due to the irregularly shaped configuration of the shoreline, multiple methods may produce the best result based upon equitable distribution.

Methodologies that may be appropriate along Ohio's Lake Erie shore are contained in several reference manuals including the 2009 "Bureau of Land Management Manual of Instructions for the Survey of the Public Lands of the Unites States," and "Brown's Boundary Control and Legal Principles." A review of Ohio case law and tests of equity for the adjoiners should be examined for each situation.

Survey products for projects under the regulatory authority of ODNR

OCM administers the Submerged Lands Lease Program for the state of Ohio based upon Ohio Revised Code Chapter 1506.11 and Ohio Administrative Code Chapter 1501-6. Submerged lands leases are different from conveyances of fee simple interest in that the state of Ohio cannot convey clear title to Public Trust Lands. However, the state can convey a limited leasehold interest to the upland parcel owner for a portion of the Territory based upon the proposed development within the waters of Lake Erie.

To enable ODNR to administer the Submerged Lands Lease Program effectively, an accurate depiction of the proposed lease boundary is needed. For most projects, the lease boundary must have a direct connection to the adjacent upland parcel and the Ohio Registered Professional Surveyor identifies this relationship by submitting a plat of survey that depicts the proposed lease boundary and the upland title lines. This requirement is intended to ensure that lease boundaries close, that the area to be leased is accurately identified and overlaps are eliminated.

ODNR evaluates the impacts of the project on the littoral rights of landowners along Lake Erie based upon the plat drawings and metes and bounds descriptions prepared by the Ohio registered professional surveyor. The plat drawing shows partition lines that indicate a separation of rights within the waters of Lake Erie in areas between upland parcel owners. The determination of the location of the partition lines must consider the equitable distribution of the shoreline and the rights of adjacent upland property owners.

The footprint of the structure, and therefore the limits of the submerged lands lease are not required to extend to the littoral rights partition lines of the upland parcel. In instances where the proposed lease boundary extends beyond the partition line, the affected adjoiner must grant their consent in writing either by providing an affidavit to that fact or by supplying an agreement between the private parties.

Depending upon the project, an application for a Lake Erie Submerged Lands Lease may require a metes and bounds description of the submerged land to be occupied with the area reported in square feet to enable an annual lease rental amount to be calculated. In certain cases, an alternate description that is referenced to the applicant's upland property description may be considered by the director of ODNR. Alternative descriptions may include: a plat of survey that depicts the boundaries of the upland relative to the occupation of submerged lands with the area reported in square feet; bounding; or coordinate descriptions for specific off-shore projects.

In 2006, the State Board of Registration for Professional Engineers and Surveyors provided an opinion to ODNR on the applicability of Ohio Revised Code Chapter 4733 and the rules adopted thereunder, to the state of Ohio Submerged Lands Lease Program. The board stated that registered professional surveyors are the only persons qualified to prepare descriptions for the establishment and retracement of lease boundaries and therefore the surveyor shall conform to the Minimum Standards for Boundary Surveys of Ohio Administrative Code Section 4733-37.

There are two exceptions to the requirement for a metes and bounds description: private floating piers and linear utility installations.

- For applications for a floating pier, a basic site plan that depicts the general location of the proposed structure is sufficient, without a field survey.
- Utility descriptions and/or plats should depict the centerline of the proposed occupation and identify a distance offset to allow for alignment adjustments during construction due to submerged features and for maintenance of the conduit.

ODNR encourages each leaseholder to file the executed submerged lands lease with the county recorder's office in which the site is located. Currently this is not a requirement, but ODNR is developing procedures to file all submerged lands instruments to enable surveyors, realtors, title agents and others to identify interests within the waters of Lake Erie.

In order to insure the submission of proper and accurate legal descriptions of the submerged lands to be occupied, ODNR provides the following guidelines.

Metes and bounds descriptions

In its best form, a written description identifies a unique area without conflict with any other portions of land. It must be retraceable for the surveyor and accurately depict the intent of the grantor. It must include monumented and identifiable commencing points, distinct calls to adjoiners and mathematically close within allowable tolerance defined by Ohio Administrative Code Section 4733-37.

Metes and bounds descriptions are used to identify the entire area of proposed, as well as existing occupation of the territory of Lake Erie. Descriptions are attached as an exhibit to the executed submerged lands lease. Current Ohio Administrative Code rules for submerged lands leases identify specific rental categories based upon the primary use of the submerged lands of Lake Erie. In instances where there are multiple uses within the same site, separate metes and bounds descriptions referenced to a common point of commencement must be provided. To allow the lease instrument to be recorded, each description must include the area reported to the nearest square foot and acreage to the appropriate decimal place according to the current conveyance standard established by the county auditor's and engineer's office where the project is located. The surveyor should review these conveyance standards, which can be accessed through the Ohio Department of Transportation web site: *www.dot.state.oh.us/Divisions/ProdMgt/Production/row/Pages/County_Conveyances.aspx*. Metes and bounds descriptions are included in the design examples in Chapter 4.

Plat of survey for the submerged lands lease parcel

A graphic representation of the proposed submerged lands lease boundary is required to accompany any metes and bounds description. The text and graphics shown on the plat of survey assist the upland owner, real estate professional, engineer and surveyor in understanding the intent of the state of Ohio to convey a limited leasehold interest for the area in the description. Other information on the plat must include:

- Any interest in submerged lands (i.e. lease or permit) on the site, including adjoiners;
- Identification of existing and/or proposed overlap or gap;
- The methodology employed in determining the partition of littoral boundaries for each adjoining shoreline parcel;
- The manner by which the coterminous boundary between the public's interest in the waters of Lake Erie and the upland parcel was established; and
- The direct relationship between the upland parcel and the proposed lease area.

The plat depicting the entire area of proposed and existing occupation of the territory of Lake Erie is attached as an exhibit to the executed submerged lands lease and must conform to the respective county conveyance standard. Survey plats are included for the design examples in Chapter 4.

Surveyor's role during project construction

Construction layout surveying along the shore and in the waters of Lake Erie can be challenging as traditional layout techniques and error tolerances must be adjusted to the site conditions. The accuracy of measurements and the type of temporary survey markers vary with the degree of precision required and type of construction.

During construction, site conditions may require that the design be modified to meet unexpected conditions or changes to the project scope. Any modification to the design of the project requires the approval of the Ohio registered professional engineer responsible for the design. Modifying the design in the field without such approval may relieve the engineer of liability for the design.

Post construction surveys

As-built surveys create a record of the site conditions after all construction activities have been completed. This is sometimes necessary to identify the actual location of features due to either planned or unplanned deviations from the design during the construction.

As-built surveys can also document the location and alignment of the shoreline prior to the impacts of littoral processes such as erosion and accretion on the project. The effects of these processes may influence the upland parcel boundary and the rights of adjoiners to the accreted material.

Ideally, the same person that performed the control, boundary, preliminary topographic and construction layout surveys would complete the as-built phase of the project. This is not a requirement for an accurate as-built, however it is required that the surveyor locate and use the horizontal and vertical control stations that were the basis for the other phases of the project. This recovery enables the surveyor to locate field changes on the same coordinate system that the design was based upon. It allows the engineer and property owner to easily identify any modifications to the design and impacts on the surrounding features.

Specific care should be taken to ensure that construction limits do not exceed littoral rights partition boundaries as determined by the Ohio Registered Professional Surveyor.

Chapter 3. Design Fundamentals

The topics discussed in this chapter are the basic design considerations that apply to nearly every shore structure project. These include determining the design water level and design wave height, calculating the run-up, and evaluating how the physical arrangement of the project can affect littoral movement and adjacent properties. At the end of the chapter, suggested standards are presented for the preparation of design drawings, engineering methods and calculations, materials specifications and supporting information.

Design water levels

The water level of Lake Erie is subject to seasonal and yearly fluctuation. Generally, water levels are higher in the spring and lower in the fall. The seasonal change is typically 1 to 2 feet. Year-to-year change may be greater depending on regional climate conditions. The difference between the low water datum and the ordinary high water elevation is 4.2 feet. Such differences should be taken into account when designing structures. A design water level (DWL) is the elevation of water used by the designer that incorporates the risk to the structure over time, and at which elevation the structure is designed to withstand the associated forces.

The U.S. Army Corps of Engineers (USACE), in 1988 and 1993, published a series of DWL frequency curves and tables used to design structures along the Lake Erie shore. The principle in developing the DWLs is similar to a hydrologic assessment of a stream or river to determine the flood elevations for probabilistic periods or return periods, as in a 100-year storm or flood.

The DWLs are based on historic water level gauge readings along the Lake Erie shore. The calculated elevations are still water levels based on the maximum mean monthly elevations plus the rise (storm surge, not waves) measured as the maximum hourly gauge reading. The DWLs reflect the recorded year to year fluctuations in water levels between 1904 and 1986 for the 1988 USACE study and 1915 thru 1989 for the 1993 Report. It should be noted that one of the highest recorded periods of lake water level occurred relatively recently in 1997 and that this data was not included in the calculations.

The DWLs in the table at right are divided by the specific reaches along Ohio's shore. These reaches are defined in the "Phase I Revised Report on Great Lakes Open-Coast Flood Levels," USACE 1988. Reaches along the Central Basin (Sandusky to Conneaut) are not as dramatically affected by the southwest or northeast storm surges as the shore along the Western Basin (Toledo to Sandusky). Note that the DWL for the Marblehead to Sheldon Marsh reach does not apply to Sandusky Bay. The

DWLs reflect the nature of Lake Erie's southwest to northeast orientation and the effects of southwest or northeast oriented storms on the water elevation of the lake. A prolonged northeast storm may result in a 5 to 6-foot rise in water level (above the still water level) at the west end of the lake in Toledo.

The ODNR Office of Coastal Management uses a DWL for a 30-year return period in its evaluations of shore structures. This has been used by convention (30-year mortgages and typical life of structures) rather than from a rigorous risk-based perspective.

There may be projects for which other return periods are appropriate. For example, the USACE typically uses a 20-year return period DWL for their structures on the Great Lakes.

There may be project designs (such as public access structures) that warrant use of a 100-year return DWL from a risk-based perspective. The 20-year, 30-year and 100-year return period DWLs have been included in the table below.

***Design water level** is the elevation of water used by the designer that incorporates the risk to the structure over time, and at which elevation the structure is designed to withstand the associated forces.*

Design Water Levels Along the Ohio Lake Erie Shore

		Feet IGLD 1985		
From	**To**	**20-Year Return**	**30-Year Return**	**100 Year Return**
Toledo	Cedar Point	576.6	577.6	577.9
Cedar Point	Locust Point	576.3	576.6	577.6
Locust Point	Marblehead	576.0	576.2	577.3
Marblehead	Sheldon Marsh	575.8	576.3	577.0
Sheldon Marsh	Huron River	575.5	575.8	576.7
Huron River	Vermilion River	575.3	575.5	576.4
Vermilion River	Black River	575.1	575.3	576.1
Black River	Avon Point	574.9	575.1	575.9
Avon Point	Rocky River	574.7	574.9	575.7
Rocky River	Perry Twp	574.6	575.5	575.6
Perry Twp	Saybrook	574.7	574.9	575.7
Saybrook	North Kingsville	574.8	575.0	575.8
North Kingsville	Pa. Line	575.0	575.2	576.0

NOTES: The above elevations are referenced to the International Great Lakes Datum (IGLD). The designation of reaches and elevation values referenced to IGLD 1955 used to calculate the 20-year and 30-year elevations are from the *Revised Report on Great Lakes Open Coast Flooding*, USACE, 1988, with the data converted to IGLD 1985. DWL values for the Rocky River to Perry Twp., Marblehead to Sheldon Marsh, and Toledo to Cedar Point reaches are based on the *Design Water Level Determination on the Great Lakes*, USACE Sept. 1993. The 100-year elevations are 100-year USACE elevations from the 1988 report with the IGLD 1955 values converted to the IGLD 1985 datum.

For development of more specific design water levels, either in terms of return period or location along the Lake Erie shore, the consultant should refer to these documents:

1. *Phase I Revised Report on Great Lakes Open-Coast Flood Levels*, Prepared by the U.S. Army Corps of Engineers for the Federal Emergency Management Agency, April 1988
2. *Design Water Level Determination on the Great Lakes*, Prepared by the Detroit District, U.S. Army Corps of Engineers, September 1993

The DWL is used to develop the design wave height (DWH) and as a basis for calculating the expected run-up of waves on a structure.

The design of watercraft access structures, piers, groins, beach fills and breakwaters usually requires evaluating those structures at other water level conditions in addition to the DWL conditions. For example, watercraft-use structures might be evaluated at an average boating season water level of 571.5 feet IGLD 1985 to assess the functionality of both the average depth at a watercraft access structure and the height from the top of the structure to watercraft.

Design wave height

Waves can exert large forces on shore structures. Fresh water weighs 62.4 pounds per cubic foot and a large wave may bring thousands of pounds of force against a structure. The structural requirements for the stability of a structure are directly related to the DWH and the forces exerted by the design wave. The higher the wave, the larger the forces, and therefore, the larger and heavier the needed structure.

Waves along the shore of Lake Erie are produced primarily by wind. Waves can also be produced by boat wakes, but these do not reach the height or intensity of wind-driven waves. Wind-driven waves can come from any direction. Most of the Lake Erie shore will be subject to the waves generated by both the most common southwest storms (summer thunderstorms) and the more intense, but less frequent northeast storms more common in late fall and spring.

As wind velocity increases, the height of waves will increase until the waves break, decreasing the height. As waves approach the shore, and the water depth shallows or shoals, waves will increase in height until they break. It is the wave height as it approaches the shore and the proposed structures that is critical to design. This is why bathymetric profiles or contours establishing the depth of water in the nearshore are important to the design of shore structures.

Fresh water weighs 62.4 pounds per cubic foot. A large wave may bring thousands of pounds of force against a structure. The larger the wave, the greater the forces, and therefore the larger and heavier the needed structure.

In most cases the depth of the water at the structure under the DWL condition is the controlling dimension in determining the DWH .

A very complete description of wave theory, meteorology, the methods of developing design wave parameters and the behavior of waves in the near shore is found in Chapter II of the USACE's *Coastal Engineering Manual* (CEM). The analytical methods described in the CEM are usually needed only for complex projects or when alternative design parameters are used.

For the design cases associated with less complex shore structures such as revetments and seawalls, the wave conditions can usually be calculated using simplified methods if certain assumptions are verified. The first assumption is that the nearshore is considered to be "shallow." With respect to waves, a shallow condition on Lake Erie usually means depths of 20 feet or less, which is generally true along the entire Lake Erie shore. The second assumption is conservative in that it assumes that the design wave will break at the structure. This results in selecting a design wave that would exert the greatest force on the structure.

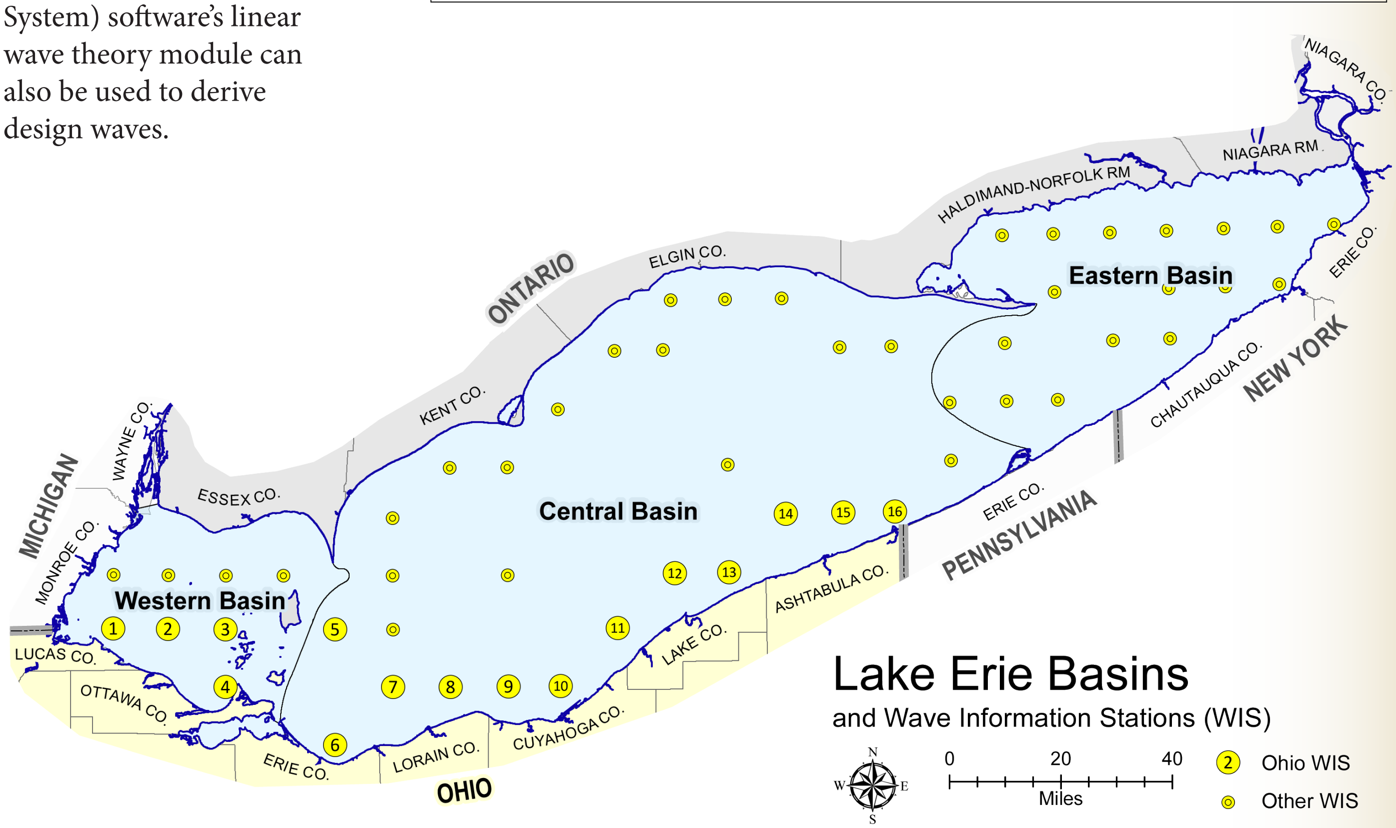
Waves in the nearshore will tend to break when the wave height reaches about 80 percent of the depth. A simple calculation based on this concept can be used to select the design wave, which is designated as “H_b” (height of the breaking wave). There are numerous equally valid means of calculating design waves based on transformation of wave hindcast data, on wave spectral analysis and based on wind conditions. In most cases the wave period, (T) and the slope (m) of the nearshore are required for those analyses. Programs such as the U.S. Army Corps of Engineers “ACES” (Automated Coastal Engineering System) software’s linear wave theory module can also be used to derive design waves.

Hindcast Wave Data for Lake Erie in Ohio

Average and Maximum Off-Shore Wave Heights and Periods
Wave Height (H) is in feet. Wave Period (T) is in seconds

WIS#	County	Station location	Ave H	Ave T	Dir	Max H	Max T	Dir
E001	LUC	N Reno Beach	1.9±0.9	3.4±0.8	WSW	7.2	8	E
E002	LUC/OTT	N Sand Beach	1.9±1.3	3.6±0.8	WSW	8.5	8	E
E003	OTT	W N. Bass Island	2.3±1.3	3.7±0.9	WSW	8.5	8	E
E004	OTT	W Catawba	1.6±1.0	3.4±0.7	SW	6.9	7	NW
E005	OTT/ERI	E Peele Island	2.6±1.6	4.0±1.0	S	10.5	9	NE
E006	ERI	N Huron	2.3±1.3	3.6±1.0	S	11.8	9	N
E007	ERI/LOR	NNE Vermilion	2.9±1.6	4.0±1.0	SSW	12.8	9	N
E008	LOR	NNE Lorain	2.9±1.6	4.0±1.0	SW	14.1	9	N
E009	CUY	N Bay Village	2.9±1.6	4.0±1.1	WSW	14.8	9	N
E010	CUY	N Cleveland	2.9±1.6	4.0±1.1	WSW	13.8	9	N
E011	LAK	NW Eastlake	2.9±1.9	4.1±1.2	SW	16.4	10	W
E012	LAK	N Painesville	2.9±1.9	4.1±1.2	SW	16.4	10	W
E013	LAK	N Perry	2.9±1.9	4.1±1.2	WSW	15.1	10	W
E014	ASH	N Saybrook	3.3±1.9	4.2±1.2	WSW	16.4	9	W
E015	ASH	N N. Kingsville	3.3±1.9	4.2±1.3	WSW	16.1	9	W
E016	ASH	N Conneaut	3.3±1.9	4.2±1.3	WSW	15.7	10	W

Source: U.S. Army Corps of Engineers Coastal and Hydraulics Lab. Wave Information System (WIS) Hindcast Data for Lake Erie. WIS Report 22, October 1991



The table on page 27 is a summary of Lake Erie off-shore hindcast wave data generated by the U.S. Army Corps of Engineers. The data is for the 16 wave information stations directly off Ohio's coast. These are shown as numbers on the Lake Erie Basin map. Data is available for the other WIS locations, but not included here.

The data provides an overview of the varying wave climates along the lake. Average wave conditions all along the lake are dominated by waves from the west through the southwest which reflect the dominant weather pattern along the Lake Erie shore. The highest waves in the western basin are from the east; from the north into the Cleveland area, and then from the west as the shore becomes oriented southwest to northeast in Lake and Ashtabula counties. Wave heights are also limited by depth and fetch distances, with the shallower western part of the lake having lower average and maximum wave heights and periods than the eastern Ohio portion.

Offshore wave data can be used to calculate the DWH as the off-shore (or deep water) wave transforms into the shore. There are a number of methods that can be used including those in the ACES wave transformation modules. The limiting conditions and applicability of the various methods of transforming deep water waves into shallow water waves are fully discussed in the CEM. There are also numerical models available for evaluating wave data and assessing nearshore wave climate conditions. The complexity of using these methods is beyond the scope of this manual.

For simple design conditions, the following formula will provide a reasonable and conservative design wave height, H_b for the breaking wave.

$$H_b = 0.78d_s$$

Where d_s is the depth of water at the structure toe under the DWL condition.

This calculation is independent of the nearshore slope and wave period and assumes that the design wave will break at the structure toe. This equation is derived from Figure 2.2 of EM 1110-2-1614, "Design of Coastal Revetments, Seawalls and Bulkhead," USACE 1995. It should be noted that the depth of water at the structure toe (d_s) can change over time if there is the potential for scour at the toe. OCM typically assumes that the ultimate d_s will be the bottom elevation of the toe, even though it may be initially entrenched in the underlying lake bottom material.

If these assumptions are not valid for the proposed design or the site conditions are complex, then development of the design wave using methods documented in the CEM or other suitable design references may be necessary.

Run-up and overtopping of structures

The wave run-up height is the additional height above the DWL that the design wave will wash upwards along the slope or over the proposed structure. The run-up height is used to set the elevation of the crest of erosion control measures and should be used to assess the impact of high water level and severe storm conditions for seawalls that have their cap elevations below expected run-up heights.

Water and wind-driven spray from run-up can wash-out and erode the upland, displace smaller sized stone and lead to severe damage to the upland and the shore structure.

Overtopping refers to the volume of water that runs up and over the structure. It is sometimes helpful to estimate the overtopping volume to design the drainage features of a project. Overtopping can be a safety concern on access structures and portions of erosion control structures that have access incorporated into the design as water on the structures' surfaces may cause slipping or falling.

Although calculating the overtopping volume is rarely required for erosion control projects, one very serious exception is for projects in the low-lying areas in the Western Basin that have been historically subject to lake flooding. Consideration of the wave climate during extreme high water years should be included in the determination of the crest height needed to prevent the overtopping of erosion control structures along the shore in these areas. The methods for calculating the overtopping volume are fully covered in the CEM and can be performed using the ACES software.

For structures such as seawalls and piers, it is not always possible to eliminate all run-up and overtopping and still have the desired functionality which usually is related to access to the water.

The equations to calculate run-up height described below can be used if the following conditions apply:

- The structure has a single slope of the same material.
- The design wave breaks at the toe of the structure.
- The structure is the same in cross section throughout the site.

The first equation for calculating the Run-up. Height (**R**) is based on the breaking wave height $\mathbf{H_b}$ multiplied by an empirical coefficient (η).

$$R = H_b \eta$$

Where $\eta = 0.7$

This equation assumes that the run-up is 70 percent of the breaking wave height, which is based on the Federal Emergency Management Agency (FEMA) run-up models. This equation will tend to underestimate the run-up height.

The second equation that can be used to calculate run-up is an empirical formula that also requires the calculation of the surf similarity parameter also known as the Iribarren number ξ (Aherns and Heimbaugh, cited in EM1110-2-1614 *Design of Coastal Revetments Seawalls and Bulkheads*, USACE 1995).

$$R = H \frac{a\xi}{1 + b\xi}$$

R = Run-up in feet
a = 1.022*
H = Design wave height in feet
b = 0.247*

*[Note: the values provided above for coefficients *a* and *b* apply only to single slope structures with rough, porous armoring. Coefficients *a* and *b* were derived by regression analysis of empirical data.]

The surf similarity parameter, $\xi = \dfrac{\tan\theta}{\sqrt{2\pi H / gT^2}}$

$\tan\theta$ = revetment slope (e.g. 2:1 slope = 0.5)

g = 32.2 ft/sec^2

T = wave period in seconds

The surf similarity parameter expresses the relationship of wave height to wave length at a given slope and is also useful in characterizing the types of breaking waves (shown on page 30).

Again, the basic and conservative design assumption is that the worst case condition is a breaking wave at the toe of the erosion control structure. Under these conditions the breaker will be collapsing onto the structure.

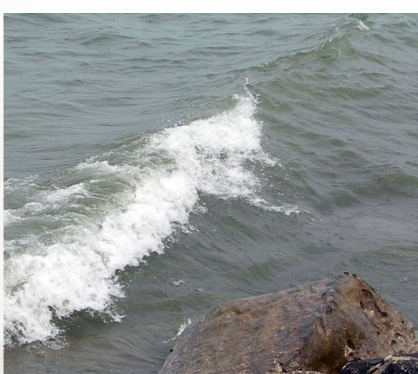
Calculating the run-up onto a structure can also be performed using a number of other formulae, including the calculation embedded into the ACES rubble-mound revetment design module. The second empirical equation above will tend to calculate a higher run-up value than the ACES module.

Types of breaking waves

ξ > 3.3 Surging or Collapsing Breaker

ξ > 0.5 and < 3.3 Plunging Breaker

ξ < 0.5 Spilling Breaker



Changes to the littoral system

The sand and gravel on beaches and moving in the littoral system are a part of the dynamic lake system. If the movement of this material is changed or interrupted, or if the total amount in the lake nearshore or entering the lake within an area is changed, there may be erosion losses at downdrift beaches. This is due to the transitory nature of beaches and the normal overall flow of littoral material across the lakeshore. Stable beaches require near constant replenishment from the littoral system. If there is a lack of sand and gravel reaching the beach, it will erode.

Eroding lakeshore bluffs are a source of material entering the littoral system. The placement of structures that minimize bluff erosion results in a decrease in the amount of material added to the littoral system. Over the design life of the structure, this can have impacts on the availability of material to form and sustain beaches.

The ODNR Division of Geological Survey frequently calculates the expected volume of littoral material prevented from entering the lake as part of the Survey's review of projects along the lake. The calculations are based on the dimensions of the project, the bluff recession rate due to erosion and the reported fractions of sand and gravel present in the bluff material. Typical losses of littoral material to the lake over 30 years from a small erosion control project can be on the order of 100 cubic yards. This impact can be offset by periodic nourishment of the area with sand.

Structures that extend onto the shore or lakeward from the shore will have an impact on the natural movement of sand and gravel in the littoral system. In general, the farther lakeward a structure extends, the greater the potential impact.

Shore-parallel structures such as seawalls will tend to reflect sufficient wave energy to suspend even gravel-sized material in the water column which severely reduces the possibility of a stable beach forming immediately lakeward of the structure. Revetments result in less reflected wave energy than seawalls, but will also tend to reduce the potential for beach formation unless they are located well upland.

Shore-perpendicular structures such as groins, jetties

When selecting pre-fill, sand that is similar to or heavier than the onsite sand will have a longer retention time at the project site.

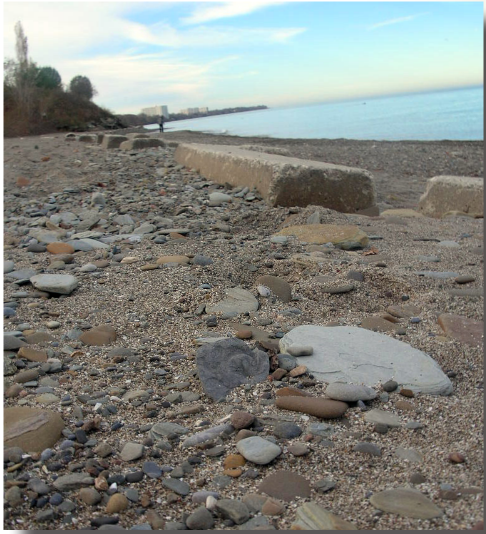
and piers will usually result in significant changes to the movement of littoral material. In most cases these structures will entrap sand and gravel permanently by interrupting the natural transport of these materials along the shore. These structures may prevent the natural replenishment of adjacent or nearby beaches that are downdrift in the direction of transport.

The design of groins usually includes a calculated volume of pre-fill sand that is placed up-drift of the structure immediately following construction. The concept of pre-fill is based on the fact that groins are expected to permanently remove a volume of sand from the littoral system and form or stabilize a beach updrift of the structure. The pre-fill volume is needed to balance the littoral system by "filling" the groin compartment, so that the littoral material passes downdrift.

Piers are generally shore perpendicular structures that are used to access the waters of the lake. Many piers consist of a solid or mostly solid design that acts like a groin. To allow the unrestricted flow of littoral material past a pier, the usual design solution is to include an open span near the shore.

Jetties are structures that protect and reduce shoaling in a harbor channel, usually on a river or creek outlet to the lake. With respect to the movement of littoral material, jetties act like groins. Jetty design would need to potentially include both pre-fill along the up-drift side and a plan for surveying and measuring the volume of any accumulated littoral material and a means for by-passing the material on a regular basis.

If the structure will intentionally impound littoral material after construction, the design normally would include the placement of additional sand from an upland source equivalent to the calculated volume that will be impounded by the new structure. USACE design guidance recommends that the design volume include a factor of safety of 1.5 to 2. This added sand pre-fill will offset the negative impact to downdrift shorelines by minimizing the amount of native material impounded by the proposed structures. The sand pre-fill should be very close in particle size distribution to the existing material along the shore. Typically, sand that is lighter (smaller diameter) than the onsite sand will be more easily transported by waves away from the project site. Sand that is similar to or heavier than the onsite sand will have a longer retention time at the project site.

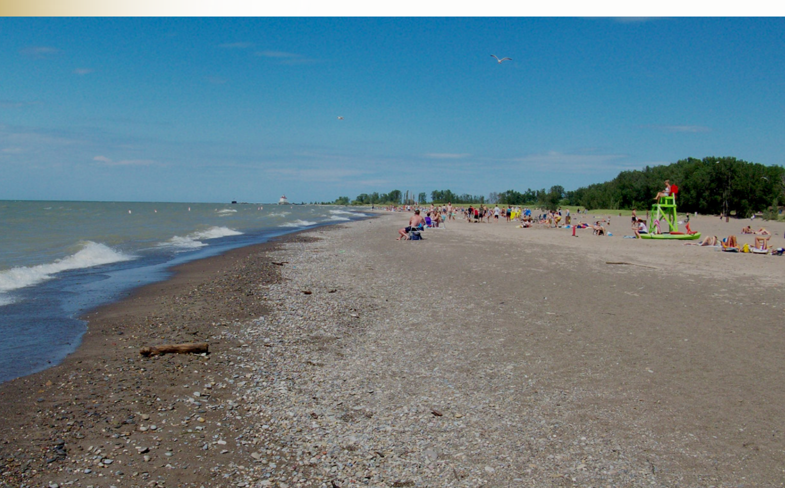


Sand along Ohio's coast varies as illustrated in these photos from public access sites: Port Clinton City Beach (top), Lorain's Lakeside Landing (middle), Willowick City Hall (bottom) and Headlands State Park (page 32).

The methods of calculating the expected volume of littoral sand required to bring the project to equilibrium under design water levels include straight-forward volumetric estimates assuming a depth of the fill over the existing lake bottom and the use of beach profiles using multiple cross-sections to calculate fill volumes.

The littoral material on beaches is not usually considered to be suitable material for stable foundations for shore structures. Sand and gravel can be readily scoured at the base of and then under a structure, leading to settlement and potential failure of the structure. If the footprint of the structure will cover existing beach material, this would result in a loss to the overall littoral drift available in the lake. In such cases, beach material must be removed from the footprint to the depth of the underlying strata before construction and side-cast along the shore.

The design objective for all shore structures is to minimize the changes to wave energy at adjacent properties and to retain the same flow of littoral material along the shore.



Effects on adjacent or nearby properties

The two most important questions related to effects on adjacent or nearby properties that must be addressed in the design of a shore structure are:

- Will the structure sufficiently change the direction or magnitude of wave energy at an adjacent or nearby property to adversely affect the shore or bluff?
- Will the project change the flow patterns, interrupt or entrap sufficient littoral material to create a deficit of beach material and increased erosion along the shore on nearby properties?

The design objective for all shore structures is to minimize the changes to wave energy at adjacent properties and to not change the flow of littoral material along the shore. If the proposed structure will result in significant changes to wave energy or the littoral system, the engineer should prepare an explanation of the expected magnitude of the potential effects, justification for the extent of potential harm and a plan to mitigate such effects.

Impact of design on habitat

As discussed in Chapter 1, structures that would occupy existing beaches or the shallow nearshore areas along Lake Erie have impacts on these unique and limited habitats. In the simplest terms, structures use space that would otherwise be available to the organisms that would normally be there.

Beaches are ephemeral over seasons and years but they can be sustained and augmented with appropriate care and design. Unfortunately, shore structures such as revetments and seawalls can result in the complete loss of the beach. Once the nearshore is filled, it is lost and cannot be replaced.

The impact of one small project may seem inconsequential, but the cumulative impact of the addition of thousands of small shore structures along the shore over many decades has significantly changed both the quality and the quantity of beach and near shore habitats.

The most straight-forward design approach to minimize the impact on beach and nearshore habitats is not to construct on the beach but instead locate structures up the bluff or bank face. This is not always possible, so the next level of habitat-impact design is to minimize the distance the structure extends from the toe of the bluff or bank.

Structures that extend lakeward beyond a minimum distance from the toe of the bluff or bank must be balanced between one person's use and the good of all the people, fish, birds, invertebrates and micro-organisms to whom Lake Erie has been entrusted.

Other design considerations in the general arrangement of shore structures

There are factors in addition to those discussed above that need to be considered in planning the general arrangement of shore structures.

First, lake access structures such as seawalls may not be necessary along the full length of a property's shore. In some cases projects will provide better functionality if access structures and erosion control measures are combined.

Second, a structure needs to be rounded and merged into the upland as it approaches the littoral property boundary to avoid both impacts to adjacent property and to minimize the potential for flanking around the ends of the structure. Straight, shore perpendicular ends of structures can lead to chaotic wave conditions that can result in increased wave-based erosion at such corners.

One of the most common issues associated with shore structures is the large size and weight of the material required. In many cases, this also means that a significant area of the upland must be used for staging, movement of materials and heavy construction equipment such as dozers, track-hoes and cranes. Access for trucks is also usually required. The use of heavy equipment on a small residential lot can have a serious impact on the property and may even result in damage to the bluff or to neighboring properties. Experienced contractors and engineers who specialize in building along the shore of Lake Erie have valuable insight into the planning and logistics needed to deal with these issues. This is also a very good reason for coordinating projects along multiple parcels involving a number of property owners.

Another challenge is construction along the vertical shale bluffs (pictured below) present in Cuyahoga and Lorain counties. At some sites the bluff can be more than 50 feet high. Dumping of material from the top of bluffs is not a good construction practice and can have negative consequences such as unintended breaking up of the material, making it susceptible to movement by wave action onto adjacent properties and also pollution of the lake by fines associated with the material.

The weight of heavy trucks and equipment at the edge of a bluff can cause damage to the bluff itself leading to loss of sections of the upper bluff. The best alternative in high, vertical bluff areas is to place material from a barge.

Construction atop a vertical shale bluff such as that pictured below can be challenging as the weight of heavy trucks and equipment at the edge of a bluff can cause damage and lead to erosion.

Design drawings, engineering methods and calculations, materials specifications and supporting information

The purpose of creating design drawings and specifications for the materials of construction is communication. The drawings, specifications and supporting information are the means by which the intentions of the owner and the engineer are communicated to the contractor who will build the structure and to agencies that will review the design and authorize the construction.

The drawings and specifications become a part of regulatory authorizations. The documents also become a permanent public record of the approved design including the exact dimensions of the project and the specific materials described by the drawings and specifications. OCM offers the following *Suggested Standards* as a step toward the goals of decreasing the time required by agencies to review design submittals and eliminating the need to revise designs during and after regulatory reviews. The drawings and engineering calculation sheets included in the design examples in Chapter 4 have been prepared using these standards.

Suggested standards for engineering and surveying drawings

1. All drawings must be identified with information in the title block. This must include the project name, address, sheet title, sheet number and engineer's name.

2. Plan views, cross sections and any other drawings depicting features of the site or structures are to be at standard scales and shall include a bar scale. The scale must be noted in the drawing title block.

3. The drawings must accurately and adequately show the features of the proposed structures and the existing site information. Existing conditions and proposed work must be on separate drawings.

4. The drawings and text on the drawings must be composed in a manner so that they can be reproduced by photocopy and scanning so that all features of the site are presented in a clear and easily readable fashion.

5. The existing plan view must include the existing contours of the upland, all potentially affected upland structures, and the existing beach and shore structures present along the beach, shore, or nearshore. The existing plan view drawing must not include any proposed structure or modification to the existing site conditions.

6. The existing plan view drawing must also include the profiles or contours of the off shore bathymetry to a distance of at least 100 feet beyond the extent of the proposed structure. The number of bathymetric profiles required to define the nearshore will vary with the project. As a general rule:
   - Property width less than 75 feet - 2 profiles
   - Property width 75 to 100 feet - 3 profiles.
   - Property width greater than 100 feet- 1 profile for every 50 feet.

7. All elevations, both bathymetric and upland topographic, must be referenced to the International Great Lakes Datum of 1985.

8. Plan view drawings of the proposed structures must include all of the site features present on the existing plan view. Changes to the upland topography after construction must be included. All proposed shore structures must be fully dimensioned in the plan view, including:
   - The linear distance along the shore.
   - The distance the structure extends from the existing toe of the bluff or shore at all significant features of the structure.
   - Elevations of structure crests, caps and toes.
   - Slopes of structures.
   - Location, extent and volume of sand pre-fill.

- Location of the area where excavated or dredged sand by-pass is to be placed.

9. Cross sectional drawings of the proposed structures must be consistent with the plan view and the location of the cross sectional views must be shown on the proposed plan view. Cross sectional views must be sufficient to detail all aspects of the structure. If there are multiple components or significant differences in dimension or the materials of construction, multiple cross sectional views will be necessary.

10. The geology of the bluff or bank and the nearshore must be shown on the cross sectional views. The elevations of changes in strata must be shown. The existing profile of the bluff or bank must be shown on the cross sectional drawings.

11. The elevations, dimensions and the arrangement of, and note of, the materials of construction of all significant features of the structure must be shown on the cross sectional view. These include the following:
   - Elevations of structure crests, caps and toes.
   - Elevations where materials of construction change.
   - Elevation of the lake bottom at the toe of the structure.
   - Slope(s) of the structures.
   - Structure dimensions such as armor stone and underlayer thickness, and toe trench depth.
   - Distance from the toe of the existing bluff to the lakeward extent of the structures.
   - Design Water and Wave Height elevations.
   - Profile of any proposed sand pre-fill.
   - Materials of construction.

12. The details pertaining to the structural stability and construction details of the structures should be included on the plan and cross sectional drawing to the extent possible. Supplemental drawings providing sufficient detail to allow evaluation of the stability and the structural connections (re-bar, tie-backs, grouting, cables, etc.) between structural elements must be provided if these features cannot be clearly represented on the plan and cross sectional views. Materials of construction, re-bar sizing and spacing and similar details can be included as notes on the drawings. All design detail and specification of construction materials must be included on the drawings.

13. The signature, date and the stamp or seal of the Ohio registered professional engineer or professional surveyor who prepared the drawings must be affixed to each drawing sheet or an appropriate, bound cover sheet. In accordance with Ohio Revised Code 4733.14, "*...Plans, specifications, plats, reports, and all other engineering or surveying work products issued by a registrant shall be stamped with the seal or bear a computer-generated seal in accordance with this section, and be signed and dated by the registrant.*"

Suggested standards for engineering methods and design calculations

Design calculations must be clearly presented to document how the selection of the structure's dimensions and materials of construction will result in a stable structure under the design water level and design wave conditions. The specific equations or engineering methods used must be noted. The basis for using assumed values must be stated.

The basis for the selected design water level and design wave height must be documented.

The basis of design for each key element of a structure must be stated. This would include design features such as revetment crest height and width, seawall cap height and width, and the length of piers.

Any specific coastal engineering data or information relied on by the engineer or related to design conditions must be clearly stated. This would include the use of wave hindcast data, wind developed wave conditions, or the assessment of fetch-limited wave conditions.

Excepting armor stone revetments and other rubble mound structures, all other proposed structures along the shore must be analyzed for both sliding and overturning stability. Consideration must be given to wave forces as well as passive earth forces if a structure will be acting as a retaining wall and a seawall.

Calculations related to the volume of littoral material required to reach equilibrium under design water levels by a structure must be fully documented, including all assumptions.

The specific, referenced engineering method, and the input values known and assumed must be cited. For example, if calculations are done using the Automated Coastal Engineering System (ACES) software, the specific module used and the input parameters must be listed.

Suggested standards for material specifications

All materials to be used in the construction must be specified and noted on the drawings. This includes:

- Cast-in-place concrete, strength and re-bar size and configuration.
- Armor stone size and weight.
- Other stone size and weight.
- Pre-cast concrete strength, reinforcing and dimensions.
- Geotextile-fabric filters: material type or manufacturer specification.
- Steel used as bulkhead or cribbing: size, weight and connection detail.

Particular care must be given to specifying fill. Common "clean, hard fill" that may be appropriate for upland applications is highly problematic when used as part of shore structure construction. A fill that contains a high percentage of fines, debris or vegetation will not be suitable for use along the shore of Lake Erie.

If "concrete rubble" is specified as a fill material it must be free of exposed rebar, free of all fines and contain no debris. The specific size or range of sizes for the concrete rubble must be included in the specification.

Sand to be used as pre-fill or beach nourishment must be specified using standard sieve sizing and gradation and in most cases must be specified as originating from an upland source.

Suggested standards for supporting information

Supporting information refers to information relative to the design of the shore structures in addition to that which appears on the design drawings and/or is documented in the engineering calculations. In many cases, this information would be submitted as part of an application for a regulating agency authorization.

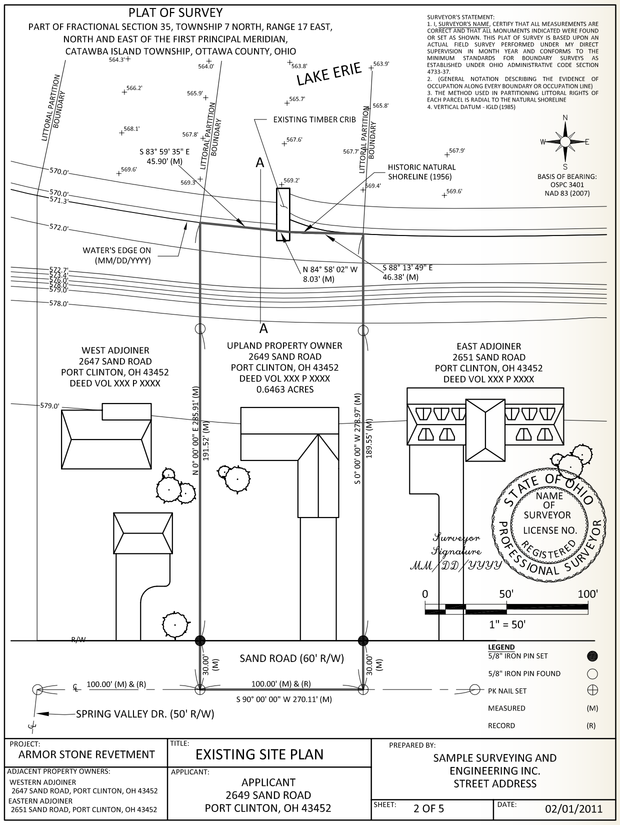
The purpose or function of each major element of the proposed work must be clearly stated.

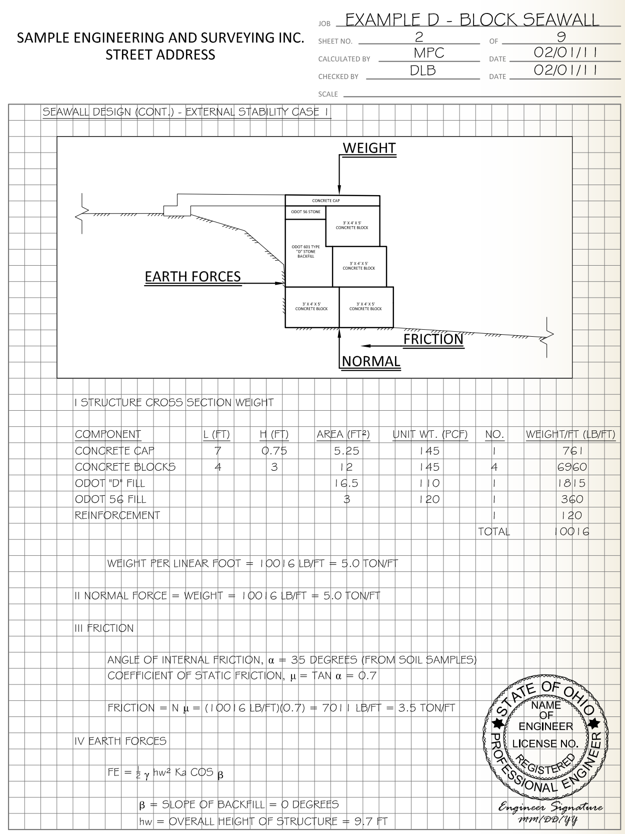
Any assumptions regarding the influence of the geology of the site must be included in the supporting information. This should include the identification of the upland strata and the composition of the nearshore.

Any expected effects on the littoral system as a result of the proposed structures must be discussed and documented.

A plan for long term monitoring, sand by-pass or beach nourishment that is to be conducted following construction, if needed as part of the project, must be included in the supporting information. The details of the plan can also be included as notes on one or more drawings that indicate monitoring profiles and the location(s) where by-passed sand is to be placed.

Any information used to develop the design or layout of the proposed work must be included as supporting information. This may include photos, studies, geotechnical or soil boring data, sediment or beach particle size data and pertinent historical information.





Existing site plan and calculations sheet. Full size versions are found in Chapter 4 in the design examples, Section 4.5.

Chapter 4. Erosion Control Structures

4.1 General Design Guidelines for Erosion Control Structures

This chapter addresses the design of stone revetments and seawalls, the most common structures used to prevent erosion along the shore of Lake Erie. These structures are designed to protect against the erosion of the lower portion of the bluff due to wave action. Erosion of the upland caused by surface water runoff, groundwater seepage or the natural weathering of the bluff may require separate, additional measures. Since they are usually designed in conjunction, guidelines for upland erosion control measures are also included in this section.

The five design examples are intended to demonstrate the design process. The example sites are fictitious. The site conditions, parcel boundaries, addresses and parcel numbers were invented to illustrate the range of engineering and surveying methods involved in design. The example sites include typical coastal features and are intended to be applicable to a large portion of Lake Erie's south shore.

Protection against wave-based erosion

The guidelines below address the elements of shore structure design common to nearly all erosion control structures subject to direct wave action and run-up.

1. Minimize the extent lakeward.

Erosion control structures should be designed with the smallest lakeward footprint possible. This minimizes the occupation of the lake bottom, limits habitat loss and usually results in a lower cost to construct the project.

In the case of stone revetments, the crest width should be only as wide as necessary for a stable structure. In general, the revetment should follow the cross-section of the bluff and be located as close to the bluff as possible.

For seawalls, the distance that the structure extends lakeward of the upland must be minimized. If the seawall height is appropriately designed to prevent the majority of overtopping, there is no engineering rationale based only on erosion control which justifies extending a seawall out into the lake.

2. Minimize the impacts to adjacent properties.

The design of the structure must consider the potential for damaging adjacent property.

Projects designed to extend lakeward of the shore will affect the movement of littoral material, reducing the overall beach forming process which in turn may cause accelerated erosion on adjacent or down-drift properties with less protective beaches.

Seawalls, (and to a lesser extent, stone revetments) change the direction (wave reflection) and intensity of wave energy along the shore. Wave reflection can cause an increase in the total energy at the seawall or revetment interface with the water, allowing sand and gravel to remain suspended in the water, which will usually prevent formation of a beach directly fronting the structure. This effect may impact the adjacent downdrift properties by either reducing beach formation (immediately adjacent) or potentially increasing beach formation (further downdrift). In extreme conditions wave reflection may allow littoral material to be transported off shore rather than along the shore, which would potentially remove that material from the littoral system and starve downdrift beaches.

3. Structural Stability.

The design must include the applicable calculations to demonstrate that the proposed structure will have long-term stability. These principles were introduced in Chapter 3.

For stone revetments, the stability of the structure depends on the unit weight of the armor stone, the slope and the design wave height. The most common calculation used is Hudson's Equation, which relates the design wave height and design slope of the revetment to the weight (and size) of the stone needed to resist uplift (and displacement) from wave energy. This calculation is presented in the revetment design section and the examples that follow.

The stability of a seawall depends on its total weight in cross-section, location lakeward of the shoreline, cap elevation, underlying geology, and the degree to which it is used to retain the upland bluff. For the purposes of this manual, a seawall is a shore-parallel structure with a nominally vertical face. Typical seawall designs common along the Lake Erie shore include stacked pre-cast concrete block, cast-in-place concrete walls and stone-filled cribs.

The design should include details and specifications that show how blocks or cribs are to be connected and sufficient reinforcing detail that shows how cast-in-place concrete walls and caps will be connected. How the seawall is to be anchored into the underlying strata must also be detailed.

4. Materials of Construction.

The specifications for all materials to be used as part of the erosion control structure must be included in the design drawings. Particular attention should be paid to the specifications of fill materials that may be used under armor stone or behind seawalls. Demolition debris and common clean fill (dirt) are not acceptable materials for structures potentially exposed to the waters of Lake Erie (either during construction or post-construction).

Concrete rubble, if specified as fill, must include a size (weight) range and be clean and free of smaller material and exposed rebar. Concrete rubble should never be specified for any exposed portion of any structure.

5. End Effects / Flanking.

The design should avoid abrupt, shore-perpendicular ends at property boundaries. In general, both revetments and seawalls should be "rounded" off at the ends and/or meet the existing bluff slope contours. This will reduce the potential for erosion at the adjacent property working its way back behind the structure and causing upland slope failure and possible failure of the end of the revetment or seawall. If existing structures are present at adjacent properties, the proposed design should transition to these as smoothly as possible.

6. Design of Toe Protection.

Adequate toe protection should be included in the design to prevent sliding failures, scour and undermining at the base of a seawall. Both revetments and seawalls should also be adequately set into the underlying strata.

For armor stone revetments it is common practice to specify that stone at the upper end of the armor stone size range be placed at the toe, or toe stone 1 to 2 tons or greater than the design median armor stone size.

Many seawalls are used for recreational or watercraft access. The use of armor stone as toe protection in the design of a seawall may interfere with this function. Nevertheless, toe protection at the seawall base is recommended as a means of preventing the scouring and undermining of the structure and increasing its expected life.

Protection against upland erosion

The height and composition of the bluffs along Lake Erie's coast are highly variable. Addressing the erosion caused by groundwater seepage, surface water run-off and natural weathering is dependent on site conditions. The Lake Erie Shore Erosion Management Plan (LESEMP) addresses many of these issues on a regional and reach basis and should be consulted as a supplement to this Manual. LESEMP information is found online at:

www.ohiodnr.com/tabid/20501/default.aspx.

The general guidelines presented here are intended to apply to the bluff and upland areas landward of a well-designed and constructed erosion control structure.

The design of the upland erosion control features at a site should complement and work in concert with the proposed shore structure. Options for stabilizing the upland include:

1. Re-grade the existing slope to at least 2 horizontal to 1 vertical.

This option applies where there is adequate distance between the shore structure top elevation and upland structures. Stabilization through re-grading and vegetating the bluff slope has been fairly successful along shores with bluffs composed of till and bluffs of medium elevation (less than about 40 feet).

2. Retain as much existing vegetation as possible.

Native trees, shrubs, and perennials are the best means of limiting erosion from surface water run-off and naturally reducing flows from groundwater seeps. This is especially important along areas with medium to high till bluffs (40-60 feet). Tree and shrub roots are also extremely effective at stabilizing existing upper bluff soils.

3. Reduce or re-direct surface water sheet flow or collected surface water drainage.

A slight swale at the top of the bluff, coupled with a well designed trench drain can eliminate most of the sheet flow down the bluff. Collected surface water should be diverted landward if at all possible; if not, the conveyance pipe should be run down the bluff to as close to the lake elevation as possible. Outlet protection should be placed at the down-slope end of the pipe to prevent erosion at that location.

As a general consideration, the less surface water conveyed over the edge of the bluff, even as limited sheet flow, the better. For sites with unfavorable geology leading to perched water and seeps at the bluff face, the less upland surface water allowed to infiltrate into the groundwater the better.

If downspouts, other surface drainage or basement sumps are currently collected and conveyed over the bluff, the optimum means of discharge should be a pipe that extends the full distance to the toe of the bluff. Pipes suspended over the bluff allow the water to erode the bluff below it.

4. Terrace the upland.

Low-height terracing can be a cost-effective means of stabilizing the upland bluff and can be designed to provide access pathways to the lake. As a general consideration, multiple, 3 to 4-foot high terraces will be less prone to a large scale bluff failure, lower in initial cost, and easier to repair than fewer, higher retaining walls. Terracing can also be effective in intercepting groundwater seeps and diverting the water along the terraces.

4.2 Armor Stone Revetment Design

This section presents a simplified approach to the design of the most common type of revetment: rough, angular stone armoring. Examples A, B and C in section 4.5 illustrate revetment designs at three types of site settings. The primary references for the design of armor stone revetments are the U.S. Army Corps of Engineers "Coastal Engineering Manual" (the CEM) and Engineering Manual 1110-2-1614, "Design of Coastal Revetments, Seawalls and Bulkheads."

Components of an armor stone revetment are:

1. The ***armor layer*** consists of sufficiently sized stone and a thickness designed to be stable under the design wave conditions and the design slope.

2. The ***filter layer*** consists of smaller stone or rubble that supports the larger armor stone and prevents erosion of the underlying bluff material. This layer may also be called a bedding layer. If this material is intended to be impermeable, it may be referred to as a "core". Many revetments include geotextile fabric under the filter layer to further reduce the potential for erosion of underlying fine-grained bluff material.

3. The ***toe stone*** consists of heavier stone placed at the lakeward edge of the revetment, and serves to prevent slipping failure of the upper revetment. In many cases the toe stone will also be placed in an excavated trench into the underlying natural material.

4. The ***crest*** is the upper elevation of armor stone. When the crest is designed as a horizontal feature, it is nominally as wide as the armor stone layer thickness. The height of the crest above the design water level is determined by the calculated run-up elevation of the design wave.

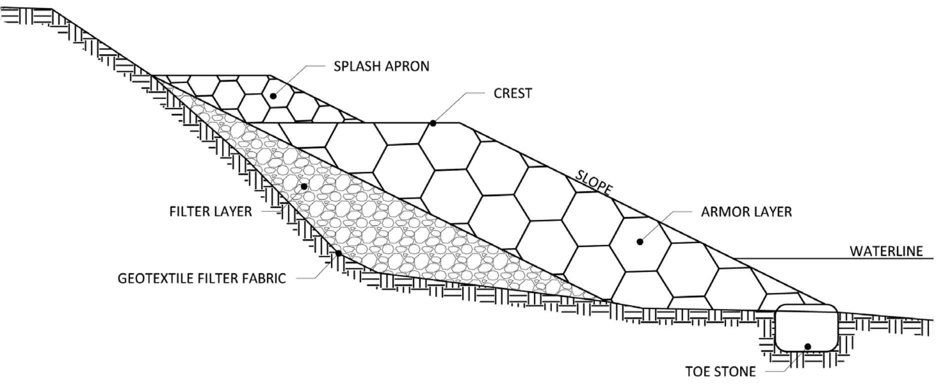
5. The ***splash apron*** is located above the crest and usually consists of much smaller stone. It serves as a less costly means of dissipating the remaining wave run-up, splash and spray that can extend above the armor layer.

Revetment Design

Armor material

The majority of armor stone used along Lake Erie is quarried limestone. Sandstone is also available. Allowances for the lighter mass density of sandstone (specific gravity of 2.2 to 2.5 for sandstone versus 2.6 for limestone) must be included in the design calculations. Sandstone is more resistant to cracking than limestone but it is also a softer material and more easily eroded. The use of concrete block or specialty concrete forms as armor material is addressed in the Corps of Engineers' CEM. Concrete typically has a specific gravity of 2.4, but it can be much lighter.

Concrete rubble should never be used as armor material due to its tendency to crack and break apart easily, reducing the unit weight of the block. It is also difficult to obtain concrete rubble of a sufficient weight per piece that would be needed to resist wave



In addition to its recreational and aesthetic features, the presence of a beach lakeward of an armor stone revetment will aid in erosion protection.

forces. Further, it is also difficult to control the size and shape of rubble since most rubble tends to be from slabs that are limited in one dimension (the slab thickness). This shape limitation tends to result in both breaks and the creation of large voids, neither of which favor a stable structure.

Revetment Design

Slope

The maximum recommended slope of a random-placed armor stone revetment is 1.5 horizontal to 1 vertical. Slopes greater than this will tend to be unstable. A 1.5H to 1V slope results in the smallest stable footprint along the shore. Where possible, revetment slopes should be selected to match the existing bluff/bank slope's stable angle of repose. In practice, revetment slopes range from 1.5 to 1 to 2.5 to 1. Slopes greater than 3 horizontal to 1 vertical are rarely specified along the Lake Erie shore, mostly due to the higher cost of armor stone needed to construct what would be a wider revetment than might be necessary.

Armor Stone Weights and Dimensions (for Limestone)

Tons / ODOT Stone Type	Pounds per Stone	Stone Diameter, (feet)	Two-unit layer thickness (feet)
8 - 9	17000	4.75 -5	9.5
7 - 8	15000	4.5 - 4.75	9
6 - 7	13000	4.25 - 4.5	8.5
5 - 6	11000	4 -4.25	8
4 - 5	9000	3.75 - 4	7.5
3 - 4	7000	3.5 - 3.75	7
2 - 3	5000	3 - 3.5	6
1 - 2	3000	2.5 - 3	5.5
ODOT "A"	1250	2	4
ODOT "B"	500	1.5	3
ODOT "C"	160	1	2
ODOT "D"	20	0.5	1

Notes
1. ODOT is Ohio Dept. of Transportation, specification 703.19 Rock and Aggregate Materials.
2. Stone size assumes rough cubic shape, quarry stone can be irregular.
3. The calculated two layer thickness is the approximate median value for the range based on the equations used by USACE. In-place thickness may be less.

Revetment Design

Armor layer

The basis of the design for sizing the necessary weight and size of the armor stone units is the relationship between the force of the design wave (design wave height) and the slope of the structure. This relationship is expressed as follows:

Hudson's Equation

$$W_{50} = \frac{W_r H^3}{K_D (S_r - 1)^3 \cot\theta}$$

Where:

- W_{50} is the 50th percentile (median) weight of the stone (lbs)
- W_r is the unit mass of the stone (lb/ft^3) Limestone typically is 160-165 lb/ft^3
- H is the design wave height (ft) at the toe of the structure
- $S_r = W_r / W_w$; (W_w = 62.4 lb/ft^3)
- K_D is an empirical value based on physical testing. For randomly placed, angular stone $K_D = 2.0$
- $\cot\theta$ is the design slope of the revetment. For a 2:1 slope, $\cot\theta = 2$

Hudson's equation addresses only the stability of armor stone with respect to wave forces at a given slope. The calculation relies on the risk assumed with a given design water level (the return period) and wave height, both of which may be exceeded during the life of the structure.

The other factors that can affect long term stability include the quality of the stone, the range of actual sizes supplied, the placement on the slope, fracturing of the stone over time and the effect of ice forces.

These factors are independent of each other and can all add to the long-term risk of failure of the revetment.

Ice forces are very unpredictable and difficult to calculate for revetments. Ice may act laterally against the slope moving and displacing stone, large ice blocks may drag stone lakeward as the ice recedes and ice can exert an uplift force on the stone as it forms along the shore and is thrust landward by wave action.

Every site and every design will have different wave conditions, materials of construction & upland geology.

Armor stone is subject to fracturing over time and during transportation and placement. The stone will fracture due to ice, freeze and thaw and wave forces, losing its unit size/weight and thus its stability.

OCM recommends a safety factor be applied to the calculated unit stone weight as a measure of risk reduction against fracturing, ice forces, and variability in stone size and placement. The engineer should consider how these factors apply to each design and assign an appropriate safety factor that also incorporates the level of risk the property owner is willing to accept in return for the cost difference between larger or smaller armor units.

It is common to specify a range of stone size, using the design weight from Hudson's equation as the lower value in the range. A range of stone size may also be a factor in the available supply of stone from a quarry. If a range of armor sizes is used, the design should specify that the larger stones be placed on the exposed layer directly receiving wave forces. This results in a conservative design that helps counter damage and poor placement of the stone during construction. USACE (in EM 1110-2-1614, "Design of Coastal Revetments, Bulkheads and Seawalls") recommends a range of armor stone between 0.75 x W_{50} and 1.25 x W_{50}. USACE in the CEM notes that uniform sizing of armor units is more economical for design wave heights greater than 4.5 feet.

The thickness of the armor layer is determined by the dimensions of the stone size selected for stability. The most common, and perhaps most cost effective arrangement is to specify two layers of armor stone.

The approximate diameters for armor stone weights and the calculated layer thickness for a two-layer armor design are included in the table on this page. The armor layer thickness will tend to be slightly less than those in the table if a larger range is specified due to closer packing of stones. The design armor layer thickness can be calculated using a formula from the CEM that requires one to assume the number of layers and the unit stone size. The rubble mound revetment design module in the ACES software also includes this calculation.

A single layer of armor stone cannot be expected to have long-term stability or effectively prevent erosion. A single displaced stone could allow wash-out and erosion of the filter layer, and potentially the bluff material, leading to failure of the revetment.

Revetment Design

Crest elevation

The crest elevation for an armor stone revetment is based on the wave run-up expected given the revetment slope, the design wave height, wave period and water level. The equations used to calculate run-up were presented in Chapter 3. The empirical formula shown below will generally result in a conservative run-up value.

$$\text{Run-up} = \quad R = H\frac{a\xi}{1+b\xi}$$

$\boldsymbol{R}$ = run-up in feet

$\boldsymbol{a}$ = 1.022

$\boldsymbol{H}$ = design wave height in feet

$\boldsymbol{b}$ = 0.247

ξ = surf similarity parameter (Iribarren number)

The surf similarity parameter ξ

$$\xi = \frac{\tan\theta}{\sqrt{2\pi H / gT^2}}$$

$\boldsymbol{\tan\theta}$ = revetment slope (e.g. 2:1 slope = 0.5)

$\boldsymbol{g}$ = 32.2 ft/sec^2

$\boldsymbol{T}$ = wave period in seconds

The calculated height of run-up is added to the DWL elevation to arrive at a conservative design elevation for the revetment crest.

Revetment Design

Function of the filter layer

The filter layer consists of graded rock or riprap and in some cases a geotextile fabric. It acts as a transition between the underlying soil and the armor structure. It prevents the migration of fine soil particles through voids in the structure, distributes the weight of the armor material to provide more uniform settlement and permit relief of hydrostatic pressures within the soils. In the case of revetments which extend above the water level, filter layers also help prevent surface water from causing erosion beneath the armor material.

The top photo shows typical concrete rubble of greatly varying size. The larger slabs may not be suitable as filter layer material. A revetment is shown in the bottom photo.

Revetment Design

Filter layer design

The long-term stability of the revetment armor layer rests, in part, on the design of the filter layer. The material(s) for the filter layer should meet the following conditions:

1. The material should be resistant to erosion caused by run-up and water washing through the armor stone. Fine grained material or a mix of larger material with fines should not be specified.

2. The material should be capable of supporting the weight of the armor stone layer without significant displacement or creation of significant voids. Random pieces of concrete rubble are problematic as filter material due to the potential for large voids and uneven settlement.

3. The material should be capable of preventing erosion and loss of the underlying bluff material. Geotextile fabric placed between the filter layer material and the bluff material can prevent loss of the fine grained bluff material.

The filter layer should be designed to minimize the amount of fill needed. The slope of the filter layer will usually be the same as the slope of the armor layer. The thickness will be determined by the cross-section of the bluff and the type and size of material to be used. In general, the filter layer thickness is two to three times the average stone size used in the filter layer. As a design guideline, the USACE recommends a filter layer stone size that is 10 percent of the size of the armor stone. The use of larger stone or rubble increases the potential for uneven settling and the creation of large voids. Smaller filter layer stone can be specified if it is underlain by impermeable bluff material and a geotextile fabric to reduce the loss of fine material from the bluff.

Neither the filter layer nor any underlying fill should ever be exposed to direct wave action or run-up.

4.3 Seawall Design

Seawalls can be effective erosion control structures and have the added functionality of providing direct access to the lake.

The negative aspects of using a seawall to control wave-based erosion include:

- The vertical or near-vertical wall generally will create higher wave run-up, splash and spray compared to a sloped stone revetment.
- The wave energy exerted on the vertical seawall is not dissipated as it is over the slope and irregular surface of a revetment. This results in greater forces on the structure and more potential for damage.
- The vertical wall will reflect a high proportion of the wave energy which increases the energy in the nearshore. This may preclude the formation of a beach directly lakeward of a seawall unless the wall is well landward of the water and a stable beach is already present.
- The toe of a seawall is subject to scour and undermining due to direct and reflected wave energy. This effect can be magnified as lake levels change seasonally and year to year. Long-term scouring at the seawall may eventually lead to the down-cutting of the lake bed, resulting in a lower lakebed elevation (and higher water level, thus higher waves) lakeward of the wall.

General considerations

Seawalls along the shore of Lake Erie have been designed and constructed in many different configurations using steel sheet pile, cast-in-place concrete, pre-cast block and rock-filled cribs. There are locations along the shore where each of these types might be appropriate, cost-effective, and feasible.

In this section the focus is on the most common types of seawalls: pre-cast block and stone-filled cribs. These types of seawalls are built with modular unit construction (blocks or cribs) that can facilitate construction and result in lower cost. Both types can be considered gravity structures in that the weight of the structure is expected to resist the wave forces as well as any earth pressures from the fill landward of the seawall.

Seawall design components:

1. ***Location of the seawall*** with respect to the shore. This is a critical design choice since it is directly related to the existing site bathymetry, the existing conditions present at the bluff, and materials along the shore.
2. The ***height of the lake-facing wall*** with respect to the design water level.
3. Total ***weight of the wall*** to the degree that its components act as a single mass.
4. The ***structural connections*** that assure a stable, unified structure able to resist sliding and overturning forces. These may include design features such as reinforcing steel to connect the vertical wall to the cap, reinforcing or cabling to connect unit blocks together, and the means of connecting the members of the crib structure together.
5. ***Fill material*** landward of the seawall face or placed within the crib structure.
6. The ***seawall cap*** which prevents overtopped water from eroding the fill material.
7. The provisions for ***drainage*** of run-up, splash, spray and groundwater.
8. Provisions for ***toe protection*** or ***prevention of scour*** or undermining.

Seawall Design

Wall & cap height

Unlike revetments, the height of a seawall is not often determined solely by calculating the run-up height and adding it to the DWL. There usually are functional concerns that come into play which result in a wall height less than what would be needed to prevent run-up and overtopping. The most common functional issue is access to the waters of the lake.

A seawall cap elevation 10 feet above the average summer lake level (about 571.5 feet IGLD 1985) would prevent run-up and overtopping a large percentage of the time, but it would also make access more difficult.

Seawalls designed to be higher than the upland elevation (protecting low-lying areas) are an example of when run-up and overtopping under severe flooding conditions are the most important design parameters.

Concrete block seawall along Ohio's shore.

Seawall height is an important aspect of the overall stability of the structure. Concrete blocks stacked more than three units high have a tendency to be much less stable unless significant interconnection and tie-backs are included in the design. Similarly, steel frame cribs become more susceptible to bending and overtopping stresses as the crib height increases.

It is common to design seawalls with relatively low wall heights (elevation 576 to 580 feet IGLD 1985) and include a retaining wall landward of the cap that serves to contain the run-up and overtopping that would be expected under high lake water level and severe storm conditions.

If a seawall height is determined for functional reasons it is appropriate that this basis of design be identified in the design information.

Seawall Design

Run-up & overtopping

Run-up height for seawalls can be estimated using the same equations presented in Chapter 3. The estimate using the empirical (FEMA) equation $R = 0.7 \times H_b$ will tend to underestimate the run-up, especially considering that the vertical face of most seawalls will force significant amounts of water into the air, which can then be carried by the wind over the crest of the wall. While the wind-borne wash may create overtopping volumes that need to be addressed for erosion or drainage control, this effect is not as significant from a structural standpoint.

If run-up and overtopping volumes will be significant, a straight-forward option is to include a second wall landward of the cap that would serve as a barrier to overtopping water reaching the bluff or bank. In many cases this would be a wall of lower height that would also function as a retaining wall. It is not recommended that the seawall cap width be designed as the means for attenuating overtopping effects. Wider seawall caps are in opposition to the design goal of minimizing the lakeward extent of an erosion control structure.

Seawall Design

Sliding and Overturning

Each seawall design should be checked for both sliding and overturning. Every site and every design will have different wave conditions, materials of construction and upland geology. The engineer should carefully evaluate all potential forces acting on the seawall and the expected types of structural failure. The simplified illustrations on this page describe some of the conditions that may be present at a site and the two most common failure modes that need to be checked. The Design Examples for concrete block and steel frame crib seawalls that follow in section 4.5 more fully detail both sliding and overturning calculations for specific site conditions including wave forces.

Basic Sliding Safety Factor Equations

$F_{safety\ factor}$ = **(N** x **tan Φ + c** x **L) / T** (the resisting forces divided by the sliding forces)

N = F_{block} **-** F_{up}, F_{block} is the weight of the seawall, F_{up} is the uplift due to the seawall being submerged.

Φ = angle of internal friction of the fill or upland material, typically 0.35 for fill

L = length of the resisting area (ft)

c = cohesive strength of the foundation material, usually ≤ 1.0 lb/ft

T = F_{earth} = earth pressure = K_a x **(W-**W_w**)** x H^2 **/ 2**

K_a is the lateral earth pressure coefficient (typically 0.22 to 0.3 for stone, based on the friction angle)

W is the weight of the block or seawall material, per square foot

W_w is the unit weight of water (62.4 lb/ft^3)

H = d_s = the height of the structure at the DWL

Seawall Design

Overturning safety factor

The factor of safety for overturning is the sum of the resisting moments divided by the sum of the overturning moments. The diagram below and the two formulas show the basic relationships.

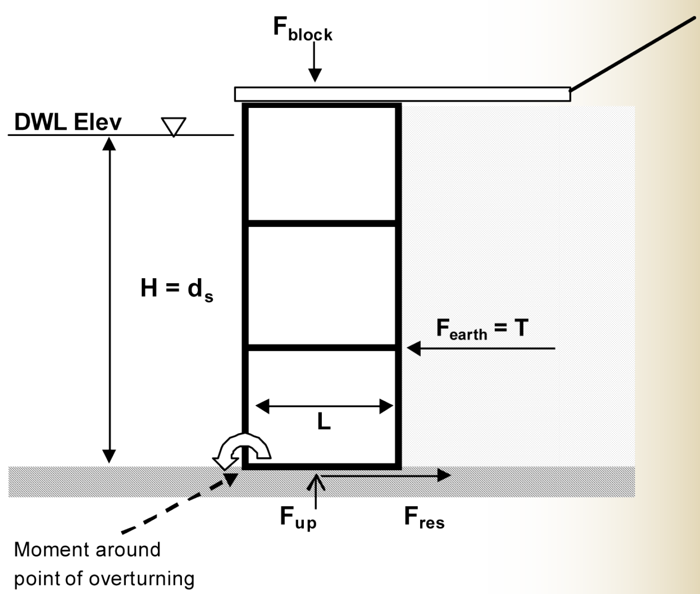
Σ Resisting forces = F_{block} x ½ block width

Σ Overturning forces = F_{up} x ½ block width + F_{earth} x 1/3 H

This case assumes that the wall is under static conditions and that the forces due to the height of water are equal on both sides. The moments due to wave forces will act in the opposite direction as the earth pressure forces, so the static condition, ignoring the wave forces (assuming that there are no waves) is considered the worst case.

Every design will have very specific conditions that must be analyzed on a case by case basis. The equations and assumptions above should be considered only as a very simple example.

Seawall Force Diagram for Static Conditions



Pre-cast concrete block seawall design

There are many pre-cast concrete block configurations and sizes. The most common use a transverse tongue and groove to resist sliding forces of the stacked blocks. The specific sizes used will depend on factors such as the equipment available for installation, the pre-cast forms used by a manufacturer, the engineer's or contractor's familiarity with a specific type of block and the overall dimensions needed for the seawall.

As the table shows, pre-cast concrete block unit weights are in the same range as typical armor stone. There are also block seawalls that use large hollow pre-cast units. These are usually connected with reinforcing bars and the open space then filled with grout or concrete.

Block seawall general arrangement

The following guidelines reflect OCM's experience reviewing many designs and observing the performance of existing structures along the shore.

1. The layout of the seawall should match the plan of the shore. If the shore is curved, the seawall should be designed to match the shore plan.
2. A second row of block landward of the lower tier of block may provide additional stability and reduce the potential for sliding failure. The two blocks of the first tier should be structurally connected.
3. Designs that include a slight over-hang of the cap (with a chamfer) can help reduce overtopping by redirecting a portion of the wave energy lakeward.
4. Stepped block seawalls, with each tier slightly set back from the one below will generally result in a more stable structure with reduced run-up and overtopping.

Typical Pre-Cast Concrete Block Sizes

Dimensions (ft)	Volume (ft^3)	Weight (lbs)	Weight (tons)
3 x 3 x 3	27	3915	2.0
3 x 4 x 5	60	8700	4.4
4 x 4 x 4	64	9280	4.6
3 x 4 x 7	84	12180	6.1

NOTE: Based on 145 lb/ft^3 unit weight concrete

Block seawall structural design

Structural design considerations include:

1. The first tier of block must be set on firm material, with sufficient bearing capacity to resist settling. Shale and hard glacial till are present below the nearshore beach material along much of the Lake Erie shore from Erie County east. The conditions at each site should be verified, as there are numerous anomalous buried stream beds and discontinuities along the shore.
2. One of the most common reasons for the failure of block seawalls is the eventual undercutting of the nearshore, causing scour of the foundation material under the block. This is due to changing lake levels and to the reflected wave energy from the seawall itself. To counter this common long-term threat to the structure the design can:
   a. Include entrenchment into the underlying material;
   b. Provide stone toe protection to reduce scour; or
   c. Locate the seawall as far landward as possible, which reduces the amount of wave energy at the structure's toe.
3. The importance of providing substantial interconnection of the blocks, cap, and any required tie-backs cannot be overstated. Although individual block units may have sufficient weight to resist wave forces, a unified structure is the best means of preventing significant failure of the seawall.

Steel frame crib design

The use of shore-fabricated steel frame cribs as an element of erosion control structures along the Lake Erie shore has been on the increase since the 1990s. Prior to this, timber frame cribs were more common. While this chapter addresses the use of cribs as seawalls for erosion protection, cribs are also commonly used as pier segments for watercraft access structures.

Steel frame cribs are essentially rigid baskets that are filled with appropriately sized stone or rubble to create a unified gravity structure that is capable of resisting the Design Wave forces. The total weight of the stone fill within the crib acts as a single mass. This is an advantage when compared with the required unit weight, size and cost of armor stone under the same design conditions.

Since the crib structure is partially open to the water on the face, and the rock is generally large in diameter, the crib must be considered a porous structure that allows the transmission of wave energy through it.

Key design issues for steel frame cribs include:

1. Sufficiently sized steel members connected in a rigid fashion to resist bending due to wave and ice forces and due to the lateral forces exerted by the stone/rock fill. The crib design should be evaluated using standard structural steel design methods.

2. Steel frame cribs are particularly susceptible to damage by ice. Bent and twisted steel cribs caused by ice heaving have been noted by the OCM and property owners. Ice forces along the shore include both horizontal and vertical forces. Vertical forces can lift the crib, potentially causing displacement of the entire structure and certainly stressing steel frame members facing the ice. Horizontal ice forces from the thermal expansion of the ice built up along the shore as temperatures rise can result in bending stresses at the crib's exposed members. Recommended design values for horizontal ice forces on cribs range from 5,000 to 20,000 lb/ft (from: "Ice Engineering Design for Marinas," C. Allen Worley, World Marina '91 Conference, American Society of Civil Engineers). For a detailed discussion of ice forces refer to Chapter 6 of the USACE "Ice Engineering" EM-1110-2-1612, Sept. 2006.

3. A means of resisting sliding forces from both wave action and earth pressure. This may be in the form of driven or drilled piles to which the crib is attached. This design feature will be highly dependent on the underlying strata. Pile can be driven into till and to a lesser extent shale, but in some cases holes must be drilled into which the pile is set and then grouted.

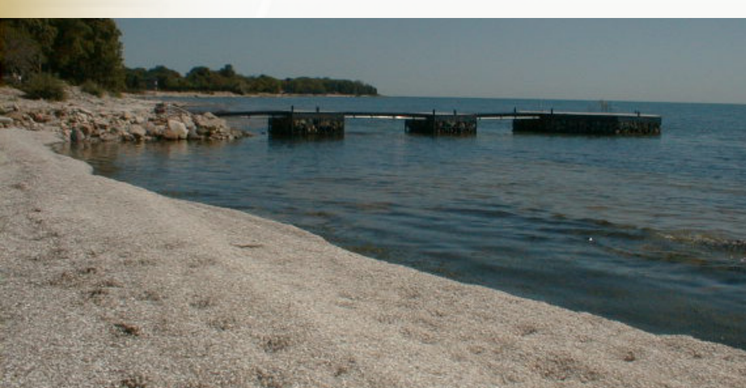
4. The spacing between cross-members needs to be small enough to retain the size of the stone or concrete rubble used as fill.

5. Since the crib fill is typically smaller in diameter and less in unit weight than armor stone, wave forces transmitted through the crib will cause uplift and movement of the material within the crib. This will cause the fill material to fracture, wear and re-settle. This leads to a common type of failure of cribs, as over time they lose a portion of the fill which reduces the total mass and increases the potential for overturning and sliding. This is a good reason to specify small armor stone rather than concrete rubble because rubble will tend to break up faster and to a greater degree than stone.

6. In most cases, the crib will include a cast-in-place reinforced concrete cap which is typically 1 foot or less in thickness.

The most common designs for steel frame cribs are modular units 10-feet wide by 15 to 20-feet long, with the height variable to meet the site bathymetry. Diagonal cross bracing is included in nearly all designs. In most designs, crib members are welded, with multiple cribs bolted together. A typical spacing between transverse members along the sides is 1 foot, allowing stone of 0.5 to 1.0 tons per unit to be used as fill.

A steel frame crib structure is shown below from three different angels. The top picture is the lakeward most crib in the bottom picture. The middle picture is taken from standing atop this crib. Design Example E describes a typical steel frame crib.



4.4 Construction, Inspection & Maintenance

Erosion control structures must be constructed as shown on the approved design drawings. This ensures that the specified materials and the location of the project features as selected by the engineer are built in a manner that leads to a stable, long-lasting installation. It is also a condition of the permit authorization.

In many cases the construction process is under the full control of the contractor, who may or may not have had input into the design. This does not relieve the owner of the responsibility of ensuring that the work is fully consistent with the design and within the footprint shown on the approved design drawings.

A property owner can engage the engineer to oversee construction activities to ensure that a project is built according to plan.

It is helpful to plan a pre-construction meeting to be attended by the contractor, engineer and property owner to discuss the project schedule and logistics, and identify any potential changes that appear necessary to the existing design. If changes to the design are needed, the engineer of record can then submit the revised drawings to the regulatory authorities for review. Construction should not proceed until those changes are approved by all authorizing agencies.

Although it is not as common with smaller projects at single owner sites, the property owner can engage the engineer to oversee the construction activities to ensure that the project is constructed according to the plans.

While experienced contractors have developed significant cost savings and potentially effective changes to designed and permitted shore structures, there have been far more instances where contractor-initiated changes have resulted in poorer structures and in some cases serious failures. While some changes may appear to be minor, they can lead to catastrophic failure. For example, the substituting of smaller armor stone, would lead to a premature failure of the armoring. Effects of changes like this may not be seen for years, but eventually a high lake level and storm conditions similar to the design conditions will impact the site and the damage will be evident. This is why all proposed changes to approved designs must be approved by the engineer of record for the project and revised authorizations be obtained from all involved agencies.

Inspection and monitoring

The development and implementation of a monitoring and inspection plan is a critical component for the long-term success of any coastal project.

For erosion control structures such as revetments and seawalls, the recommended monitoring and inspection can be as straight-forward as looking for and documenting any significant changes after construction has been completed and on a periodic basis thereafter. Typical post-construction problems that should be identified include:

1. Displacement down the revetment slope or movement of armor stone.
2. Cracked armor stone or concrete.
3. Uneven settling of a seawall section or crib.
4. Slumped upland bluff areas above the revetment or seawall.
5. Increased erosion at the ends or flanks of the construction.
6. Significant changes to the beach either at the site or along adjacent or nearby properties.

Inspection and monitoring should be performed on a routine basis, at least once a year. Documentation can include photos, record of the water level at the time of inspection, and notations about the condition of the various features of the structure.

It is appropriate to engage the services of the design engineer for inspection and monitoring, especially if the project is complex or difficult to access, but in most cases the property owner can carry out inspections and document the results without difficulty.

Maintenance and repair

Through the monitoring and inspection of a project the required maintenance is likely to be discovered.

Minor repairs to authorized structures may not require additional regulatory authorization. It is advisable to contact the applicable regulatory agencies to determine if authorizations are required prior to completing any planned maintenance or repairs.

4.5 Design Examples

The five design examples that follow include three armor stone revetment designs (A, B and C) and two seawall designs (D and E). Each example begins with a narrative describing the site and the engineering and surveying performed. This is followed by engineering calculation sheets, the engineering design drawings, the submerged lands lease metes and bounds descriptions and plat. Examples C and D share the same fictional site location, as do Examples B and E.

Design Example A

The following example demonstrates the design of an armor stone revetment as erosion protection at a site with high (50 to 60-foot) bluffs along the shore. The project site is fictitious but similar to the coastal features common to Ashtabula County and eastern Lake County.

Project Purpose

The purpose of Example Project A is to protect the toe of the glacial till bluffs from erosion due to wave action. An armor stone revetment was selected to best achieve the project purpose at this site.

Site Description

The Design Example A site is located along the shore of Lake Erie in Saybrook Township, Ashtabula County, Ohio, approximately 6 miles west of the Ashtabula Port. The shore along this stretch is fairly uniform with small embayments and headlands. The project shore is oriented from southwest to the northeast. The predominant direction of sediment transport in the littoral zone is from west to east.

The shore at the project site consists of 50 to 55 foot glacial till bluffs reaching an elevation of 630 feet as referenced to the International Great Lakes Datum of 1985 (IGLD 1985). The toe of the bluff is located at approximately 575 feet IGLD 1985 and is covered with concrete rubble fill. A narrow, 10 to 15-foot wide, sand and gravel beach is perched above a wall of existing concrete block modules.

The geology of the area consists of a thin layer of top soil or fill over a thick (25 to 30-foot) layer of soft glacial till. Below is a thick (30 to 35-foot) layer of hard glacial till over shale bedrock at approximately 570 feet of elevation (referenced to IGLD 1985). Shale bedrock is exposed in the nearshore and slopes at 3 to 4 degrees for the first 100 feet then continues at a shallower (1 degree) slope farther offshore.

The site is exposed to storm waves from all angles from west-southwest to east-northeast. A review of historic wave information results in a significant wave height of 3.3 feet at a period of 4.3 seconds. The most frequent wave direction was from the southwest. The largest wave recorded over the 32 year study was 16.4 feet with a 9.0 second wave period, from the west. The average direction of the largest waves was 264.0 degrees. Wave data was measured at WIS station E14 located approximately 10 miles north of the project site in 72-foot deep water.

The project site is located in a designated Coastal Erosion Area based on the Final 2010 mapping with an expected erosion rate of 34.2 to 42.9 feet over 30 years. There are no surface drainage issues causing erosion at the project site.

The shoreline in this area is generally consistent; the eastern and western adjacent properties are similar to the project site. The bluff and upland topography are constant in this area. Both the eastern and western adjoining properties include a small sand and gravel beach held in place with large concrete blocks and vertical concrete sewer pipes. The concrete rubble at the toe of the bluff is continuous across the site and adjoining properties.

Field Survey

The upland parcel is located within Connecticut Western Reserve district of Ohio's Public Lands Survey System more specifically part of Original Lot (O.L.) 55, Fractional Section 3, Town 13 North, Range 4 West. Being within Saybrook Township and outside of any incorporated municipal boundaries, the parcel boundary extends to the centerline of the county road with a sixty (60) foot right of way reservation for public ingress and egress centered on said centerline.

Horizontal control was established for this site by evaluating the location of published monumentation through the National Geodetic Survey (NGS) website: *www.ngs.noaa.gov*. The closest station to this site was determined to be "Woodring" (PID MB2112) which is approximately one (1) kilometer east. Based upon the NGS datasheet, the horizontal accuracy of the station is Third Order with reports that attempt to recover the station failed in 1993 and 1996. Therefore this station was not used within the horizontal control network.

These photos show the view from standing atop the bluff looking out at Lake Erie (this page) and from standing on the beach (left page) looking toward the bluff. This site has similar characteristics to Design Example A.

Global Positioning System (GPS) observations of approximately 30 minutes in length were performed on two control stations along Lake Road West. The raw data files were uploaded to the NGS Online Positioning User Service (OPUS) for the rapid-static sessions. The resultant Ohio State Plane 3401(NAD 83) coordinates provided by the OPUS solution were utilized as the controlling stations for an adjusted closed field traverse.

Vertical control was established for this site by evaluating the location of published monumentation through the NGS website. The closest station to this site was determined to be "P 8" (PID MB1001) which is approximately 4 kilometers southeast. Based upon the NGS datasheet the vertical accuracy of the station is First Order Class II with reports that attempt to recover the station were successful in 1993 and 2009. The U.S. Coast and Geodetic Survey disk, established in 1934, has a reported dynamic height of 645.93 feet at 45 degrees latitude. NGS Vertical Datum Transformation software (VDatum) was used to adjust for the hydraulic corrections for the project location based upon the latitude and longitude positions in the OPUS solution. The resultant adjusted elevations provided by a closed level circuit were utilized for the project after confirming the elevation, relative to IGLD 1985, of the control stations by benching into the water level on a calm day with minimal wave activity and comparing that value to the water level station data retrieved from NOAA's Great Lakes Online website: *www.glakesonline.nos.noaa.gov/monitor.html* for station #9063053 (Fairport Harbor).

With the horizontal and vertical control network established, recovery of boundary evidence was performed. Monumentation found and held as controlling stations included a ¾-inch iron pin in a monument box at the southwest corner of O.L. 55 and a 2-inch splined axel shaft at the southeast corner of O. L. 55. Subsequent intermediate points were located along Lake Road West including P-K nails found at the southwest and southeast corners of the subject parcel and were used in the final determination of the upland parcel boundary lines.

A topographic survey was performed that located the cultural (i.e. buildings, survey monuments, coastal structures) and natural (i.e. top and toe of bluff) features on the subject parcel and adjoiners. Presence of concrete modules and rubble along the bluff and shore indicate that fill material has been placed artificially and has altered the location of the natural shoreline.

Analysis

A technical assistance request was made to the ODNR Office of Coastal Management to help in identifying the location of the natural shoreline prior to the artificial placement of the concrete material. A drawing was provided to the consultant that depicted the location of the natural shoreline on the April 1973 aerial photograph. This location was transferred to the site and compared to the descriptions within the current and previous title deeds. The natural shoreline was slightly adjusted based upon the description within the 1971 general warranty deed for the subject parcel.

Parcel data provided by the Ashtabula County Auditor's Office was imported into the computer-aided design (CAD) drawing to establish a general orientation of the shoreline for a reach of approximately 1.5 kilometer. Methodology for partitioning the boundaries between the littoral adjoiners was examined including extending the upland parcel boundary lakeward without deflection and a radial projection from the general alignment of the 1.5 kilometer reach of shore from the intersection of the natural shoreline and the parcel sidelines. The radial projection method provided the most equitable distribution between the subject parcel and the east and west adjoiners.

A base map was provided to the engineering consultant that depicted the locations of the existing site improvements relative to the established parcel boundaries and littoral partitions. A general statement that the survey and plat were prepared that conforms to Ohio Administrative Code (OAC) Section 4733-37 was included and the Ohio registered professional surveyor's signature and seal were affixed to the plat of survey (see *Existing Site Plan "A"*).

Design

The maximum slope normally considered for the long-term stability of an armor stone revetment is 1.5 horizontal to 1 vertical. Based on the wave climate in the area of the project site a slope of 2 horizontal to 1 vertical was selected for a conservative design, which also matches the planned re-graded upland slope. The existing concrete modules are to be removed and re-used as part of the revetment core. This allows the toe of the revetment to be placed at the 569.8 foot IGLD 1985 elevation of the shale bedrock at the shore.

The project site is located in the Saybrook to Kingsville reach of the "Revised Report on Great Lakes Open Coast Flooding" (USACE 1988) and has a design water level of 575.0 feet IGLD 1985 for a 30-year return period.

A 5.2-foot structure depth was calculated based on the lake bottom elevation at the structure toe and the design water level. Using the breaking wave equation presented in Chapter 3, a design wave height of 4.1 feet was calculated for this case.

Since the toe of the structure was designed to be entrenched 2.5 feet into the shale bedrock, the depth of the structure at the base of the toe will be 7.7 feet. Future scouring at the toe of the structure due to the fractures and wear of the shale would result in an increase in water depth from 5.2 to 7.7 feet and a design wave height of 6.0 feet for this conservative case. The scour of shale bedrock may not always be a reasonable assumption, but for this example, it was assumed that the fractures caused during entrenchment would lead to scour, aided by the presence of a significant amount of cobble and gravel along the nearshore that could abrade the shale.

Hudson's Equation was used to calculate the median armor stone size to resist displacement due to wave action. Using the unit weight for the specified limestone, the minimum median armor stone size is 0.3 tons for the non-scour case. The minimum median armor stone size was 1.0 ton per unit if the toe of the structure is scoured.

A factor of safety of 2.0 was selected for the armor stone size to account for potential effects of ice forces, and long-term fracturing of the stone. Using the conservative 1.0 ton per unit value from Hudson's Equation, the safety factor results in a lower limit for the armor stone of 2.0 tons per unit. The resulting design specification of a 2 to 4-ton range for the armor stone layer also provides additional mass that improves the long-term ability of the revetment to resist earth forces from the upland. A double layer of 2 to 4-ton limestone will be stacked in a 6-foot thick armor layer.

The filter layer was specified as stone or clean concrete rubble about 1/3 of the diameter of the armor stone. For economy of design, the existing concrete modules and concrete rubble at the toe of the bluff will be relocated to form the filter layer for the revetment. Due to the variability of the filter layer material and the fine-grained till composition of the bluff a geotextile filter fabric is specified.

Wave run-up on the structure was calculated using the empirical formula introduced in Chapters 3. Wave run-up of 5.4 feet to an elevation of 580.4 feet IGLD 1985 was calculated for the initial design case. If the toe of the structure is scoured the wave run-up increases to 7.4 feet to an elevation of 582.4 feet IGLD 1985. The crest of the revetment was placed at 583.0 feet IGLD 1985.

To stabilize the upper portion of the bluff face the existing bluff will be re-graded to a 2 horizontal to 1 vertical slope above the revetment. To protect the re-graded bluff face from erosion resulting from spray, a splash apron was included in the design. The splash apron was specified as new ODOT 601 Type "B" stone and will extend to an elevation of 586.0 feet IGLD 1985.

To prevent sliding failure along the slope of the revetment, larger stones are placed at the lakeward base for toe protection. In this case 4 to 5-ton armor stones are to be entrenched 2.5 feet into the shale bedrock. Toe stones are typically specified to be 1 to 2 tons heavier than stones used for the armor layer.

To reduce the risk of causing increased erosion on adjacent properties and to prevent potential failure of the ends of structure, it is essential to appropriately terminate the structure at the property boundaries. To mitigate end effects, the ends of revetment are curved back into the bluff face. In this case, the ends of the structure are rounded off with a radius approximately equal to the plan view width of the armor layer.

Discussion

To reduce the overall project footprint and minimize effects on littoral processes and adjacent properties the revetment has been placed with the armor layer immediately adjacent to the existing bluff face. The revetment has also been designed to closely follow the shape of the shore. The revetment will extend a maximum of 36.2 feet from the existing bluff toe. This distance is determined by the required crest elevation and revetment slope and can not be reduced without compromising the functionality or stability of the structure. In this way it has been appropriately designed to minimize effects on lake processes and adjacent properties.

The revetment is intended to prevent wave-based erosion of the existing bluff and will therefore decrease the amount of material added to the littoral system. Sand or gravel in the footprint of the revetment must be excavated and sidecast into the lake prior to construction to prevent sediment from being permanently removed from the littoral system.

As the structure will extend approximately 36 feet lakeward of the bluff toe, it will affect the littoral transport of material along the shore. In this case, the impact is expected to be minimal due to the location of concrete modules and rubble on adjacent properties. The structure may also cause changes in wave energy that could adversely affect adjacent properties. This risk has been reduced with the use of rough, angular limestone placed at a slope of 2H:1V. Much of the wave energy will be absorbed and dissipated by the revetment, minimizing the wave energy reflected in the nearshore zone.

Final Survey Products

Based on the design from the Ohio registered professional engineer, a plat that depicted the boundaries of the submerged lands lease was prepared. The adjusted historic natural shoreline serves as the southern limit of the lease. Due to the use of the artificially placed fill material (concrete rubble) two separate lease parcels are depicted according to the definitions provided within OAC 1501-6-01. (see Submerged Lands Plat “A”)

Two metes and bounds descriptions have been written for the areas depicted on the plat of survey with direct relationship to the upland parcel boundaries as required in Ohio Revised Code Section 1506.11(B). (see Submerged Lands Lease descriptions for Parcel “A” and “B”).

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB EXAMPLE A - HIGH BLUFF
SHEET NO. 1 OF 3
CALCULATED BY MPC DATE 02/01/11
CHECKED BY DLB DATE 02/01/11
SCALE

REVETMENT DESIGN

A. DESIGN WATER LEVEL

30 YEAR DESIGN WATER LEVEL = 575.0 FT IGLD 1985
REFERENCE: "REVISED REPORT ON GREAT LAKES OPEN COAST FLOODING" USACE, 1988.

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE
LAKE BOTTOM ELEVATION = 569.8 FEET IGLD 1985
STRUCTURE DEPTH = ds = 575.0 FT - 569.8 FT = 5.2 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 5.2 FT = 4.1 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED
TOE OF STRUCTURE = 567.3 FEET IGLD 1985
STRUCTURE DEPTH = ds = 575.0 FT - 567.3 FT = 7.7 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 7.7 FT = 6.0 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

C. ARMOR STONE SIZE

USE HUDSON'S EQUATION:

MEDIAN ARMOR STONE SIZE = $W50 = \dfrac{\omega r \, H^3}{Kd\,(Sr-1)^3 \, \cot\theta}$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22

ωr = UNIT WEIGHT OF ARMOR STONE = 165 LB/FT^3
ASSUME H = BREAKING WAVE HEIGHT = Hb
Kd = 2.0 FOR ROUGH ANGULAR QUARRY STONES
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22
COT θ = STRUCTURE SLOPE = 2.0

$Sr = \dfrac{\omega r}{\omega w}$

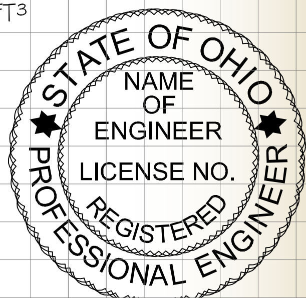
ωr = SPECIFIC WEIGHT OF STONE = 165 LB/FT^3
ωw = SPECIFIC WEIGHT OF WATER = 62.4 LB/FT^3

INITIAL DESIGN CASE

BREAKING WAVE HEIGHT = Hb = 4.1 FT

$W50 = \dfrac{(165\ LB/FT^3)\,(4.1\ FT)^3}{2.0\,(165/62.4-1)^3\,(2.0)} = 640\ LB = 0.3\ TON$

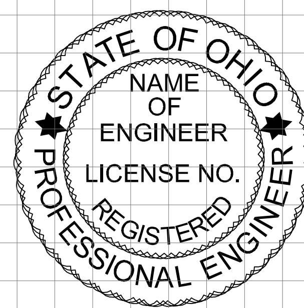
MEDIAN STONE SIZE = W50 x FS = 0.3 TON x 2.0 = 0.6 TON



Engineer Signature
mm/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE A - HIGH BLUFF
SHEET NO. 2 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:



Engineer Signature
MM/DD/YY

REVETMENT DESIGN (CONT.)

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

BREAKING WAVE HEIGHT = Hb = 6.0 FT

$$W50 = \frac{(165\ LB/FT^3)\ (6.0\ FT)^3}{2.0\ (165/62.4-1)^3\ (2.0)} = 2004\ LB = 1.0\ TON$$

MEDIAN STONE SIZE = W50 x FS = 1.0 TON x 2.0 = 2.0 TON

TO BE CONSERVATIVE USE 2 TO 4 TON ARMOR STONE

*NOTE: ACES CALCULATIONS SUPPORT RESULTS

INITIAL DESIGN CASE
W50 = 1221 LB = 0.6 TON
ARMOR LAYER THICKNESS = 3.9 FEET

CONSERVATIVE DESIGN CASE
W50 = 3453 LB = 1.7 TON
ARMOR LAYER THICKNESS = 5.5 FEET

C. WAVE RUNUP AND OVERTOPPING

EMPIRICAL FORMULA: $$R = \frac{Hb\ (a \times \xi)}{1 + (b \times \xi)}$$

REFERENCE: "WAVE PERIOD EFFECT ON THE STABILITY OF RIPRAP" ASCE, 1975, P 1019- 1034.

a = 0.775 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
b = 0.361 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
REFERENCE: "COST-EFFECTIVE OPTIMIZATION OF RUBBLE-MOUND BREAKWATER CROSS SECTIONS" USACE, 1986, P 45-53.

$$\text{IRIBARREN NO.} = \xi = \frac{\tan \Theta}{\sqrt{(2\pi\ Hb / g\ T^2)}}$$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE VI-5-6.

Θ = ANGLE OF STRUCTURE FACE
g = 32.2 FT/SEC²
T = WAVE PERIOD = 8 SECOND PERIOD ASSUMED*

*AN 8 SECOND PERIOD IS A CONSERVATIVE ESTIMATE BASED ON WIS DATA. THE LARGEST WAVE RECORDED AT WIS STATION E14 OVER A 32 YEAR STUDY (1956-1987) HAD A PERIOD OF 9.0 SECONDS. - REFERENCE: "WIS REPORT 22, HINDCAST WAVE INFORMATION FOR THE GREAT LAKES: LAKE ERIE" USACE, 1991, P A86.

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE A - HIGH BLUFF
SHEET NO. 3 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

REVETMENT DESIGN (CONT.)

INITIAL CASE

IRIBARREN NO. $= \xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(4.1\text{ FT}) / (32.2\text{ FT/SEC}^2)\,(8\text{ SEC})^2}}$ $\qquad \xi = 4.5$

WAVE RUNUP: $R = \dfrac{(4.1\text{ FT})\,(0.775 \times 4.5)}{1 + (0.361 \times 4.5)}$

R = 5.4 FT (FOR INITIAL CASE)

RUNUP ELEVATION = 575.0 FT IGLD 1985 + 5.4 FT = 580.4 FT IGLD 1985

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

IRIBARREN NO. $= \xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(6.0\text{ FT}) / (32.2\text{ FT/SEC}^2)\,(8\text{ SEC})^2}}$ $\qquad \xi = 3.7$

WAVE RUNUP: $R = \dfrac{(6.0\text{ FT})\,(0.775 \times 3.7)}{1 + (0.361 \times 3.7)}$

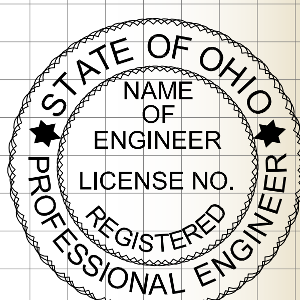
R = 7.4 FT (FOR CONSERVATIVE CASE)

RUNUP ELEVATION = 575.0 FT IGLD 1985 + 7.4 FT = 582.4 FT IGLD 1985

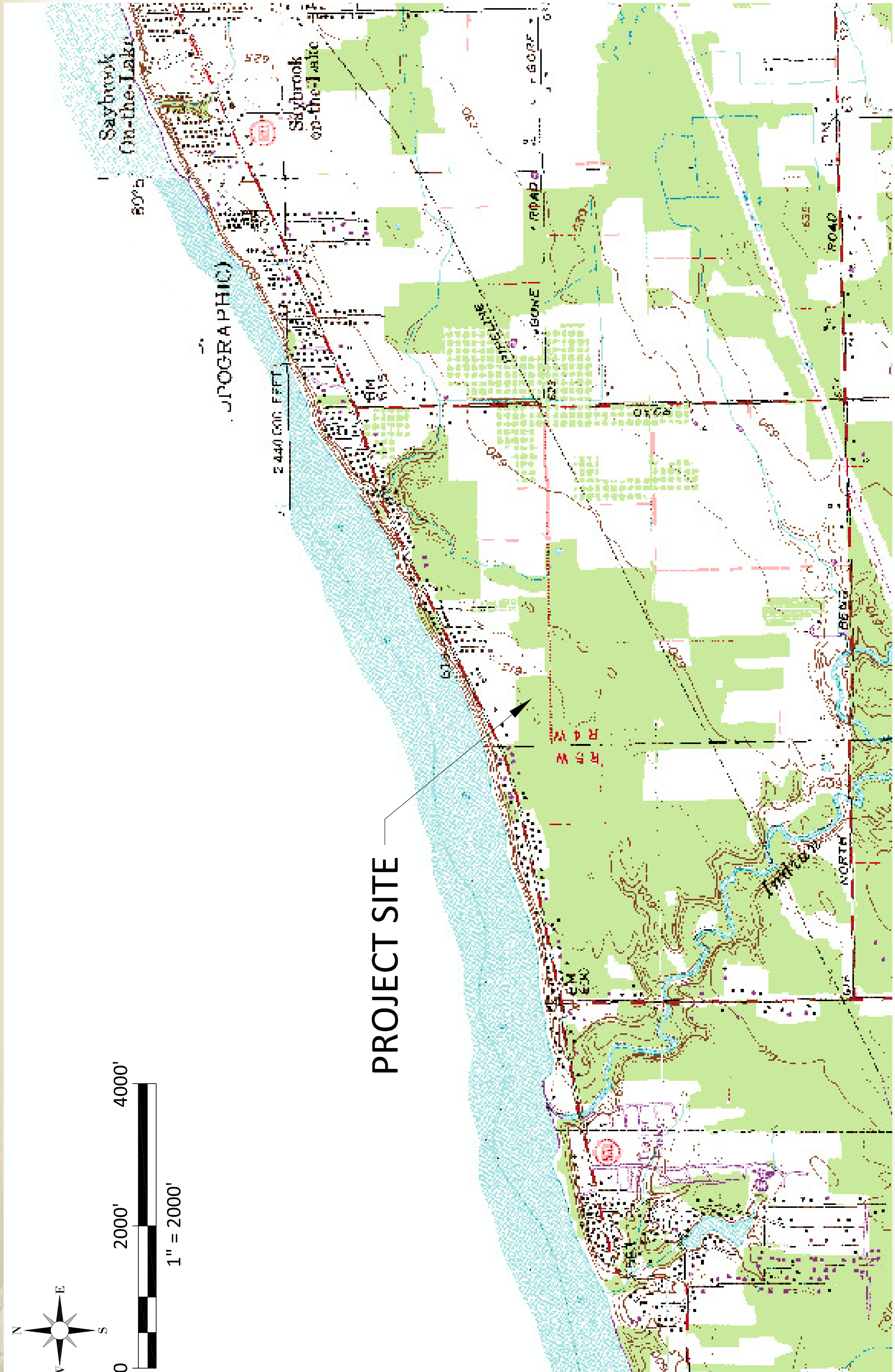
CONSERVATIVE DESIGN: SET TOP OF ARMOR STONE AT 583.0 FT IGLD 1985
SET TOP OF SPLASH APRON AT 586.0 FT IGLD 1985

*NOTE: ACES CALCULATIONS SUPPORT RESULTS
INITIAL: RUNUP = 5.4 FT TO AN ELEVATION OF 580.4 FT IGLD 1985
CONSERVATIVE: RUNUP = 7.4 FT TO AN ELEVATION OF 582.4 FT IGLD 1985

*NOTE: THE CALCULATIONS INCLUDED IN THIS EXAMPLE WERE ORIGINALLY COMPUTED USING EXCEL SPREADSHEETS. THE SOFTWARE DISPLAYS A SPECIFIED NUMBER OF SIGNIFICANT FIGURES BUT RETAINS THE ORIGINAL NUMBER FOR OPERATIONS. AS A RESULT SMALL ROUNDING ERRORS ARE INTRODUCED IN TRANSCRIBING THE STEP-BY-STEP CALCULATIONS. THESE ERRORS ARE ACCEPTABLE CONSIDERING THE OVERALL ACCURACY OF THE CALCULATION METHODS AND THE PURPOSE OF THIS DESIGN MANUAL.



Engineer Signature
MM/DD/YY



PROJECT:
ARMOR STONE REVETMENT

ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
7371 LAKE RD WEST, ASHTABULA, OH 44004
EASTERN ADJACENT PROPERTY OWNER
7311 LAKE RD WEST, ASHTABULA, OH 44004

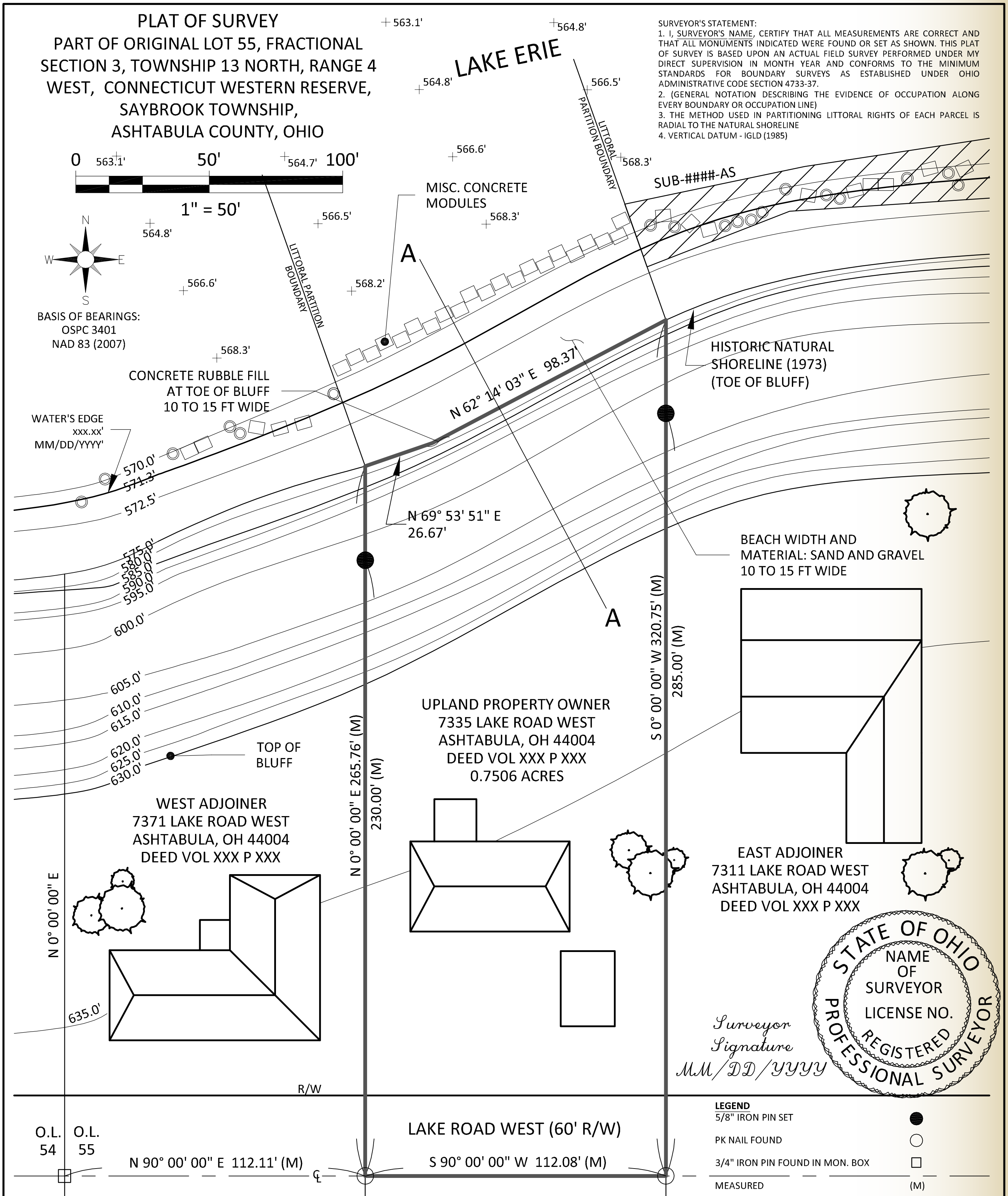
TITLE:
VICINITY MAP

APPLICANT:
SAMPLE PROPERTY OWNER
7335 LAKE ROAD WEST,
ASHTABULA, OH 44004

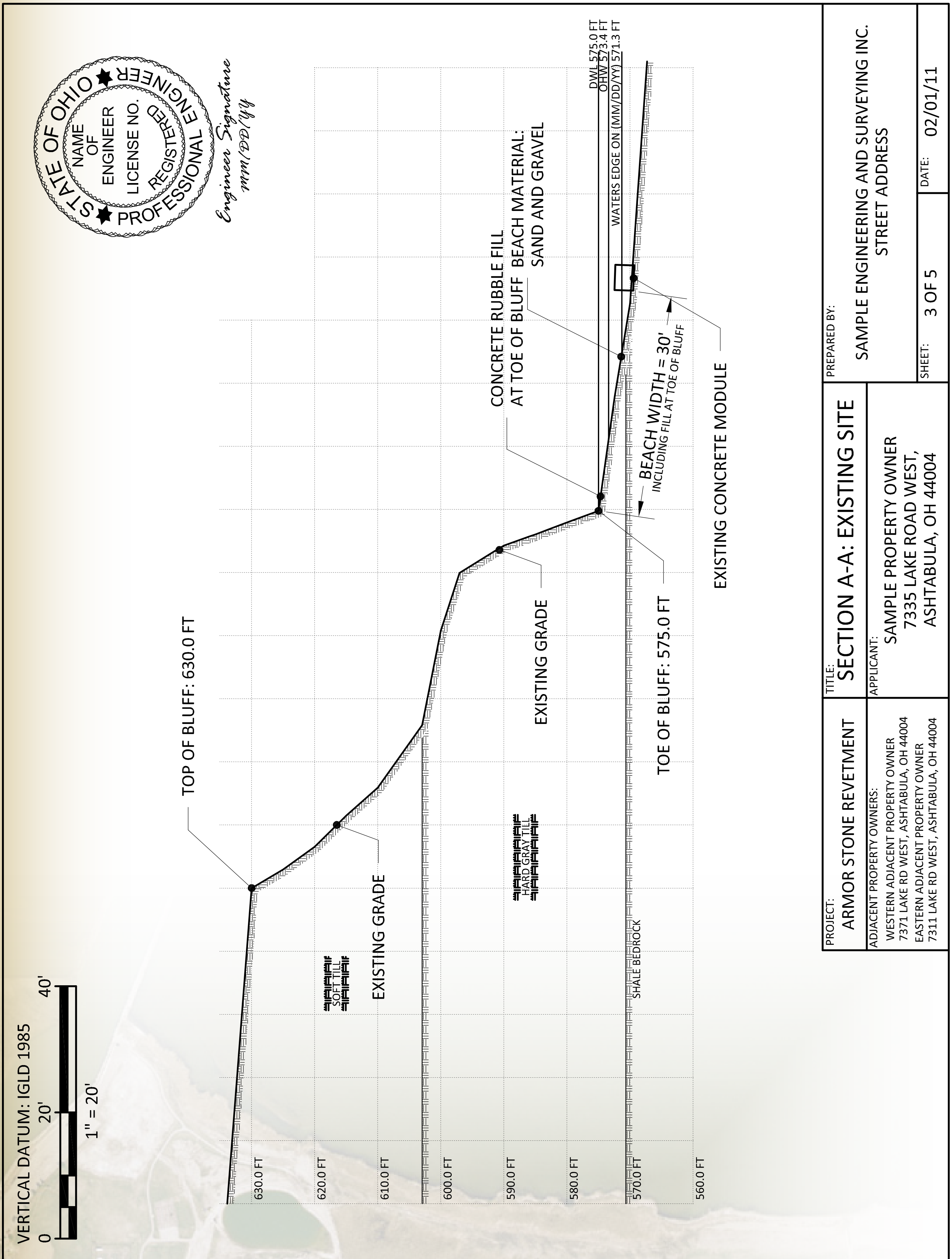
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

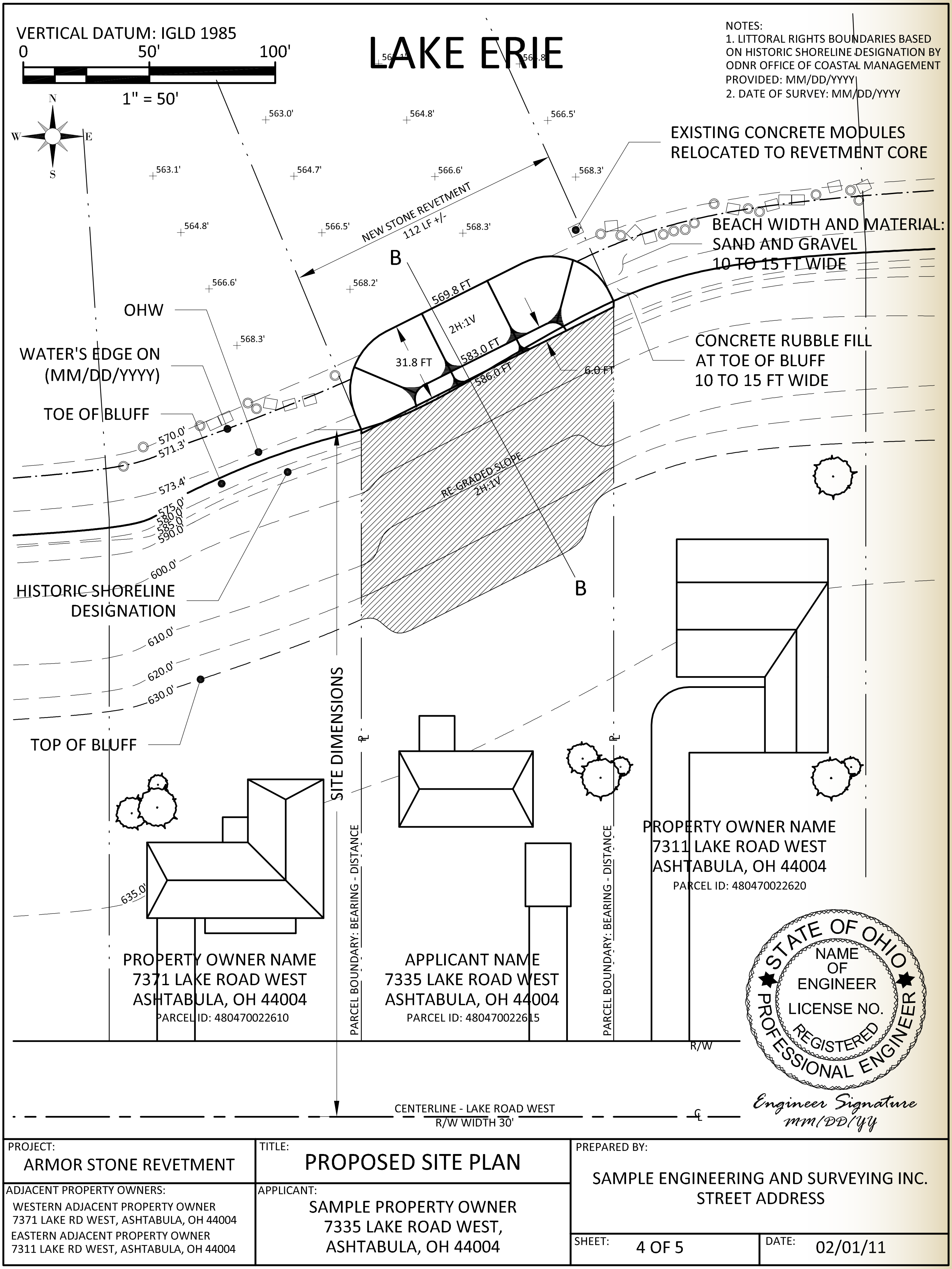
SHEET: 1 OF 5

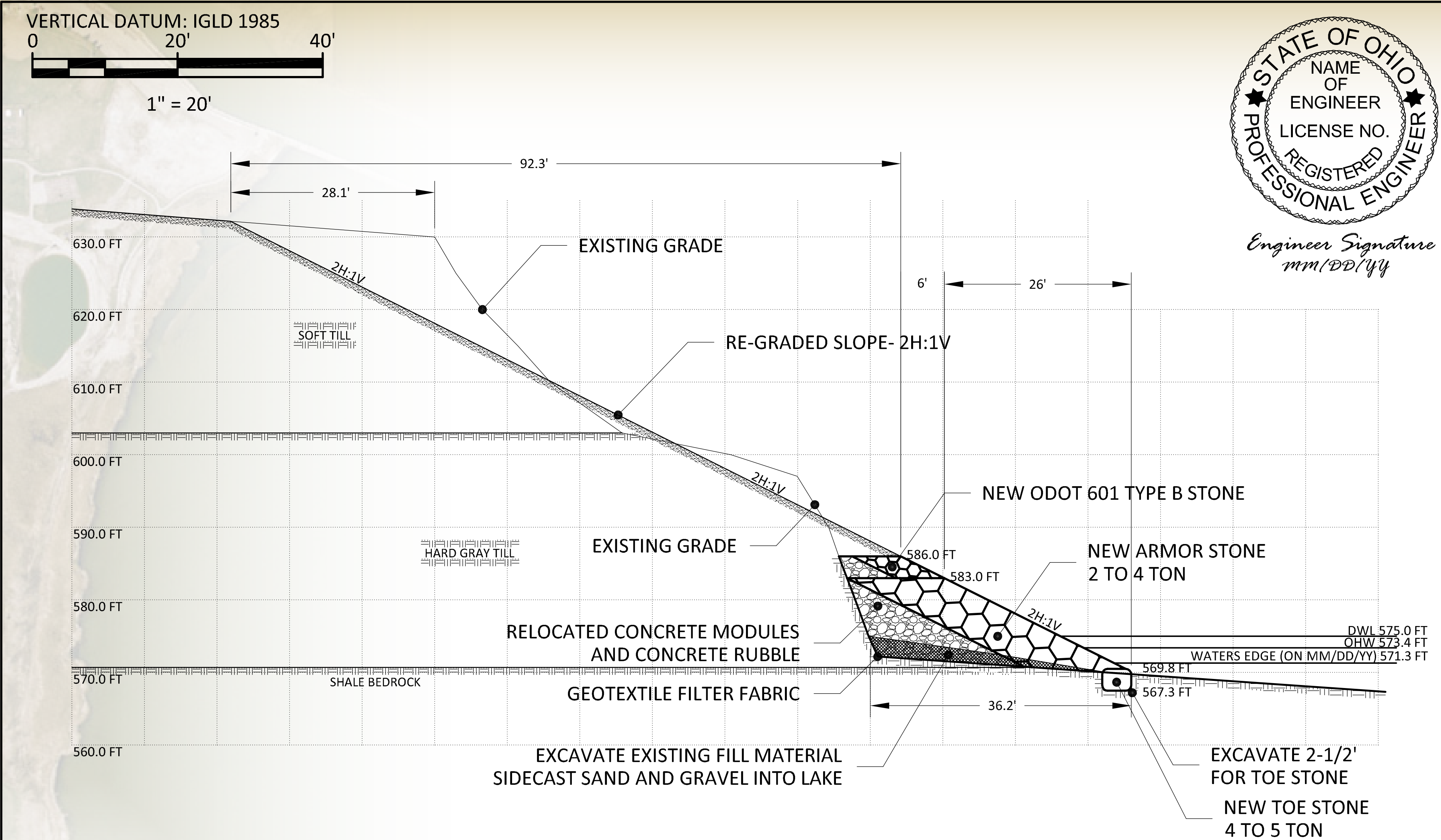
DATE: 02/01/11



PROJECT: ARMOR STONE REVETMENT	TITLE: EXISTING SITE PLAN	PREPARED BY: SAMPLE SURVEYING AND ENGINEERING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WEST ADJOINER 7371 LAKE RD WEST, ASHTABULA, OH 44004 EAST ADJOINER 7311 LAKE RD WEST, ASHTABULA, OH 44004	APPLICANT: APPLICANT 7335 LAKE ROAD WEST, ASHTABULA, OH 44004	SHEET: 2 OF 5 DATE: 02/01/2011


VERTICAL DATUM: IGLD 1985
0
20'
40'
1" = 20'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
MM/DD/YY
TOP OF BLUFF: 630.0 FT
EXISTING GRADE
SOFT TILL
HARD GRAY TILL
EXISTING GRADE
SHALE BEDROCK
CONCRETE RUBBLE FILL AT TOE OF BLUFF
BEACH MATERIAL: SAND AND GRAVEL
DWL 575.0 FT
OHW 573.4 FT
WATERS EDGE ON (MM/DD/YY) 571.3 FT
BEACH WIDTH = 30'
INCLUDING FILL AT TOE OF BLUFF
TOE OF BLUFF: 575.0 FT
EXISTING CONCRETE MODULE
630.0 FT
620.0 FT
610.0 FT
600.0 FT
590.0 FT
580.0 FT
570.0 FT
560.0 FT
PROJECT:
ARMOR STONE REVETMENT
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
7371 LAKE RD WEST, ASHTABULA, OH 44004
EASTERN ADJACENT PROPERTY OWNER
7311 LAKE RD WEST, ASHTABULA, OH 44004
TITLE:
SECTION A-A: EXISTING SITE
APPLICANT:
SAMPLE PROPERTY OWNER
7335 LAKE ROAD WEST,
ASHTABULA, OH 44004
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
SHEET: 3 OF 5
DATE: 02/01/11


VERTICAL DATUM: IGLD 1985
0
50'
100'
1" = 50'
N
S
E
W
LAKE ERIE
NOTES:
1. LITTORAL RIGHTS BOUNDARIES BASED ON HISTORIC SHORELINE DESIGNATION BY ODNR OFFICE OF COASTAL MANAGEMENT PROVIDED: MM/DD/YYYY
2. DATE OF SURVEY: MM/DD/YYYY
563.0'
564.8'
566.5'
563.1'
564.7'
566.6'
568.3'
564.8'
566.5'
568.3'
566.6'
568.2'
568.3'
EXISTING CONCRETE MODULES RELOCATED TO REVETMENT CORE
NEW STONE REVETMENT
112 LF +/-
BEACH WIDTH AND MATERIAL: SAND AND GRAVEL 10 TO 15 FT WIDE
B
569.8 FT
2H:1V
583.0 FT
586.0 FT
31.8 FT
6.0 FT
OHW
WATER'S EDGE ON (MM/DD/YYYY)
TOE OF BLUFF
CONCRETE RUBBLE FILL AT TOE OF BLUFF 10 TO 15 FT WIDE
570.0'
571.3'
573.4'
575.0'
580.0'
585.0'
590.0'
600.0'
610.0'
620.0'
630.0'
635.0'
RE-GRADED SLOPE 2H:1V
HISTORIC SHORELINE DESIGNATION
TOP OF BLUFF
SITE DIMENSIONS
PARCEL BOUNDARY: BEARING - DISTANCE
PARCEL BOUNDARY: BEARING - DISTANCE
PROPERTY OWNER NAME
7311 LAKE ROAD WEST
ASHTABULA, OH 44004
PARCEL ID: 480470022620
PROPERTY OWNER NAME
7371 LAKE ROAD WEST
ASHTABULA, OH 44004
PARCEL ID: 480470022610
APPLICANT NAME
7335 LAKE ROAD WEST
ASHTABULA, OH 44004
PARCEL ID: 480470022615
R/W
CENTERLINE - LAKE ROAD WEST
R/W WIDTH 30'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
MM/DD/YY
PROJECT: ARMOR STONE REVETMENT
TITLE: PROPOSED SITE PLAN
PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
7371 LAKE RD WEST, ASHTABULA, OH 44004
EASTERN ADJACENT PROPERTY OWNER
7311 LAKE RD WEST, ASHTABULA, OH 44004
APPLICANT:
SAMPLE PROPERTY OWNER
7335 LAKE ROAD WEST,
ASHTABULA, OH 44004
SHEET: 4 OF 5
DATE: 02/01/11



NOTES:

1. ARMOR LAYER CONSISTS OF ROUGH, ANGULAR QUARRY STONE (LIMESTONE).
2. STONES SHALL BE PLACED INDIVIDUALLY TO MAXIMIZE CONTACT AREA BETWEEN STONES AND MINIMIZE VOIDS. STONES SHOULD NOT BE DROPPED.
3. FILTER LAYER CONSISTS OF RELOCATED CONCRETE MODULES AND LARGE CONCRETE RUBBLE FROM BEACH AREA.
4. EXCAVATE EXISTING BEACH TO SHALE BEDROCK. DEPOSIT EXCAVATED SAND & GRAVEL LAKEWARD OF PROJECT. NO SAND OR GRAVEL SHOULD BE TRAPPED UNDER REVETMENT.
5. EXCAVATE TOE TRENCH 2-1/2 FT (MINIMUM) INTO SHALE BEDROCK.

PROJECT: ARMOR STONE REVETMENT	TITLE: SECTION B-B: PROPOSED SITE	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 7371 LAKE RD WEST, ASHTABULA, OH 44004 EASTERN ADJACENT PROPERTY OWNER 7311 LAKE RD WEST, ASHTABULA, OH 44004	APPLICANT: SAMPLE PROPERTY OWNER 7335 LAKE ROAD WEST, ASHTABULA, OH 44004	SHEET: 5 OF 5	DATE: 02/01/11

Lake Erie Submerged Lands Legal Description Parcel "A"
Adjacent to 7335 Lake Road West, Saybrook Township

Situate in the State of Ohio and located within the waters of Lake Erie, County of Ashtabula, Saybrook Township, Township 13 North, Range 4 West of the Connecticut Western Reserve, adjacent to a portion of fractional Section 3, Original Lot 55 conveyed to (NAME OF UPLAND OWNER) by Deed Volume (XXX), Page (XXX), of the deed records of said county and being more particularly described as follows:

Commencing at a 3/4 inch solid iron pin found in a monument box at the intersection of the centerline of sixty (60) foot Lake Road West and the westerly line of Original Lot 55, said point also being the southwest corner of a parcel of land conveyed to (NAME OF WEST ADJOINER) by Deed Volume (XXX), Page (XXX);

Thence along the centerline of sixty (60) foot Lake Road West, also being the south line of said (NAME OF WEST ADJOINER) parcel, North 90 degrees, 00 minutes, 00 seconds East, 112.11 feet to a P-K nail found, also being the southwest corner of said (NAME OF UPLAND OWNER);

Thence along the west line of said (NAME OF UPLAND OWNER) parcel, North 00 degrees, 00 minutes, 00 seconds East, 265.76 feet, and passing for reference, a 5/8 inch solid iron pin set at 230.00 feet witnessing the location of the natural shoreline of Lake Erie present in (1973) as determined by the Ohio Department of Natural Resources, also being the northwest corner of said (NAME OF UPLAND OWNER) parcel; said point being the True Point of Beginning of the Lease Property described;

Thence departing the northwest corner of said (NAME OF UPLAND OWNER) parcel, along the littoral partition boundary between said (NAME OF UPLAND OWNER) and (NAME OF WEST ADJOINER) as determined by radial means, North 19 degrees, 29 minutes, 45 seconds West, 25.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence departing the littoral partition boundary across the open waters of Lake Erie, North 62 degrees, 32 minutes, 04 seconds East, 125.22 feet to a point, not monumented due to the location on submerged lands of Lake Erie, on the littoral partition boundary of said (NAME OF UPLAND OWNER) parcel's east line as determined by radial means, also being the westerly boundary of Lake Erie Submerged Lands Lease File Number SUB-####-AS conveyed to (NAME OF EAST ADJOINER) by Lease Volume (XXX), Page (XXX) of the lease records of said county;

Thence along the littoral partition boundary between said (NAME OF UPLAND OWNER) parcel and (NAME OF EAST ADJOINER)as determined by radial means, also being the westerly boundary said Lake Erie Submerged Lands Lease File Number SUB-####-AS, South 19 degrees, 29 minutes, 45 seconds East, 27.93 feet to a point not monumented due to location on submerged lands of Lake Erie, also being the location of said natural shoreline and the northeast corner of said (NAME OF UPLAND OWNER) parcel;

Thence along said natural shoreline, South 62 degrees, 14 minutes, 03 seconds West, 98.37 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, South 69 degrees, 53 minutes, 51 seconds West, 26.67 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 3457 square feet (0.0794 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: The alignment of the centerline of Lake Road West (North 00 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)

Lake Erie Submerged Lands Legal Description Parcel "B"
Adjacent to 7335 Lake Road West, Saybrook Township

Situate in the State of Ohio and located within the waters of Lake Erie, County of Ashtabula, Saybrook Township, Township 13 North, Range 4 West of the Connecticut Western Reserve, adjacent to a portion of fractional Section 3, Original Lot 55 conveyed to (NAME OF UPLAND OWNER) by Deed Volume (XXX), Page (XXX), of the deed records of said county and being more particularly described as follows:

Commencing at a 3/4 inch solid iron pin found in a monument box at the intersection of the centerline of sixty (60) foot Lake Road West and the westerly line of Original Lot 55, said point also being the southwest corner of a parcel of land conveyed to (NAME OF WEST ADJOINER) by Deed Volume (XXX), Page (XXX);

Thence along the centerline of sixty (60) foot Lake Road West, also being the south line of said (NAME OF WEST ADJOINER) parcel, North 90 degrees, 00 minutes, 00 seconds East, 112.11 feet to a P-K nail found, also being the southwest corner of said (NAME OF UPLAND OWNER);

Thence along the west line of said (NAME OF UPLAND OWNER) parcel, North 00 degrees, 00 minutes, 00 seconds East, 265.76 feet, and passing for reference, a 5/8 inch solid iron pin set at 230.00 feet witnessing the location of the natural shoreline of Lake Erie present in (1973) as determined by the Ohio Department of Natural Resources, also being the northwest corner of said (NAME OF UPLAND OWNER) parcel;

Thence departing the northwest corner of said (NAME OF UPLAND OWNER) parcel, across the open waters of Lake Erie, along the littoral partition boundary between said (NAME OF UPLAND OWNER) and (NAME OF WEST ADJOINER) as determined by radial means, North 19 degrees, 29 minutes, 45 seconds West, 25.00 feet, to a point not monumented due to location on submerged lands of Lake Erie, said point being the True Point of Beginning of the Lease Property described;

Thence continuing along said littoral partition boundary across the open waters of Lake Erie, North 19 degrees, 29 minutes, 45 seconds West, 19.00 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence departing said littoral partition boundary, across the open waters of Lake Erie, North 63 degrees, 10 minutes, 11 seconds East, 125.03 feet, to a point not monumented due to location on submerged lands of Lake Erie on the littoral partition boundary of said (NAME OF UPLAND OWNER) parcel east line as determined by radial means, also being the westerly boundary of Lake Erie Submerged Lands Lease File Number SUB-####-AS conveyed to (NAME OF EAST ADJOINER) by Lease Volume (XXX), Page (XXX) of the lease records of said county;

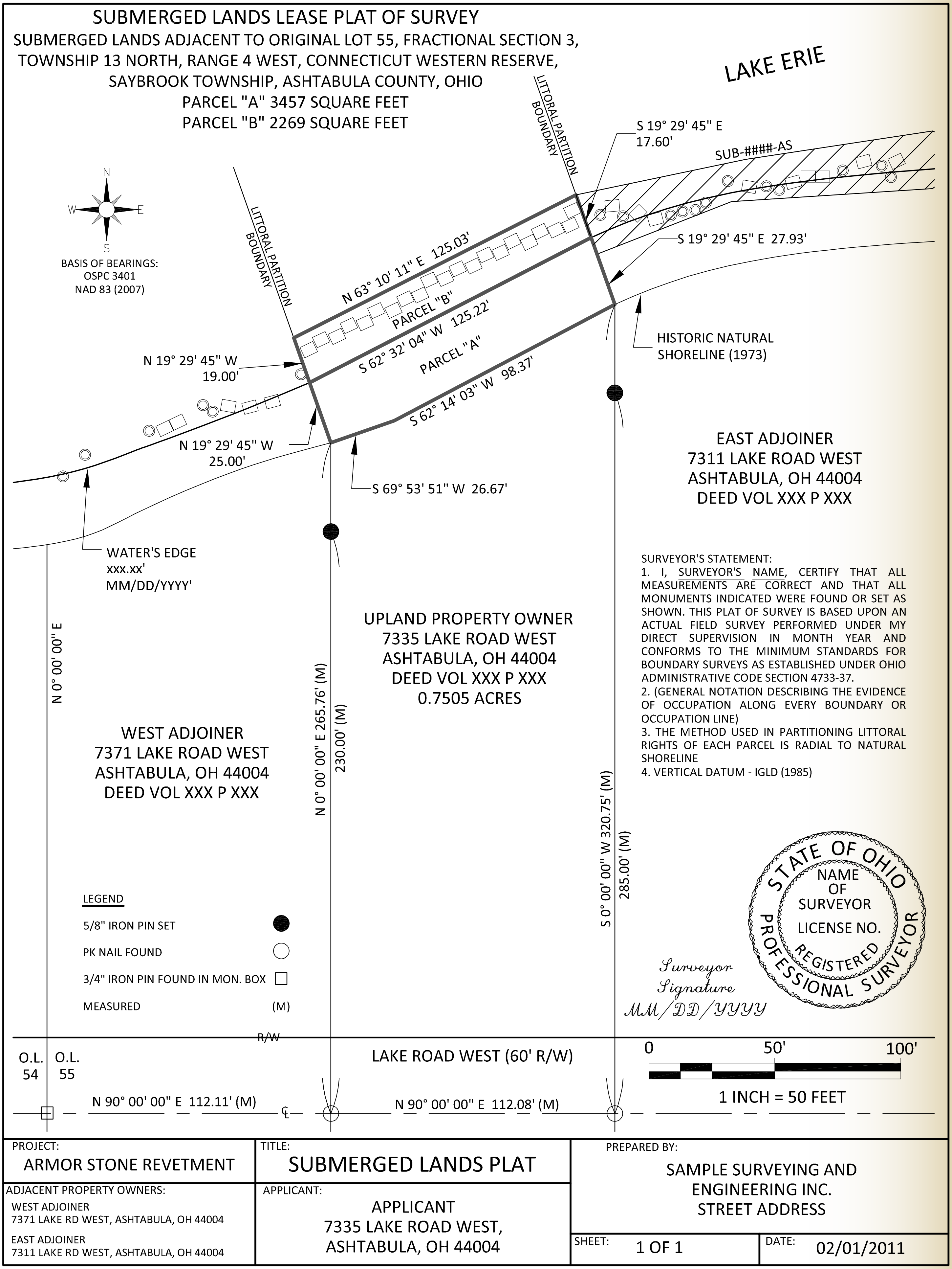
Thence across the open waters of Lake Erie, along the littoral partition boundary between said (NAME OF UPLAND OWNER) and said (NAME OF EAST ADJOINER) parcel as determined by radial means , also being the westerly boundary of said Lake Erie Submerged Lands Lease File Number SUB-####-AS, South 19 degrees, 29 minutes, 45 seconds East, 17.60 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence across the open waters of Lake Erie, South 62 degrees, 32 minutes, 04 seconds West, 125.22 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 2269 square feet (0.0509 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: The alignment of the centerline of Lake Road West (North 00 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)


SUBMERGED LANDS LEASE PLAT OF SURVEY
SUBMERGED LANDS ADJACENT TO ORIGINAL LOT 55, FRACTIONAL SECTION 3,
TOWNSHIP 13 NORTH, RANGE 4 WEST, CONNECTICUT WESTERN RESERVE,
SAYBROOK TOWNSHIP, ASHTABULA COUNTY, OHIO
PARCEL "A" 3457 SQUARE FEET
PARCEL "B" 2269 SQUARE FEET
LAKE ERIE
N
W
E
S
BASIS OF BEARINGS:
OSPC 3401
NAD 83 (2007)
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
S 19° 29' 45" E
17.60'
SUB-####-AS
S 19° 29' 45" E 27.93'
N 63° 10' 11" E 125.03'
PARCEL "B"
S 62° 32' 04" W 125.22'
PARCEL "A"
S 62° 14' 03" W 98.37'
N 19° 29' 45" W
19.00'
N 19° 29' 45" W
25.00'
S 69° 53' 51" W 26.67'
HISTORIC NATURAL
SHORELINE (1973)
WATER'S EDGE
xxx.xx'
MM/DD/YYYY'
EAST ADJOINER
7311 LAKE ROAD WEST
ASHTABULA, OH 44004
DEED VOL XXX P XXX
UPLAND PROPERTY OWNER
7335 LAKE ROAD WEST
ASHTABULA, OH 44004
DEED VOL XXX P XXX
0.7505 ACRES
WEST ADJOINER
7371 LAKE ROAD WEST
ASHTABULA, OH 44004
DEED VOL XXX P XXX
N 0° 00' 00" E
N 0° 00' 00" E 265.76' (M)
230.00' (M)
S 0° 00' 00" W 320.75' (M)
285.00' (M)
SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)
STATE OF OHIO
NAME OF SURVEYOR
LICENSE NO.
REGISTERED
PROFESSIONAL SURVEYOR
Surveyor Signature
MM/DD/YYYY
LEGEND
5/8" IRON PIN SET
PK NAIL FOUND
3/4" IRON PIN FOUND IN MON. BOX
MEASURED (M)
R/W
LAKE ROAD WEST (60' R/W)
O.L. 54
O.L. 55
0
50'
100'
1 INCH = 50 FEET
N 90° 00' 00" E 112.11' (M)
℄
N 90° 00' 00" E 112.08' (M)
PROJECT:
ARMOR STONE REVETMENT
TITLE:
SUBMERGED LANDS PLAT
PREPARED BY:
SAMPLE SURVEYING AND ENGINEERING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WEST ADJOINER
7371 LAKE RD WEST, ASHTABULA, OH 44004
EAST ADJOINER
7311 LAKE RD WEST, ASHTABULA, OH 44004
APPLICANT:
APPLICANT
7335 LAKE ROAD WEST,
ASHTABULA, OH 44004
SHEET:
1 OF 1
DATE:
02/01/2011

Design Example B

The following example demonstrates the design of an armor stone revetment for erosion protection at a site with medium (20 to 30-foot high) bluffs along the shore. The project site is fictitious but similar to the coastal features common along the south coast of Lake Erie's central basin.

Project Purpose

The purpose of Example Project B is to protect the toe of the glacial till bluff from erosion due to wave action. An armor stone revetment is selected to best achieve the project purpose.

Site Description

The project site is located along the shore of Lake Erie in Vermilion, Erie County, approximately 3.5 miles west of the Vermilion River. The shore in this area is oriented from west to east. The predominant direction of sediment transport in the littoral zone is from east to west.

The shore at the project site is irregular in shape due to the installation of the shore perpendicular structures. The site property is oriented in a slight northwest to southeast direction. At the east end of the property there is a small embayment suggesting increased erosion in this area.

The bluffs at the project site are 15 to 20 feet in height and have been partially regraded to an approximately 1.7 horizontal to 1 vertical slope. The bluff extends from 575.1 feet at the toe to a top elevation of 589.1 feet as referenced to the International Great Lakes Datum of 1985 (IGLD 1985). A 15 to 20-foot wide sand and gravel beach is present at the project site.

The bluffs are composed primarily of till overlain with glaciolacustrine silts and clays. In the nearshore zone, shale makes up the bottom. Sand and a nearshore bar system are located as far as 700 feet offshore near the site location. Closer to shore, in the beach zone, sand beaches are trapped by the area's groin structures and range from 0.5 to 3-feet thick. The bottom slope from 100 to 1500 feet offshore is approximately 100 horizontal to 1 vertical.

The site is exposed to storm waves from all angles from west-southwest to east-northeast. A review of historic wave information results in a significant wave height of 2.3 feet at a period of 3.6 seconds. The most frequent wave direction was from 180 degrees (referenced to 0/360 degrees north). The largest wave recorded over the 32-year study was 11.8 feet with a 9.0 second period. The average direction of the largest waves was 11.0 degrees. Wave data was measured at WIS station E06 located approximately 4.5 miles north of the project site in 33-foot deep water.

The project site is not located in a designated Coastal Erosion Area based on the 2010 mapping, but has an expected erosion rate of 0.1 to 0.8 feet over 30 years. There are no existing drainage measures causing localized erosion at the project site.

The eastern and western adjoining properties are similar to the project site in bluff elevation and upland topography. The western adjoining property is undeveloped and includes no shore protection. A 15 to 20-foot wide sand and gravel beach is present at the toe of the bluff. The eastern adjoining property includes an existing structure for erosion protection in the form of a rubble mound revetment. The structure is in poor condition due to undersized concrete rubble being fractured and displaced by wave action.

Field Survey

The upland parcel is located within the Firelands portion of the Connecticut Western Reserve district of Ohio's Public Lands Survey System more specifically part of Original Lot (O.L.) 34, Town 13 North, Range 20 West. Being within the incorporated boundaries of the city of Vermilion, the parcel boundary extends to north right of way of the 60 foot dedicated right of way centered on said centerline.

Horizontal control was established for this site by evaluating the location of published monumentation through the National Geodetic Survey (NGS) website: *www.ngs.noaa.gov*. The closest station to this site was determined to be "A 319" (PID MC0927) which is approximately 2.5 kilometers east. Based upon the NGS datasheet the horizontal accuracy of the station is reported as a Cooperative Base Network Control Station with reports that attempts to recover the station were successful in 2003, 2004 and 2009. Therefore this station was used within the horizontal control network. An open traverse was performed between "A 319" and a Third Order station "Ceylon" (PID MC1118) with intermediate stations located close to the project site. No adjustment was made to the resultant coordinates based upon Ohio State Plane 3401(NAD 83).

Vertical control was established for this site by evaluating the location of published monumentation through the NGS website. The closest station to this site was determined to be "Z 318" (PID MC0928) which is approximately 0.1 kilometers south. Based upon the NGS datasheet, the vertical accuracy of the station is First Order Class II with reports that an attempt to recover the station was successful in 2004. The NGS stainless steel rod, established in 1980, has a reported dynamic height of 597.99 feet at 45 degrees latitude. NGS Vertical Datum Transformation software (VDatum) was used to adjust for the hydraulic corrections for the project location based upon the latitude and longitude positions in the NGS datasheet for station "A 319." A closed level circuit was completed. Confirmation of the elevation, relative to IGLD 1985, of the control stations was performed by benching into the water level on a calm day with minimal wave activity and comparing that value to the water level station data retrieved from NOAA's Great Lakes Online website: *www.glakesonline.nos.noaa.gov/monitor.html* for station #9063063 (Cleveland).

With the horizontal and vertical control network established, recovery of boundary evidence was performed. Monumentation was found, and held as controlling stations included 5/8-inch iron pins at the southwest corner of Sub Lot 5 and the southeast corner of Sub Lot 6. Subsequent points were located along the north right of way of West Lake Road

within the Water's Edge Subdivision, and proration of any surplus was calculated and applied to the subject parcels in the final determination of the boundary lines. A topographic survey was performed that located the cultural (i.e. buildings, survey monuments, coastal structures) and natural (i.e. top and toe of bluff) features on the subject parcel and adjoiners. Notwithstanding the presence of random rubble along the shore on the east portion of the upland parcel, the natural shoreline appears to be unaltered by artificially placed fill material.

Analysis

Parcel data provided by the Erie County Auditor's Office was imported into the computer-aided design (CAD) drawing to establish a general orientation of the shoreline for a reach of approximately 1.5 kilometers. Methodology for partitioning the boundaries between the littoral adjoiners was examined including extending the upland parcel boundary lakeward without deflection and a radial projection from the general alignment of the 1.5 kilometer reach of shore from the intersection of the natural shoreline and the parcel sidelines. The radial projection method provided the most equitable distribution between the subject parcel and the east and west adjoiners.

A base map was provided to the engineering consultant that depicted the locations of the existing site improvements relative to the established parcel boundaries and littoral partitions. A general statement that the survey and plat were prepared in accordance with Ohio Administrative Code (OAC) Section 4733-37 was included and the Ohio registered professional surveyor's signature and seal were affixed to the survey plat (see Existing Site Plan "A").

Design

The maximum slope normally considered for the long-term stability of an armor stone revetment is 1.5 horizontal to 1 vertical. Based on the wave climate in the area of the project site, a slope of 2 horizontal to 1 vertical was selected for a conservative design. Placing a 2H:1V sloped revetment over the existing 1.7H:1V slope also offers the advantage of not having to excavate the existing slope while minimizing the amount of fill required. The toe of the structure is entrenched 2.5 feet into shale bedrock at an elevation of 567.5 feet IGLD 1985.

The project site is located in the Huron to Vermilion reach of the "Revised Report on Great Lakes Open Coast Flooding," (USACE 1988) and has a design water level of 575.5 feet IGLD 1985 for a 30-year return period.

A 5.5-foot structure depth was calculated based on the lake bottom elevation at the structure toe and the design water level. Using the breaking wave equation presented in Chapter 3, a design wave height of 4.3 feet was calculated for this case.

Since the toe of the structure was designed to be entrenched 2.5 feet into the shale bedrock, the depth of the structure at the base of the toe will be 8.0 feet. Future scouring at the toe of the structure due to the fractures and wear of the shale would result in an increase in water depth from 5.2 to 7.7 feet and a design wave height of 6.0 feet for this conservative case. The scour of shale bedrock may not always be a reasonable assumption, but for this example, it was assumed that the fractures caused during entrenchment would lead to scour.

Hudson's Equation was used to calculate the median armor stone size to resist displacement due to wave action. Using the unit weight for the specified limestone, the minimum median armor stone size is 0.4 tons for the non-scour case. The minimum median armor stone size was 1.1 ton per unit if the toe of the structure is scoured.

A factor of safety of 2.0 was selected for the armor stone size to account for potential effects of ice forces and long-term fracturing of the stone. Using the conservative 1.1 ton per unit value from Hudson's Equation, the safety factor results in a lower limit for the armor stone of 2.2 tons per unit and a range of 1.6 to 2.7 tons per unit. The selected design specification of a 2 to 4-ton range for the armor stone layer also provides additional mass that improves the long-term ability of the revetment to resist earth forces from the upland. A double layer of 2 to 4-ton limestone will be stacked in a 6-foot thick armor layer.

The filter layer was specified as stone or clean concrete rubble about 1/3 of the diameter of the armor stone. For economy of design, the existing concrete modules and concrete rubble at the toe of the bluff will be relocated to form the filter layer for the revetment. Due to the variability of the filter layer material and the fine-grained till composition of the bluff, a geotextile filter fabric is specified.

Wave run-up on the structure was calculated using the empirical formula introduced in Chapters 3. Wave run-up of 5.7 feet to an elevation of 581.2 feet IGLD 1985 was calculated for the initial design case. If the toe of the structure is scoured, the wave run-up increases to 7.6 feet, to an elevation of 583.1 feet IGLD 1985. For an economical design, the crest of the revetment is set to 582.0 feet IGLD 1985 and a splash apron is specified to 585.0 feet IGLD 1985. The splash apron is specified as a double layer of new ODOT 601 Type "B" stone. The upper bluff will be stabilized by re-grading a gentle slope from the top of the splash apron at 585.0 feet IGLD 1985 to the top of the bluff at 589.1 feet IGLD 1985. A thin layer of ODOT 601 Type 56 stone will be used as a base for the re-graded slope in the area of the 12 to 24-inch filter layer stone.

To prevent sliding failure along the slope of the revetment, 4 to 5-ton armor stones are to be entrenched 2.5 feet into the shale bedrock. Toe stones are typically specified to be 1 to 2 tons heavier than stones used for the armor layer.

To mitigate end effects, the west end of revetment will be curved back into the bluff face with a radius approximately equal to the plan view width of the armor layer. The east end of the structure is extended to the property line to be continuous with the existing revetment on the eastern adjacent property. This should sufficiently reduce the risk to adjacent properties and prevent potential upland slope failure at the ends of structure.

Discussion

In this example, the revetment has been designed to closely follow the shape of the shore. The revetment will extend a maximum of 29.2 feet from the toe of the existing bluff. This distance is determined by the required crest elevation and revetment slope and cannot be reduced without compromising the functionality or stability of the structure. Therefore this structure has been appropriately designed to minimize effects on lake processes and adjacent properties.

The revetment is intended to prevent erosion of the existing bluff and will decrease the amount of material added to the littoral system. Any sand or gravel in the footprint of the revetment must be excavated and sidecast into the lake prior to construction to prevent sediment from being permanently removed from the littoral system.

As the structure will extend approximately 29 feet lakeward of the bluff toe, it will affect the littoral transport of material along the shore. In this case, the impact is expected to be minimal due to the existing rubble mound revetment on the eastern adjacent property. It is unlikely that this structure will trap sediment. The structure may cause changes in wave energy that could adversely affect adjacent properties. This risk has been addressed with the use of rough, angular limestone placed at a slope of 2H:1V. Much of the wave energy will be absorbed and dissipated by the revetment, minimizing the wave energy reflected in the nearshore zone.

Final Survey Products

Based upon the design from the Ohio registered professional engineer, a plat that depicted the boundaries of the submerged lands lease has been prepared. The project site includes two separate parcels, and a lot consolidation has not been planned by the parcel owner. Therefore two separate lease parcels are depicted using the location of the water's edge on the date of the field survey as the natural shoreline. (see Submerged Lands Plat "B").

Two metes and bounds descriptions have been written for the areas depicted on the plat of survey with direct relationship to the upland parcel boundaries as required in Ohio Revised Code Section 1506.11(B). (See Submerged Lands Lease descriptions for Parcel "A" and "B.")

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE B - MEDIUM BLUFF
SHEET NO. 1 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

REVETMENT DESIGN

A. DESIGN WATER LEVEL

30 YEAR DESIGN WATER LEVEL = 575.5 FT IGLD 1985
REFERENCE: "REVISED REPORT ON GREAT LAKES OPEN COAST FLOODING" USACE, 1988.

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE
LAKE BOTTOM ELEVATION = 570.0 FEET IGLD 1985
STRUCTURE DEPTH = ds = 575.5 FT - 570.0 FT = 5.5 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 5.5 FT = 4.3 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED
TOE OF STRUCTURE = 567.5 FEET IGLD 1985
STRUCTURE DEPTH = ds = 575.5 FT - 567.5 FT = 8.0 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 8.0 FT = 6.2 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

C. ARMOR STONE SIZE

USE HUDSON'S EQUATION:

MEDIAN ARMOR STONE SIZE = $W50 = \dfrac{\omega r\, H^3}{Kd\,(Sr-1)^3 \cot\theta}$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22

ωr = UNIT WEIGHT OF ARMOR STONE = 165 LB/FT³
ASSUME H = BREAKING WAVE HEIGHT = Hb
Kd = 2.0 FOR ROUGH ANGULAR QUARRY STONES
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22
COT θ = STRUCTURE SLOPE = 2.0

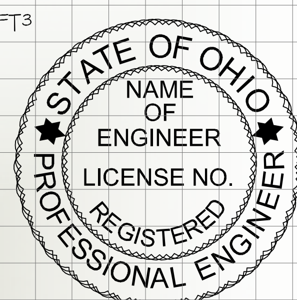
$Sr = \dfrac{\omega r}{\omega w}$ ωr = SPECIFIC WEIGHT OF STONE = 165 LB/FT³
ωw = SPECIFIC WEIGHT OF WATER = 62.4 LB/FT³

INITIAL DESIGN CASE

BREAKING WAVE HEIGHT = Hb = 4.3 FT

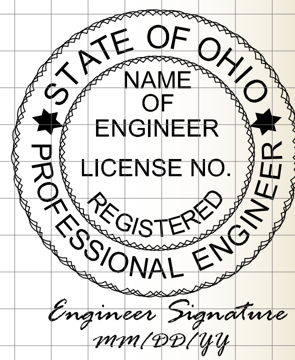
$W50 = \dfrac{(165\ LB/FT^3)(4.3\ FT)^3}{2.0\,(165/62.4-1)^3\,(2.0)} = 738\ LB = 0.4\ TON$

MEDIAN STONE SIZE = W50 x FS = 0.4 TON x 2.0 = 0.8 TON



Engineer Signature
MM/DD/YY

REVETMENT DESIGN (CONT.)



CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

BREAKING WAVE HEIGHT = Hb = 6.2 FT

$$W50 = \frac{(165\ LB/FT^3)(6.2\ FT)^3}{2.0\,(165/62.4-1)^3\,(2.0)} = 2212\ LB = 1.1\ TON$$

MEDIAN STONE SIZE = W50 x FS = 1.1 TON x 2.0 = 2.2 TON

TO BE CONSERVATIVE USE 2 TO 4 TON ARMOR STONE

*NOTE: ACES CALCULATIONS SUPPORT RESULTS

INITIAL DESIGN CASE
W50 = 1399 LB = 0.7 TON
ARMOR LAYER THICKNESS = 4.1 FEET

CONSERVATIVE DESIGN CASE
W50 = 3717 LB = 1.9 TON
ARMOR LAYER THICKNESS = 5.6 FEET

C. WAVE RUNUP AND OVERTOPPING

EMPIRICAL FORMULA: $R = \dfrac{Hb\,(a \times \xi)}{1 + (b \times \xi)}$

REFERENCE: "WAVE PERIOD EFFECT ON THE STABILITY OF RIPRAP" ASCE, 1975, P 1019- 1034.

a = 0.775 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
b = 0.361 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
REFERENCE: "COST-EFFECTIVE OPTIMIZATION OF RUBBLE-MOUND BREAKWATER CROSS SECTIONS" USACE, 1986, P 45-53.

IRIBARREN NO. = $\xi = \dfrac{\tan\Theta}{\sqrt{(2\pi\,Hb / g\,T^2)}}$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE VI-5-6.

Θ = ANGLE OF STRUCTURE FACE
g = 32.2 FT/SEC^2
T = WAVE PERIOD = 8 SECOND PERIOD ASSUMED*

*AN 8 SECOND PERIOD IS A CONSERVATIVE ESTIMATE BASED ON WIS DATA. THE LARGEST WAVE RECORDED AT WIS STATION E06 OVER A 32 YEAR STUDY (1956-1987) HAD A PERIOD OF 9.0 SECONDS. - REFERENCE: "WIS REPORT 22, HINDCAST WAVE INFORMATION FOR THE GREAT LAKES: LAKE ERIE" USACE, 1991, P A86.

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE B - MEDIUM BLUFF
SHEET NO. 3 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

REVETMENT DESIGN (CONT.)

INITIAL CASE

IRIBARREN NO. = $\xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(4.3\text{ FT}) / (32.2\text{ FT/SEC}^2)(8\text{ SEC})^2}}$ $\xi = 4.4$

WAVE RUNUP: $R = \dfrac{(4.3\text{ FT})(0.775 \times 4.4)}{1 + (0.361 \times 4.4)}$

R = 5.7 FT (FOR INITIAL CASE)

RUNUP ELEVATION = 575.5 FT IGLD 1985 + 5.7 FT = 581.2 FT IGLD 1985

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

IRIBARREN NO. = $\xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(6.2\text{ FT}) / (32.2\text{ FT/SEC}^2)(8\text{ SEC})^2}}$ $\xi = 3.6$

WAVE RUNUP: $R = \dfrac{(6.2\text{ FT})(0.775 \times 3.6)}{1 + (0.361 \times 3.6)}$

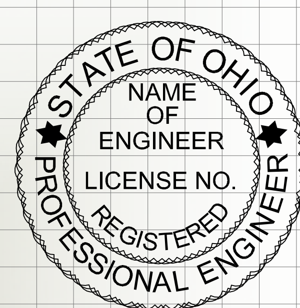
R = 7.6 FT (FOR CONSERVATIVE CASE)

RUNUP ELEVATION = 575.5 FT IGLD 1985 + 7.6 FT = 583.1 FT IGLD 1985

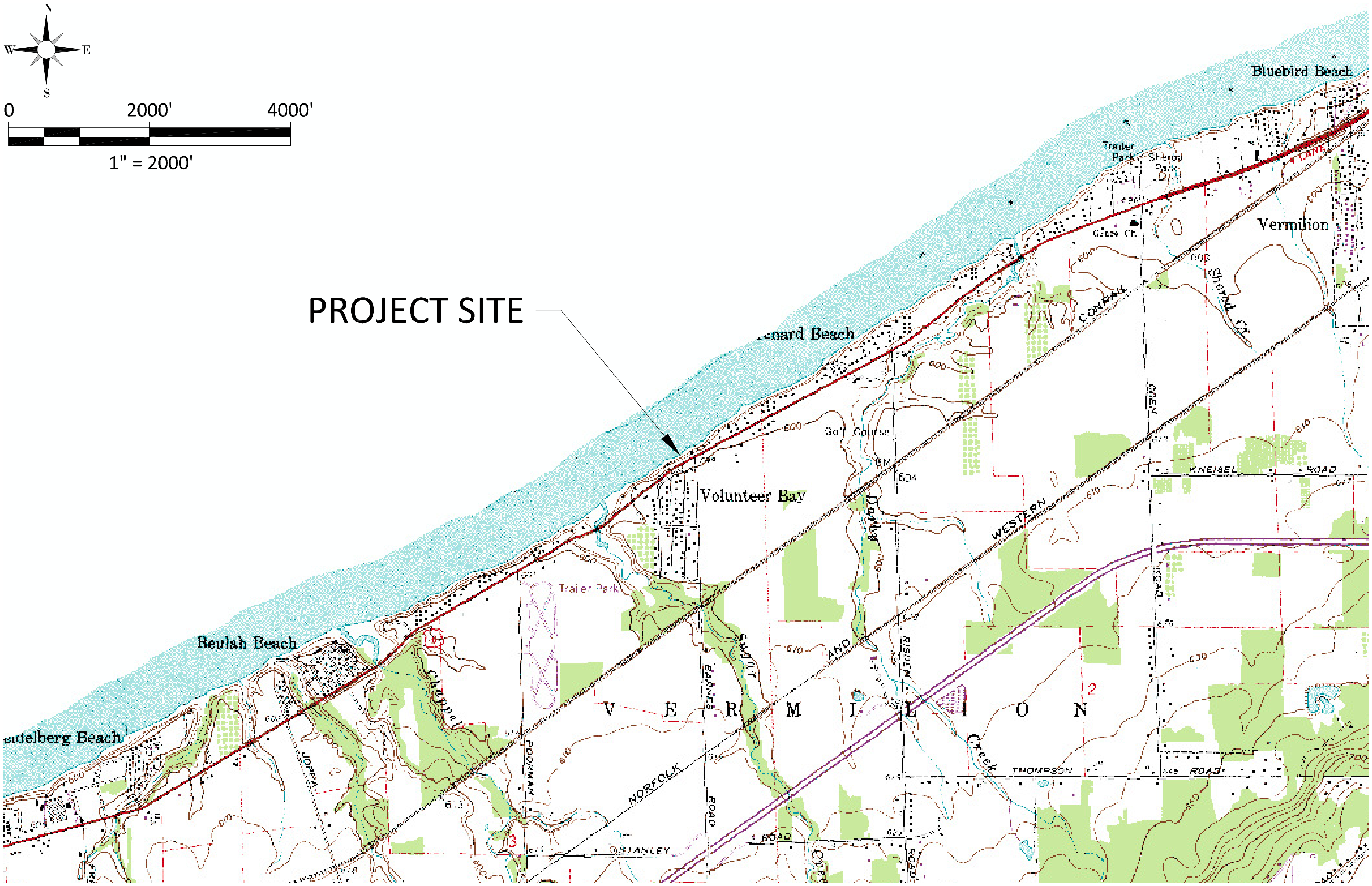
CONSERVATIVE DESIGN: SET TOP OF ARMOR STONE AT 582.0 FT IGLD 1985
SET TOP OF SPLASH APRON AT 585.0 FT IGLD 1985

*NOTE: ACES CALCULATIONS SUPPORT RESULTS
INITIAL: RUNUP = 5.6 FT TO AN ELEVATION OF 581.1 FT IGLD 1985
CONSERVATIVE: RUNUP = 7.6 FT TO AN ELEVATION OF 583.1 FT IGLD 1985

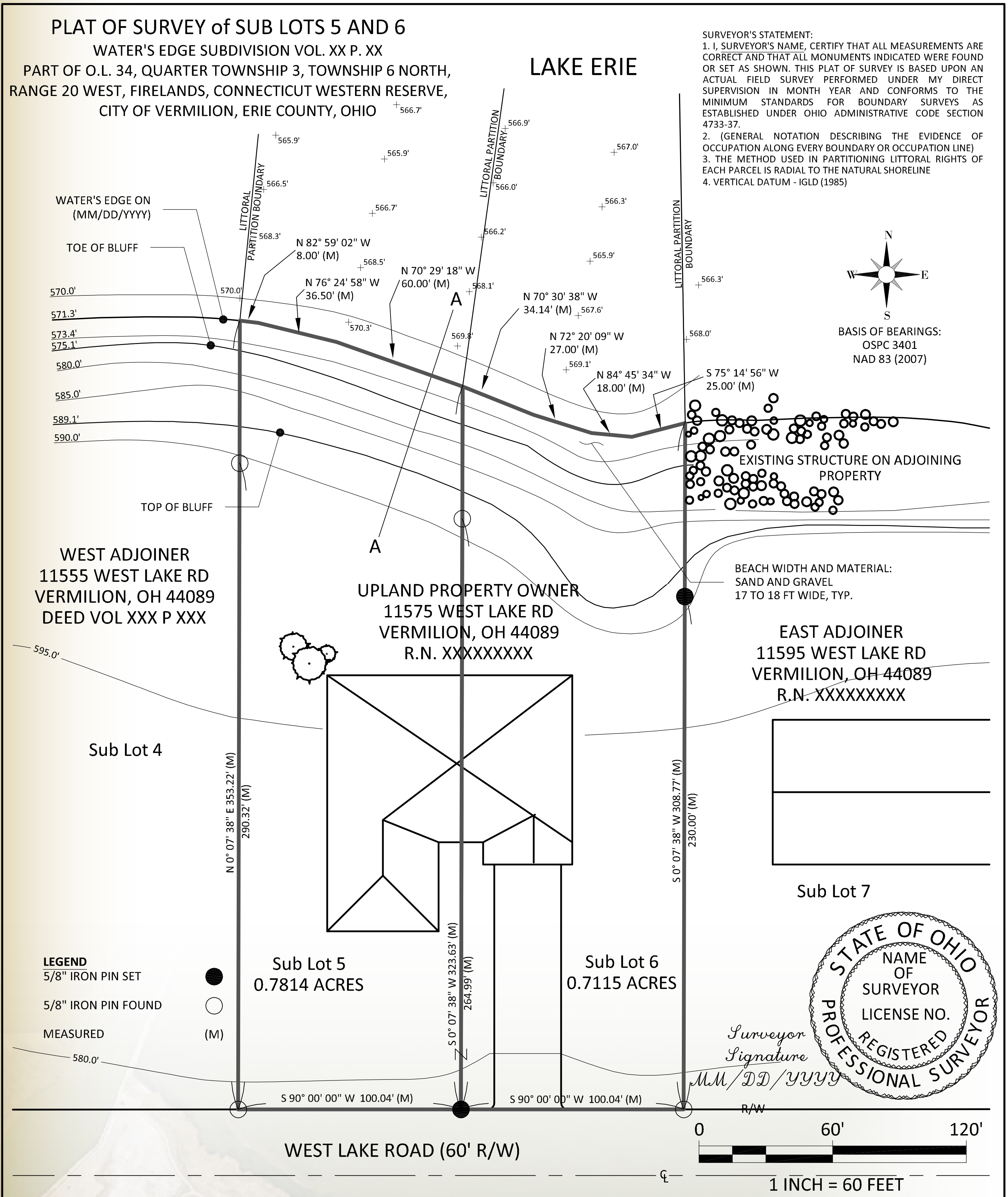
*NOTE: THE CALCULATIONS INCLUDED IN THIS EXAMPLE WERE ORIGINALLY COMPUTED USING EXCEL SPREADSHEETS. THE SOFTWARE DISPLAYS A SPECIFIED NUMBER OF SIGNIFICANT FIGURES BUT RETAINS THE ORIGINAL NUMBER FOR OPERATIONS. AS A RESULT SMALL ROUNDING ERRORS ARE INTRODUCED IN TRANSCRIBING THE STEP-BY-STEP CALCULATIONS. THESE ERRORS ARE ACCEPTABLE CONSIDERING THE OVERALL ACCURACY OF THE CALCULATION METHODS AND THE PURPOSE OF THIS DESIGN MANUAL.



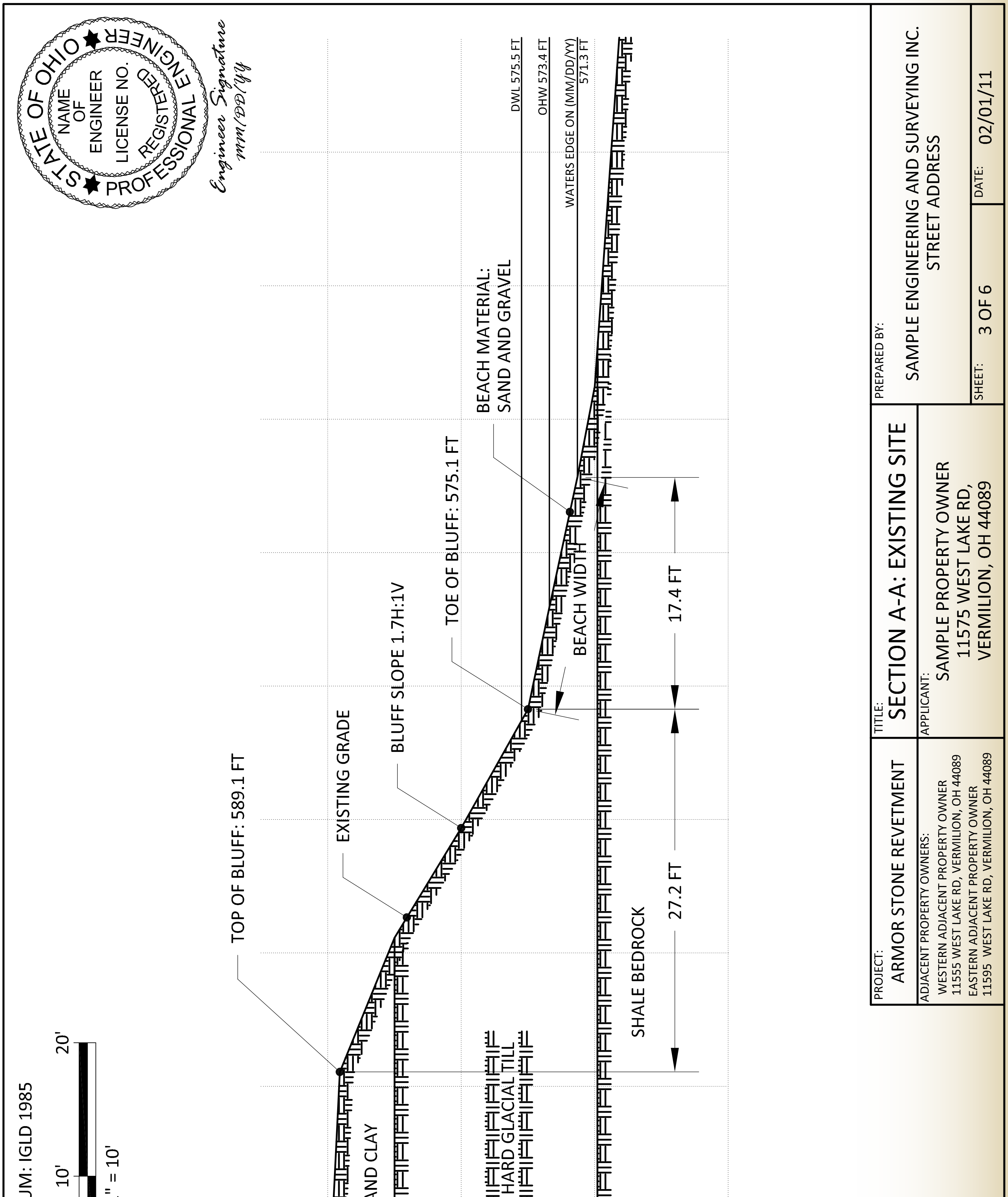
Engineer Signature
mm/DD/YY

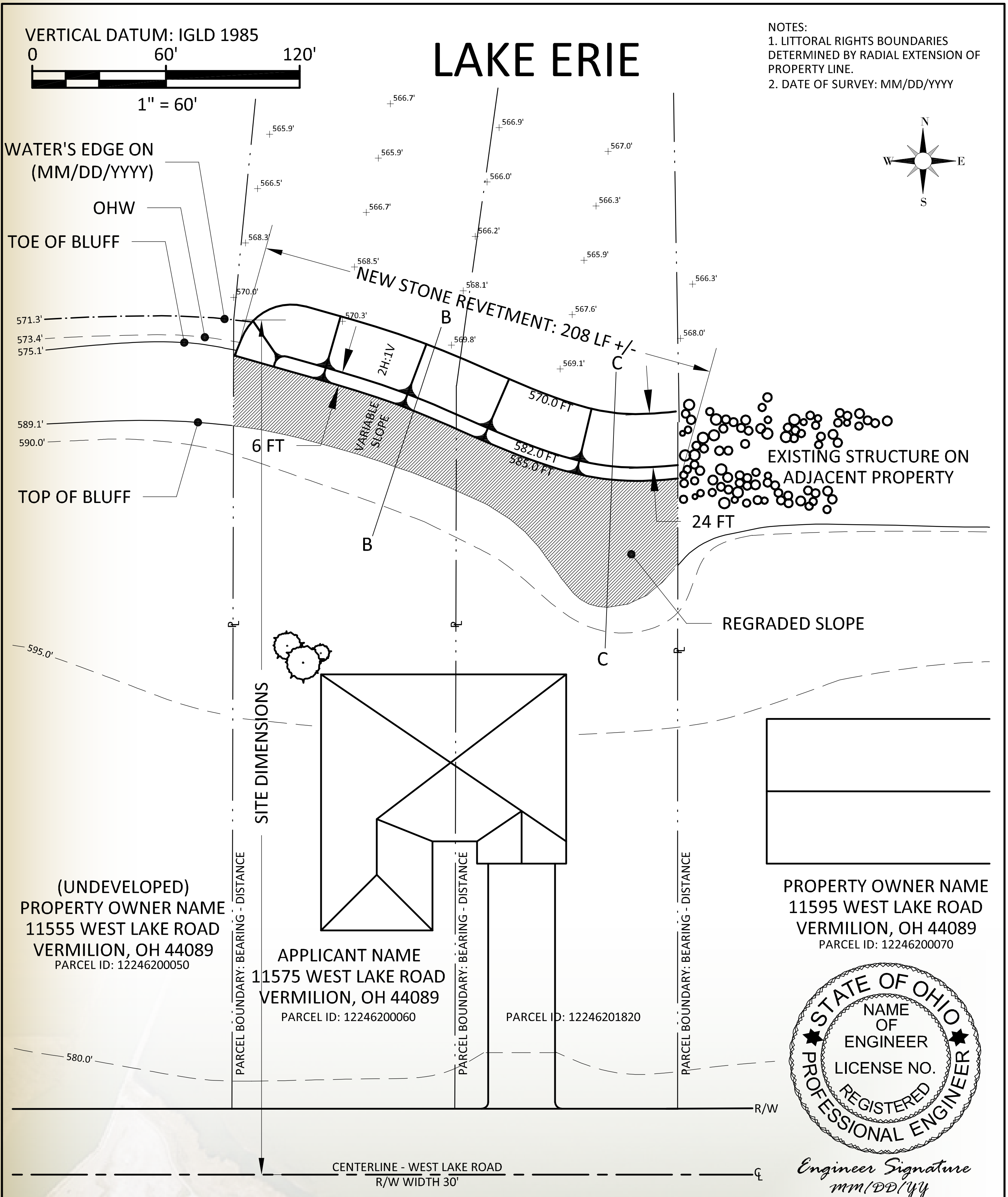


PROJECT: ARMOR STONE REVETMENT	TITLE: VICINITY MAP	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 1 OF 6	DATE: 02/01/11

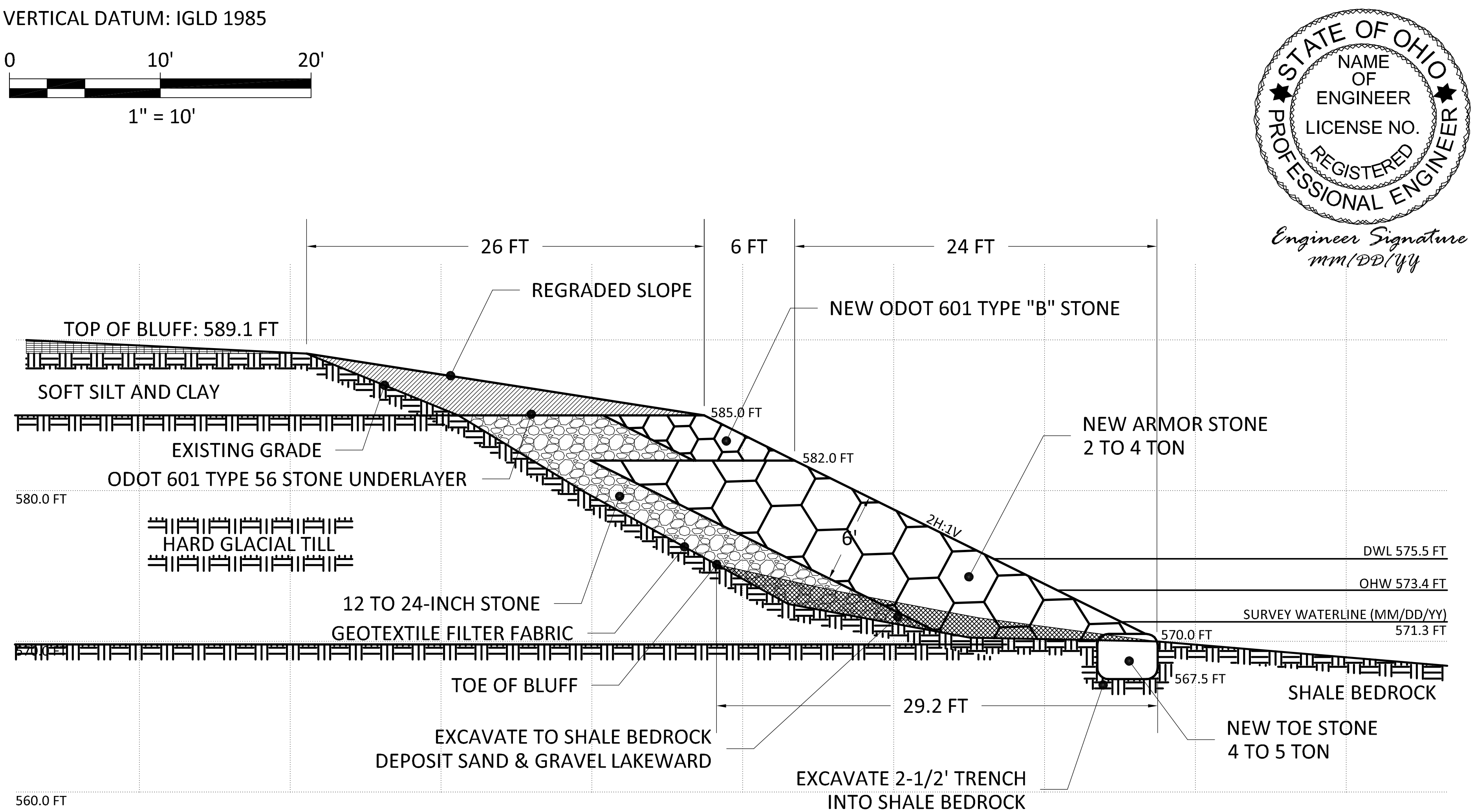


PROJECT: ARMOR STONE REVETMENT	TITLE: EXISTING SITE PLAN	PREPARED BY: SAMPLE SURVEYING AND ENGINEERING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WEST ADJOINER 11555 WEST LAKE RD, VERMILION, OH 44089 EAST ADJOINER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: APPLICANT 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 2 OF 6 / DATE: 02/01/2011


VERTICAL DATUM: IGLD 1985
0
10'
20'
1" = 10'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
MM/DD/YY
590.0 FT
580.0 FT
570.0 FT
560.0 FT
TOP OF BLUFF: 589.1 FT
EXISTING GRADE
BLUFF SLOPE 1.7H:1V
TOE OF BLUFF: 575.1 FT
BEACH MATERIAL:
SAND AND GRAVEL
DWL 575.5 FT
OHW 573.4 FT
WATERS EDGE ON (MM/DD/YY)
571.3 FT
SOFT SILT AND CLAY
HARD GLACIAL TILL
SHALE BEDROCK
BEACH WIDTH
27.2 FT
17.4 FT
PROJECT:
ARMOR STONE REVETMENT
TITLE:
SECTION A-A: EXISTING SITE
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
11555 WEST LAKE RD, VERMILION, OH 44089
EASTERN ADJACENT PROPERTY OWNER
11595 WEST LAKE RD, VERMILION, OH 44089
APPLICANT:
SAMPLE PROPERTY OWNER
11575 WEST LAKE RD,
VERMILION, OH 44089
SHEET:
3 OF 6
DATE:
02/01/11



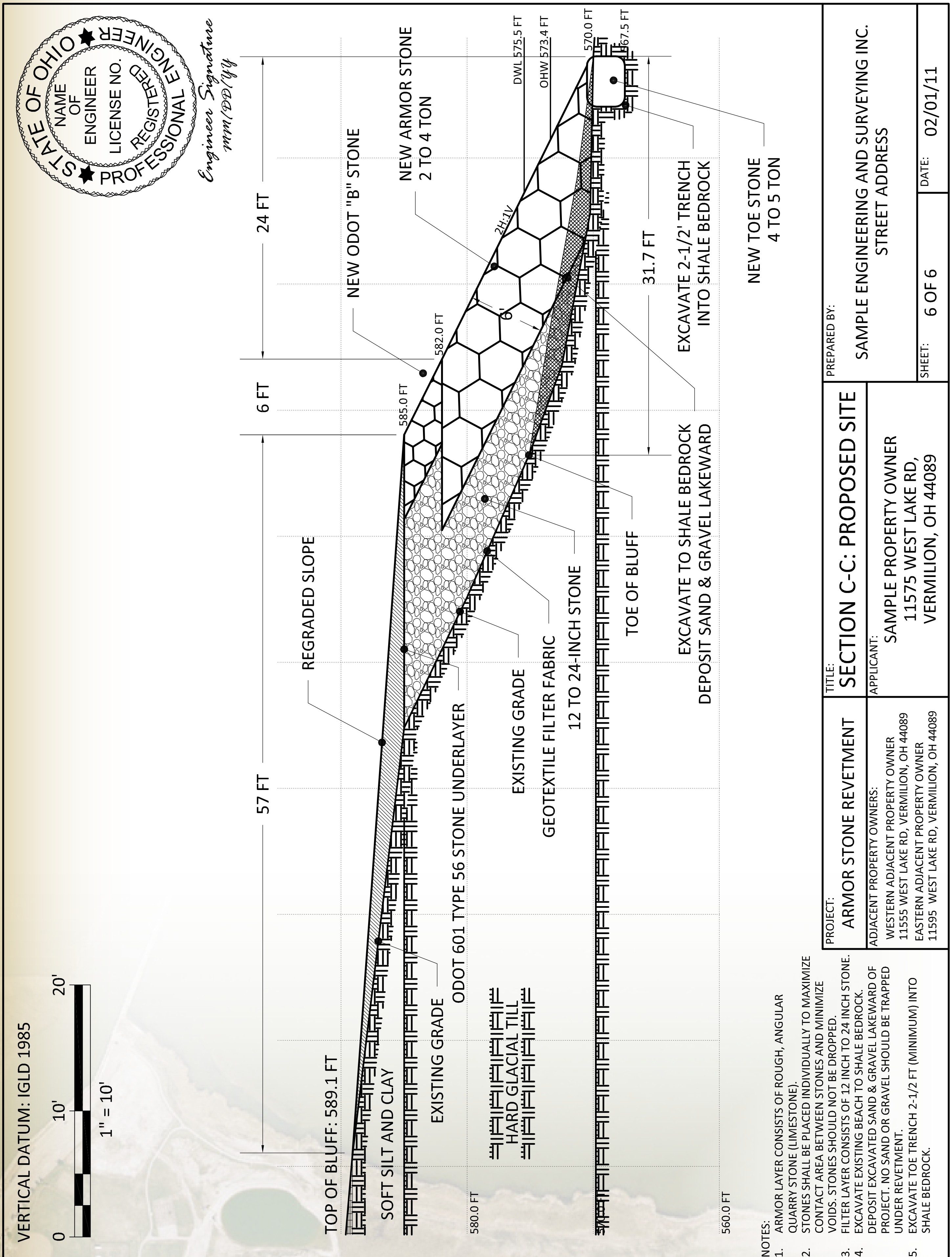
PROJECT: ARMOR STONE REVETMENT	TITLE: PROPOSED SITE PLAN	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 4 OF 6	DATE: 02/01/11



NOTES:

1. ARMOR LAYER CONSISTS OF ROUGH, ANGULAR QUARRY STONE (LIMESTONE).
2. STONES SHALL BE PLACED INDIVIDUALLY TO MAXIMIZE CONTACT AREA BETWEEN STONES AND MINIMIZE VOIDS. STONES SHOULD NOT BE DROPPED.
3. FILTER LAYER CONSISTS OF 12 INCH TO 24 INCH STONE.
4. EXCAVATE EXISTING BEACH TO SHALE BEDROCK. DEPOSIT EXCAVATED SAND & GRAVEL LAKEWARD OF PROJECT. NO SAND OR GRAVEL SHOULD BE TRAPPED UNDER REVETMENT.
5. EXCAVATE TOE TRENCH 2-1/2 FT (MINIMUM) INTO SHALE BEDROCK.

PROJECT:	TITLE:	PREPARED BY:
ARMOR STONE REVETMENT	SECTION B-B: PROPOSED SITE	SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 5 OF 6 DATE: 02/01/11



VERTICAL DATUM: IGLD 1985
0
10'
20'
1" = 10'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
MM/DD/YY
TOP OF BLUFF: 589.1 FT
SOFT SILT AND CLAY
EXISTING GRADE
ODOT 601 TYPE 56 STONE UNDERLAYER
HARD GLACIAL TILL
REGRADED SLOPE
EXISTING GRADE
GEOTEXTILE FILTER FABRIC
12 TO 24-INCH STONE
TOE OF BLUFF
EXCAVATE TO SHALE BEDROCK
DEPOSIT SAND & GRAVEL LAKEWARD
NEW ODOT "B" STONE
NEW ARMOR STONE
2 TO 4 TON
EXCAVATE 2-1/2' TRENCH
INTO SHALE BEDROCK
NEW TOE STONE
4 TO 5 TON
57 FT
6 FT
24 FT
31.7 FT
585.0 FT
582.0 FT
2H:1V
6'
DWL 575.5 FT
OHW 573.4 FT
570.0 FT
567.5 FT
580.0 FT
560.0 FT
NOTES:
1. ARMOR LAYER CONSISTS OF ROUGH, ANGULAR QUARRY STONE (LIMESTONE).
2. STONES SHALL BE PLACED INDIVIDUALLY TO MAXIMIZE CONTACT AREA BETWEEN STONES AND MINIMIZE VOIDS. STONES SHOULD NOT BE DROPPED.
3. FILTER LAYER CONSISTS OF 12 INCH TO 24 INCH STONE.
4. EXCAVATE EXISTING BEACH TO SHALE BEDROCK. DEPOSIT EXCAVATED SAND & GRAVEL LAKEWARD OF PROJECT. NO SAND OR GRAVEL SHOULD BE TRAPPED UNDER REVETMENT.
5. EXCAVATE TOE TRENCH 2-1/2 FT (MINIMUM) INTO SHALE BEDROCK.
PROJECT:
ARMOR STONE REVETMENT
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
11555 WEST LAKE RD, VERMILION, OH 44089
EASTERN ADJACENT PROPERTY OWNER
11595 WEST LAKE RD, VERMILION, OH 44089
TITLE:
SECTION C-C: PROPOSED SITE
APPLICANT:
SAMPLE PROPERTY OWNER
11575 WEST LAKE RD,
VERMILION, OH 44089
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
SHEET:
6 OF 6
DATE:
02/01/11

Lake Erie Submerged Lands Legal Description Parcel “A”
Adjacent to 11575 West Lake Road, Vermilion

Situate in the State of Ohio and located within the waters of Lake Erie, County of Erie, City of Vermilion, part of Original Lot 34, Quarter Township 3, Township 6 North, Range 20 West of the Firelands portion of the Connecticut Western Reserve, adjacent to the Water's Edge Subdivision, Sub Lot 5 as recorded in Plat Volume (XX), Page (XX) of said county records and being adjacent to a parcel of land conveyed to (NAME OF UPLAND OWNER) by Record Number (XXXXXXXXX) of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin set at the southeast corner of Sub Lot 5 of Water's Edge Subdivision, said point also being the southwest corner of Sub Lot 6 conveyed to (NAME OF EAST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the east line of said Sub Lot 5, also being the west line of Sub Lot 6, North 00 degrees, 07 minutes, 38 seconds East, 323.63 feet to a point on the natural shoreline as determined by a field survey on (DATE) not monumented due to the location on the submerged lands of Lake Erie, and passing for reference a 5/8 inch solid iron pin found at 264.99 feet, also being the northeast corner of said Sub Lot 5 and the northwest corner of said Sub Lot 6, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said Sub Lot 5, across the open waters of Lake Erie, along the littoral partition boundary between said Sub Lot 5 and said Sub Lot 6 as determined by radial means, North 07 degrees, 57 minutes, 10 seconds East, 12.50 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence across the open waters of Lake Erie, North 70 degrees, 32 minutes, 59 seconds West, 79.34 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 69 degrees, 03 minutes, 43 seconds West, 16.00 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 41 degrees, 49 minutes, 55 seconds West, 6.00 feet to a point not monumented due to location on submerged lands of Lake Erie, also being the location of said natural shoreline;

Thence along said natural shoreline, South 76 degrees, 24 minutes, 58 seconds East, 36.50 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, South 70 degrees, 29 minutes, 18 seconds East, 60.00 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 1135 square feet (0.0260 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: The alignment of the 60' north right of way of West Lake Road (North 90 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

____________________ **SEAL**

(Name of Surveyor)
Registered Surveyor (#XXXX)

Lake Erie Submerged Lands Legal Description Parcel “B”
Adjacent to 11575 West Lake Road, Vermilion

Situate in the State of Ohio and located within the waters of Lake Erie, County of Erie, City of Vermilion, part of Original Lot 34, Quarter Township 3, Township 6 North, Range 20 West of the Firelands portion of the Connecticut Western Reserve, adjacent to the Water's Edge Subdivision, Sub Lot 6 as recorded in Plat Volume (XX), Page (XX) of said county records and being adjacent to a parcel of land conveyed to (NAME OF UPLAND OWNER) by Record Number (XXXXXXXXX) of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin set at the southwest corner of Sub Lot 6 of Water's Edge Subdivision, said point also being the southeast corner of Sub Lot 5 conveyed to (NAME OF WEST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the west line of said Sub Lot 6, also being the east line of said Sub Lot 5, North 00 degrees, 07 minutes, 38 seconds East, 323.63 feet to a point on the natural shoreline of Lake Erie as determined by a field survey on (DATE) not monumented due to location on submerged lands of Lake Erie, and passing for reference a 5/8 inch solid iron pin found at 264.99 feet, also being the northwest corner of said Sub Lot 6 and the northeast corner of said Sub Lot 5, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said Sub Lot 6, across the open waters of Lake Erie, along the littoral partition boundary between said Sub Lot 5 and said Sub Lot 6 as determined by radial means, North 07 degrees, 57 minutes, 10 seconds East, 12.50 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence across the open waters of Lake Erie, South 68 degrees, 06 minutes, 27 seconds East, 52.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 77 degrees, 36 minutes, 38 seconds East, 25.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, North 84 degrees, 22 minutes, 58 seconds East, 25.65 feet to a point not monumented due to the location on submerged lands of Lake Erie on the littoral partition boundary as determined by radial means of said Sub Lot 6 and Sub Lot 7 as conveyed to (NAME OF EAST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the littoral partition boundary between said Sub Lot 6 and said Sub Lot 7 as determined by radial means, South 00 degrees, 59 minutes, 40 seconds East, 5.00 feet to a point not monumented due to location on submerged lands of Lake Erie, also being the location of said natural shoreline and the northeast corner of said Sub Lot 6;

Thence along said natural shoreline, South 75 degrees, 14 minutes, 56 seconds West, 25.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, North 84 degrees, 45 minutes, 34 seconds West, 18.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

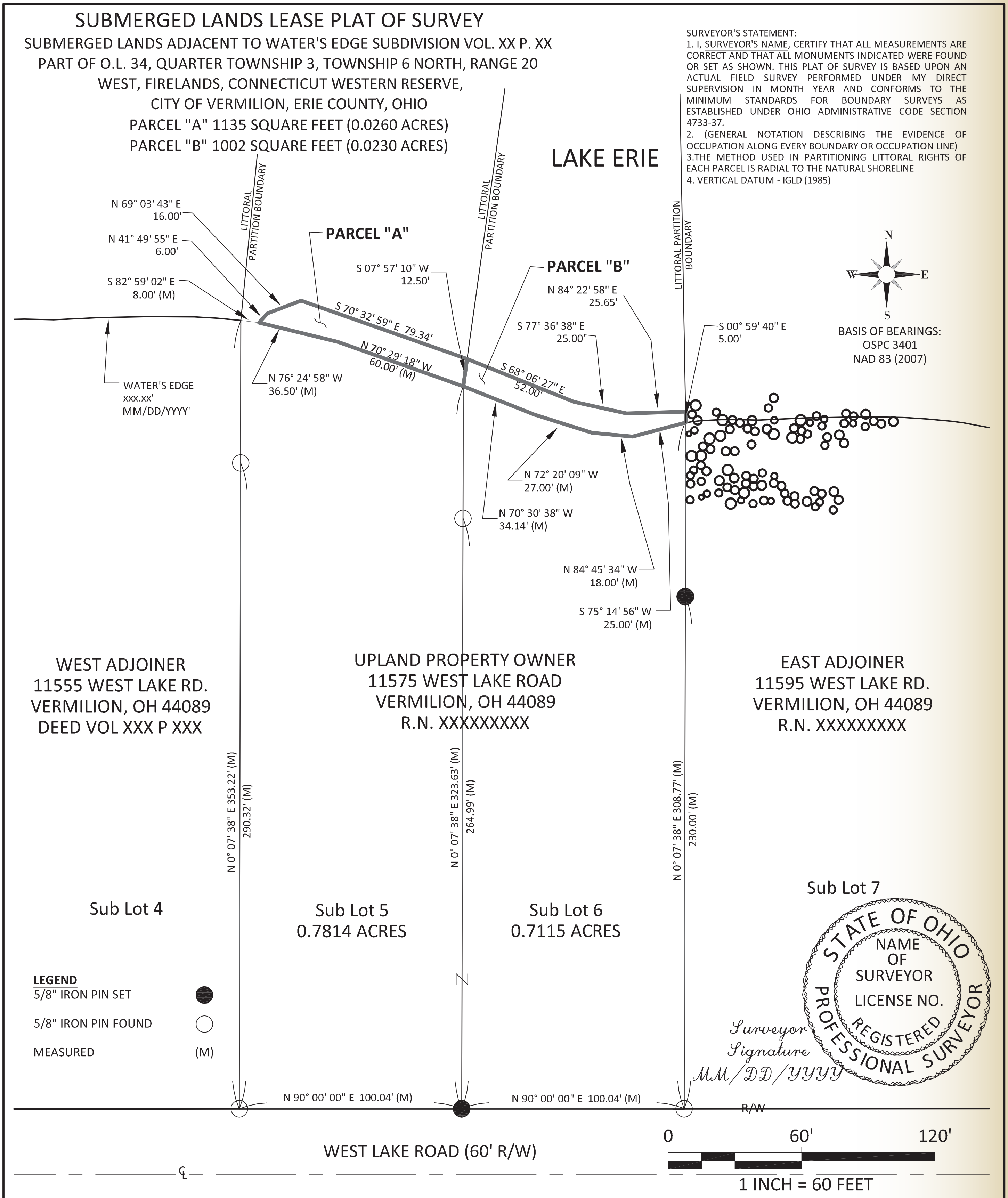
Thence continuing along said natural shoreline, North 72 degrees, 20 minutes, 09 seconds West, 27.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, North 70 degrees, 30 minutes, 38 seconds West, 34.14 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 1002 square feet (0.0230 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: Basis of Bearings: The alignment of the 60' north right of way of West Lake Road (North 90 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

______________________ **SEAL**

(Name of Surveyor)
Registered Surveyor (#XXXX)



PROJECT: ARMOR STONE REVETMENT	TITLE: SUBMERGED LANDS PLAT	PREPARED BY: SAMPLE SURVEYING AND ENGINEERING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WEST ADJOINER 11555 OAK ST, VERMILION, OH 44089; EAST ADJOINER 11595 OAK ST, VERMILION, OH 44089	APPLICANT: APPLICANT 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 1 OF 1 — DATE: 02/01/2011

Design Example C

The following example demonstrates the design of an armor stone revetment as erosion protection at a site with low (0 to 15-foot high) bluffs along the shore. The project site is fictitious but similar to the coastal features common along the south coast of Lake Erie's western basin.

Project Purpose

The purpose of Example Project C is to protect the toe of the silt and clay bluff from erosion due to wave action. An armor stone revetment is selected to best achieve the project purpose.

Site Description

The project site is located along the shore of Lake Erie in Ottawa County, between Port Clinton and Catawba Island. The shore in this area is oriented from west to east, and is irregular in shape with small bays and headlands. The predominant direction of sediment transport in the littoral zone is from northeast to southwest.

The shore at the project site consists of a 30 to 40-foot wide sand and gravel beach that fronts a 6-foot high bluff (embankment). The bluff extends from a toe elevation of 572.7 feet to 579.0 feet at the crest as referenced to the International Great Lakes Datum of 1985 (IGLD 1985). A timber crib pier is present at the center of the site property and is trapping a small amount of sediment on its east edge. The crib pier is made up of two 16-foot long by 8-foot wide timber cribs with a crest elevation of 576.0 IGLD 1985.

The bluff is composed primarily of silt and clay with a thin layer of topsoil. A 2 to 4-foot thick layer of sand covers till in the nearshore zone and is distributed in a bar system. Limestone bedrock is present at an unknown depth. The nearshore slopes at approximately 4 degrees for the first 100 feet then levels to approximately 1 degree.

The site is exposed to storm waves from west-northwest to north directions but is partially protected by Catawba Island and the Bass Islands from northeast waves. A review of historic wave information results in a significant wave height of 1.6 feet at a period of 3.4 seconds. The most frequent wave direction was from 225.0 degrees (referenced to 0/360 degrees north). The largest wave recorded over the 32-year study was 6.9 feet with a 7.0 second period. The average direction of the largest waves was 321.0 degrees. Wave data was measured at WIS station E04 located approximately 3.5 miles north of the project site in 20-foot deep water.

The expected erosion rate at the project site is 0.0 feet over 30 years based on the 2010 Coastal Erosion Area maps. The site is not located in a designated Coastal Erosion Area. There are no existing drainage measures causing localized erosion at the project site.

The eastern and western adjoining properties are similar to the project site in bluff elevation and upland topography. The beach width varies from 30 to 40 feet on both the eastern and western adjoining properties. There are no existing shore structures on either adjoining property.

Field Survey

The upland parcel is located within the Congress Lands district north and east of the First Principal Meridian of the Public Lands Survey System more specifically part of Fractional Section 35, Town 7 North, Range 17 East. Being within Catawba Island Township, and outside of any incorporated municipal boundaries, the parcel boundary extends to the centerline of the county road with a 60-foot right of way reservation for public ingress and egress centered on said centerline.

Horizontal control was established for this site by evaluating the location of published monumentation through the National Geodetic Survey (NGS) website: *www.ngs.noaa.gov*. The closest station to this site was determined to be "Clintport AZ MK" (PID MC1546) which is approximately 1.5 kilometers east. Based upon the NGS datasheet, the horizontal accuracy of the station is reported as a Cooperative Base Network Control Station with reports that attempts to recover the station were successful in 1995. Therefore this station was used within the horizontal control network. A closed traverse was performed between station "Clintport AZ MK" and the inter-visible station "Clintport" (PID MC1541) with intermediate stations located close to the project site. A least squares adjustment was made to generate resultant coordinates based upon Ohio State Plane 3401(NAD 83).

Vertical control was established for this site by evaluating the location of published monumentation through the NGS website. The closest station to this site was determined to be "J 317" (PID MC0994) which is approximately three (3) kilometers southwest. Based upon the NGS datasheet the vertical accuracy of the station is First Order Class II with reports that attempts to recover the station were successful in 2004 and 2009. The NGS stainless steel rod, established in 1980, has a reported dynamic height of 585.05 feet at 45 degrees latitude. NGS Vertical Datum Transformation software (VDatum) was used to adjust for the hydraulic corrections for the project location based upon the latitude and longitude positions in the NGS datasheet for station "J 317." The resultant adjusted elevations provided by a closed level circuit were utilized for the project after confirming the elevation, relative to IGLD85, of the control stations by benching into the water level on a calm day with minimal wave activity and comparing that value to the water level station data retrieved from NOAA's Great Lakes Online website: *www.glakesonline.nos.noaa.gov/monitor.html* for station #9063079 (Marblehead).

With the horizontal and vertical control network established, recovery of boundary evidence was performed. Monumentation was found, and held as controlling stations included 5/8-inch iron pins at the intersecting centerlines of 60-foot Sand Road and 50-foot Spring Valley Road, and along the centerline of Sand Road. A topographic survey was performed that located the cultural (i.e. buildings, survey monuments, coastal structures) and natural (i.e. top and toe of bluff) features on the subject parcel and adjoiners. Notwithstanding the presence of the timber crib pier along the shore and centered on the upland parcel, the natural shoreline appears to be unaltered by artificially placed fill material.

Analysis

A technical assistance request was made to the ODNR Office of Coastal Management to help in identifying the location of the natural shoreline prior to the artificial placement of the concrete material. A drawing was provided to the consultant that depicted the location of the natural shoreline on the May 1956 aerial photograph. This location was transferred to the site and compared to the descriptions within the current and previous title deeds. The natural shoreline was slightly adjusted based upon the

description within the 1993 limited warranty deed for the subject parcel.

Parcel data provided by the Ottawa County Auditor's Office was imported into the computer-aided design (CAD) drawing to establish a general orientation of the shoreline for a reach of approximately 1.5 kilometers. Methodology for partitioning the boundaries between the littoral adjoiners was examined including extending the upland parcel boundary lakeward without deflection and a radial projection from the general alignment of the 1.5 kilometer reach of shore from the intersection of the natural shoreline and the parcel sidelines. The radial projection method provided the most equitable distribution between the subject parcel and the east and west adjoiners.

A base map was provided to the engineering consultant that depicted the locations of the existing site improvements relative to the established parcel boundaries and littoral partitions. A general statement that the survey and plat were prepared that conforms to Ohio Administrative Code (OAC) Section 4733-37 was included and the Ohio registered professional surveyor's signature and seal were affixed to the plat of survey (see Existing Site Plan "C").

Design

The customary minimum slope based on standard engineering design practice for an armor stone revetment is 1.5 horizontal to 1 vertical. Based on the wave climate in the area of the project site, a slope of 2 horizontal to 1 vertical is selected for a conservative design. The toe of the structure will be entrenched to an elevation of 567.8 feet IGLD 1985 into the underlying till.

The project site is located in the Locust Point to Marblehead reach of the "Revised Report on Great Lakes Open Coast Flooding," (USACE 1988) and has a design water level of 576.2 feet IGLD 1985.

Sand and gravel in the footprint of the revetment will be sidecast into the lake, however, beach sand immediately lakeward of the structure will be left in place as shown in Section B-B. The water depth for the initial design condition includes the small amount of beach cover over the toe of the revetment. An initial 4.2-foot structure depth was calculated from the beach profile elevation at the toe of the structure and the design water level. Based on the breaking wave equation a design wave height of 3.3 feet was calculated for the initial case. If the beach sand and till at the toe of the structure are scoured, the water depth at the toe of the structure would increase to 8.4 feet. In this case, the design wave height would increase to 6.6 feet.

Hudson's Equation was used to calculate the median armor stone size to resist displacement due to wave action. Using the unit weight for the specified limestone, the minimum median armor stone size is 0.2 tons for the non-scour case. The minimum median armor stone size was 1.3 tons per unit if the toe of the structure is scoured.

A factor of safety of 2.0 was selected for the armor stone size to account for potential effects of ice forces and long-term fracturing of the stone. Using the conservative 1.3 ton per unit value from Hudson's Equation, the safety factor results in a lower limit for the armor stone of 2.6 tons per unit. A double layer of 2 to 4-ton limestone will be stacked in a 6-foot thick armor layer.

The filter layer was specified as stone or clean concrete rubble about 1/3 of the diameter of the armor stone. For economy of design, the existing concrete modules and concrete rubble at the toe of the bluff will be relocated to form the filter layer for the revetment. Due to the variability of the filter layer material and the fine-grained till composition of the bluff a geotextile filter fabric was specified.

Wave run-up on the structure is calculated using the empirical formula introduced in Chapters 3 and 4. Wave run-up of 4.1 feet to an elevation of 580.3 feet IGLD 1985 is calculated for the initial design case. If the toe of the structure is scoured the wave run-up increases to 6.9 feet to an elevation of 583.1 feet IGLD 1985. In this case, the crest of the revetment is set to 584.0 feet IGLD 1985. It should be noted that in this case the crest of the revetment will be well above the 579.0 feet IGLD 1985 elevation of the top of the bluff. The higher crest elevation in this location along the shore will help protect the upland during periods of open coast flooding associated with high lake water levels and northeast storms.

To prevent sliding failure along the slope of the revetment, larger stones are placed at the lakeward base for toe protection. In this case, 4 to 5-ton armor stones are to be entrenched 2.5 feet into the shale bedrock. Toe stones are typically specified to be 1 to 2 tons heavier than stones used for the armor layer.

To mitigate end effects, the ends of revetment are curved back into the bluff face. In this case, the ends of the structure are rounded off with a radius approximately equal to the plan view width of the armor layer.

On the landward site of the revetment, smaller ODOT 601 Type "B" stone is specified at a slope of 1.75 horizontal to 1 vertical. A smaller stone is acceptable in this application because it will not be subject to wave action. A 2 to 4-ton armor stone entrenched 2 feet into the top of the bluff is specified to prevent sliding failures on the landward slope.

Discussion

Although the entire structure is located on the beach area above the water level at the time of the survey, an appropriate design still considers minimization of the overall project footprint. The revetment will extend lakeward a maximum of 23 feet from the toe of the existing bluff. This distance is determined by the required crest elevation and revetment slope and can not be reduced without compromising the functionality or stability of the structure. The revetment was also designed so that the armor layer is immediately adjacent to the existing bluff face.

This reduces the amount of fill added to the site as well as the lakeward extent of the structure. In this case it also allows for the largest possible width of beach to be preserved lakeward of the structure.

The revetment is intended to prevent erosion of the existing bluff and will therefore decrease the amount of material added to the littoral system. Any sand or gravel in the footprint of the revetment must be excavated and sidecast into the lake prior to construction to prevent sediment from being permanently removed from the littoral system.

As the structure will extend approximately 23 feet toward the lake, it may also affect the littoral transport of material along the shore in high water conditions. The structure may cause changes in wave energy that could adversely affect the stability of the beach at this site and on adjacent properties. The interaction between the wave and structure will cause an increase in wave energy in the nearshore zone due to wave reflection. The structure's effect on wave motions also increases the likelihood of scour of the beach fronting the structure.

These risks have been reduced with the use of rough angular limestone at a slope of 2H:1V. Much of the wave energy will be absorbed and dissipated by the revetment, minimizing the wave energy reflected in the nearshore zone. Observing and measuring changes to the beach over time should be part of the routine inspection of the structure's performance in the years following construction. A beach monitoring plan should be developed to quantify and mitigate long term effects of the structure.

Final Survey Products

Based upon the design from the Ohio registered professional engineer, a plat that depicted the boundaries of the submerged lands lease has been prepared. The proposed design of the armor stone revetment locates its occupation landward of the natural shoreline and therefore is not included in any lease parcel. The existing occupation of the timber crib pier is bisected by the location of the natural shoreline and therefore the lease parcel only includes the area lakeward of said natural shoreline (see Submerged Lands Plat).

A metes and bounds description has been written for the area depicted on the plat of survey with direct relationship to the upland parcel boundaries as required in Ohio Revised Code Section 1506.11(B) (see Submerged Lands Lease Description).

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB	EXAMPLE C - LOW BLUFF		
SHEET NO.	1	OF	3
CALCULATED BY	MPC	DATE	02/01/11
CHECKED BY	DLB	DATE	02/01/11
SCALE			

REVETMENT DESIGN

A. DESIGN WATER LEVEL

30 YEAR DESIGN WATER LEVEL = 576.2 FT IGLD 1985

REFERENCE: "REVISED REPORT ON GREAT LAKES OPEN COAST FLOODING" USACE, 1988.

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE

LAKE BOTTOM ELEVATION = 572.0 FEET IGLD 1985 (TO SAND COVERING REVETMENT TOE)

STRUCTURE DEPTH = ds = 576.2 FT - 572.0 FT = 4.2 FT IGLD 1985

BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 4.2 FT = 3.3 FT

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

TOE OF STRUCTURE = 567.8 FEET IGLD 1985

STRUCTURE DEPTH = ds = 576.2 FT - 567.8 FT = 8.4 FT IGLD 1985

BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 8.4 FT = 6.6 FT

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

C. ARMOR STONE SIZE

USE HUDSON'S EQUATION:

MEDIAN ARMOR STONE SIZE = $W50 = \dfrac{\omega r\, H^3}{Kd\,(Sr-1)^3 \cot\theta}$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22

ωr = UNIT WEIGHT OF ARMOR STONE = 165 LB/FT^3

ASSUME H = BREAKING WAVE HEIGHT = Hb

Kd = 2.0 FOR ROUGH ANGULAR QUARRY STONES

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-22

COT θ = STRUCTURE SLOPE = 2.0

$Sr = \dfrac{\omega r}{\omega w}$

ωr = SPECIFIC WEIGHT OF STONE = 165 LB/FT^3

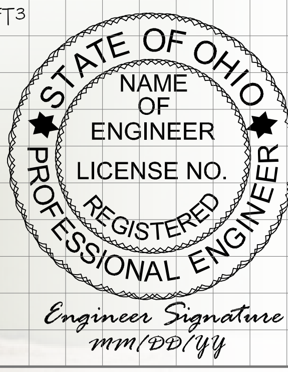
ωw = SPECIFIC WEIGHT OF WATER = 62.4 LB/FT^3

INITIAL DESIGN CASE

BREAKING WAVE HEIGHT = Hb = 3.3 FT

$W50 = \dfrac{(165\ \text{LB/FT}^3)(3.3\ \text{FT})^3}{2.0\,(165/62.4-1)^3\,(2.0)} = 333\ \text{LB} = 0.2\ \text{TON}$

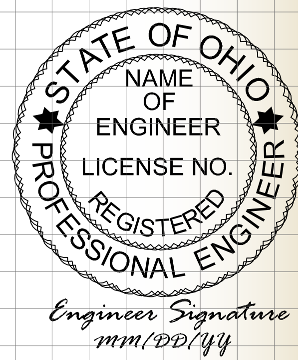
MEDIAN STONE SIZE = W50 x FS = 0.2 TON x 2.0 = 0.4 TON



SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE C - LOW BLUFF
SHEET NO. 2 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

REVETMENT DESIGN (CONT.)



CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

BREAKING WAVE HEIGHT = Hb = 6.6 FT

$$W50 = \frac{(165\ LB/FT^3)\,(6.6\ FT)^3}{2.0\,(165/62.4-1)^3\,(2.0)} = 2668\ LB = 1.3\ TON$$

MEDIAN STONE SIZE = W50 x FS = 1.3 TON x 2.0 = 2.6 TON

TO BE CONSERVATIVE USE 2 TO 4 TON ARMOR STONE

*NOTE: ACES CALCULATIONS SUPPORT RESULTS

INITIAL DESIGN CASE
W50 = 576 LB = 0.3 TON
ARMOR LAYER THICKNESS = 3.0 FEET

CONSERVATIVE DESIGN CASE
W50 = 2779 LB = 1.4 TON
ARMOR LAYER THICKNESS = 5.1 FEET

C. WAVE RUNUP AND OVERTOPPING

EMPIRICAL FORMULA: $$R = \frac{Hb\ (a \times \xi)}{1 + (b \times \xi)}$$

REFERENCE: "WAVE PERIOD EFFECT ON THE STABILITY OF RIPRAP" ASCE, 1975, P 1019- 1034.

a = 0.775 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
b = 0.361 FOR DOUBLE LAYER WITH CORE OR FILTER LAYER
REFERENCE: "COST-EFFECTIVE OPTIMIZATION OF RUBBLE-MOUND BREAKWATER CROSS SECTIONS" USACE, 1986, P 45-53.

IRIBARREN NO. = $$\xi = \frac{\tan\Theta}{\sqrt{(2\pi\ Hb / g\ T^2)}}$$

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE VI-5-6.

Θ = ANGLE OF STRUCTURE FACE
$g = 32.2\ FT/SEC^2$
T = WAVE PERIOD = 8 SECOND PERIOD ASSUMED*

*A 6 SECOND PERIOD IS A CONSERVATIVE ESTIMATE BASED ON WIS DATA. THE LARGEST WAVE RECORDED AT WIS STATION E04 OVER A 32 YEAR STUDY (1956-1987) HAD A PERIOD OF 7.0 SECONDS. - REFERENCE: "WIS REPORT 22, HINDCAST WAVE INFORMATION FOR THE GREAT LAKES: LAKE ERIE" USACE, 1991, P A86.

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE C - LOW BLUFF
SHEET NO.: 3 OF 3
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

REVETMENT DESIGN (CONT.)

INITIAL CASE

IRIBARREN NO. = $\xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(3.3\text{ FT}) / (32.2\text{ FT/SEC}^2)\,(6\text{ SEC})^2}}$ $\xi = 3.8$

WAVE RUNUP: $R = \dfrac{(3.3\text{ FT})\,(0.775 \times 3.8)}{1 + (0.361 \times 3.8)}$

R = 4.1 FT (FOR INITIAL CASE)

RUNUP ELEVATION = 576.2 FT IGLD 1985 + 4.1 FT = 580.3 FT IGLD 1985

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED

IRIBARREN NO. = $\xi = \dfrac{(1/2.0)}{\sqrt{2\pi\,(6.6\text{ FT}) / (32.2\text{ FT/SEC}^2)\,(6\text{ SEC})^2}}$ $\xi = 2.6$

WAVE RUNUP: $R = \dfrac{(6.6\text{ FT})\,(0.775 \times 2.6)}{1 + (0.361 \times 2.6)}$

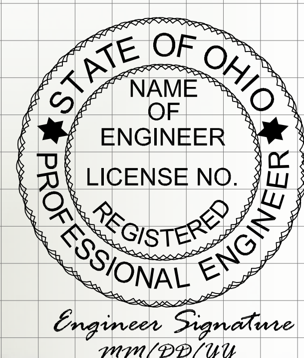
R = 6.9 FT (FOR CONSERVATIVE CASE)

RUNUP ELEVATION = 576.2 FT IGLD 1985 + 6.9 FT = 583.1 FT IGLD 1985

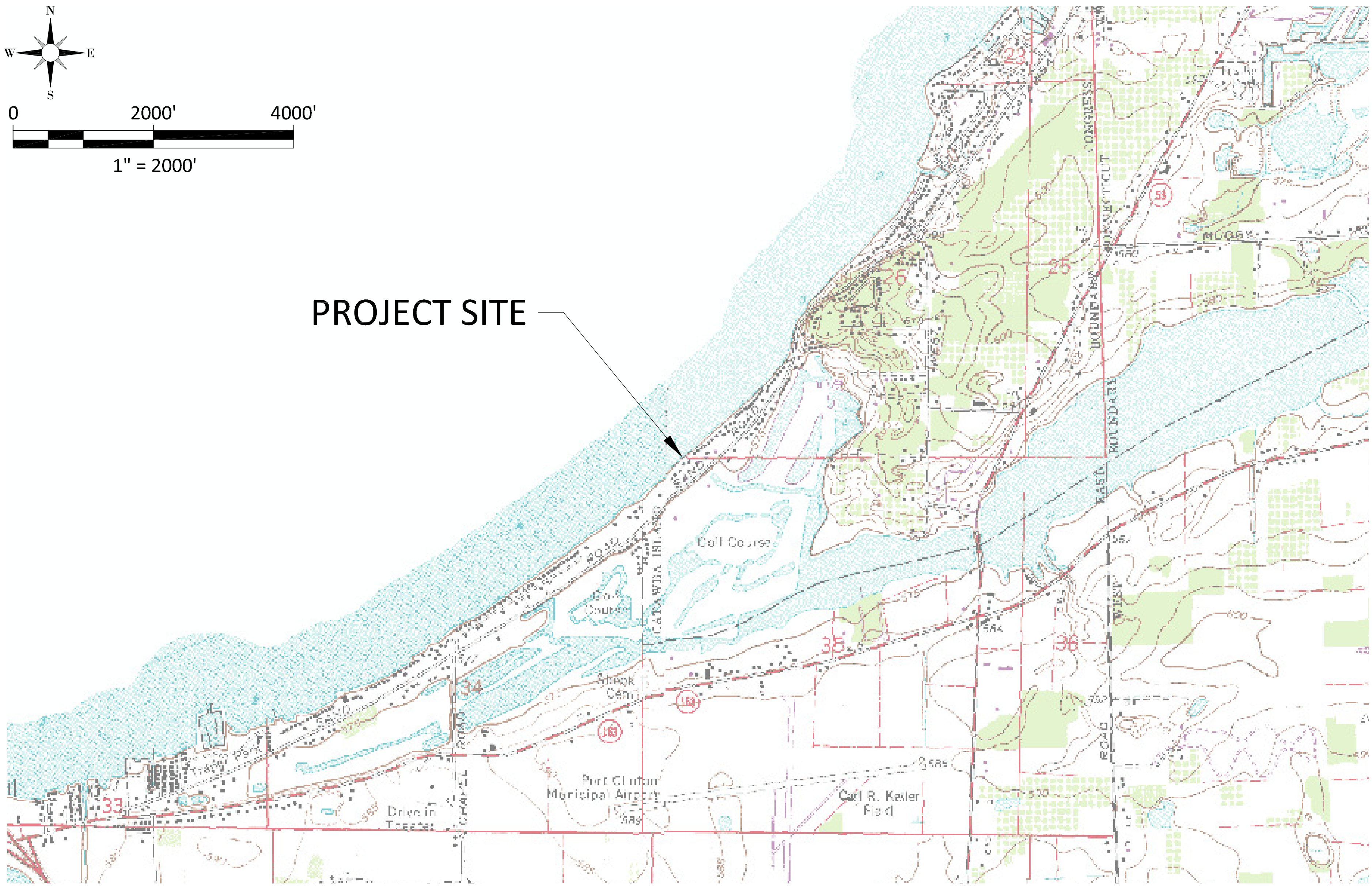
CONSERVATIVE DESIGN: SET TOP OF REVETMENT AT 584.0 FT IGLD 1985

*NOTE: ACES CALCULATIONS SUPPORT RESULTS
INITIAL: RUNUP = 4.0 FT TO AN ELEVATION OF 580.2 FT IGLD 1985
CONSERVATIVE: RUNUP = 6.9 FT TO AN ELEVATION OF 583.1 FT IGLD 1985

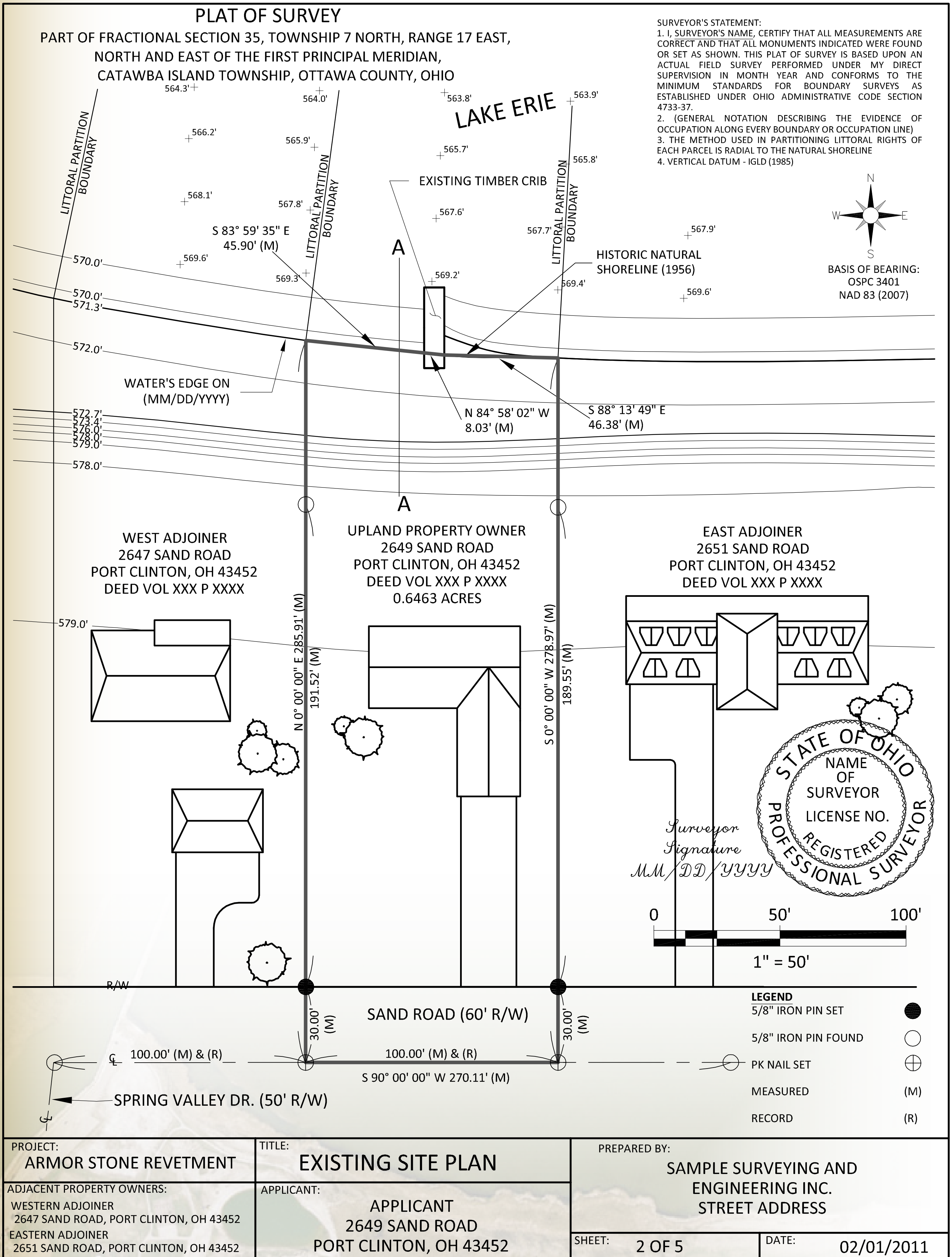
*NOTE: THE CALCULATIONS INCLUDED IN THIS EXAMPLE WERE ORIGINALLY COMPUTED USING EXCEL SPREADSHEETS. THE SOFTWARE DISPLAYS A SPECIFIED NUMBER OF SIGNIFICANT FIGURES BUT RETAINS THE ORIGINAL NUMBER FOR OPERATIONS. AS A RESULT SMALL ROUNDING ERRORS ARE INTRODUCED IN TRANSCRIBING THE STEP-BY-STEP CALCULATIONS. THESE ERRORS ARE ACCEPTABLE CONSIDERING THE OVERALL ACCURACY OF THE CALCULATION METHODS AND THE PURPOSE OF THIS DESIGN MANUAL.

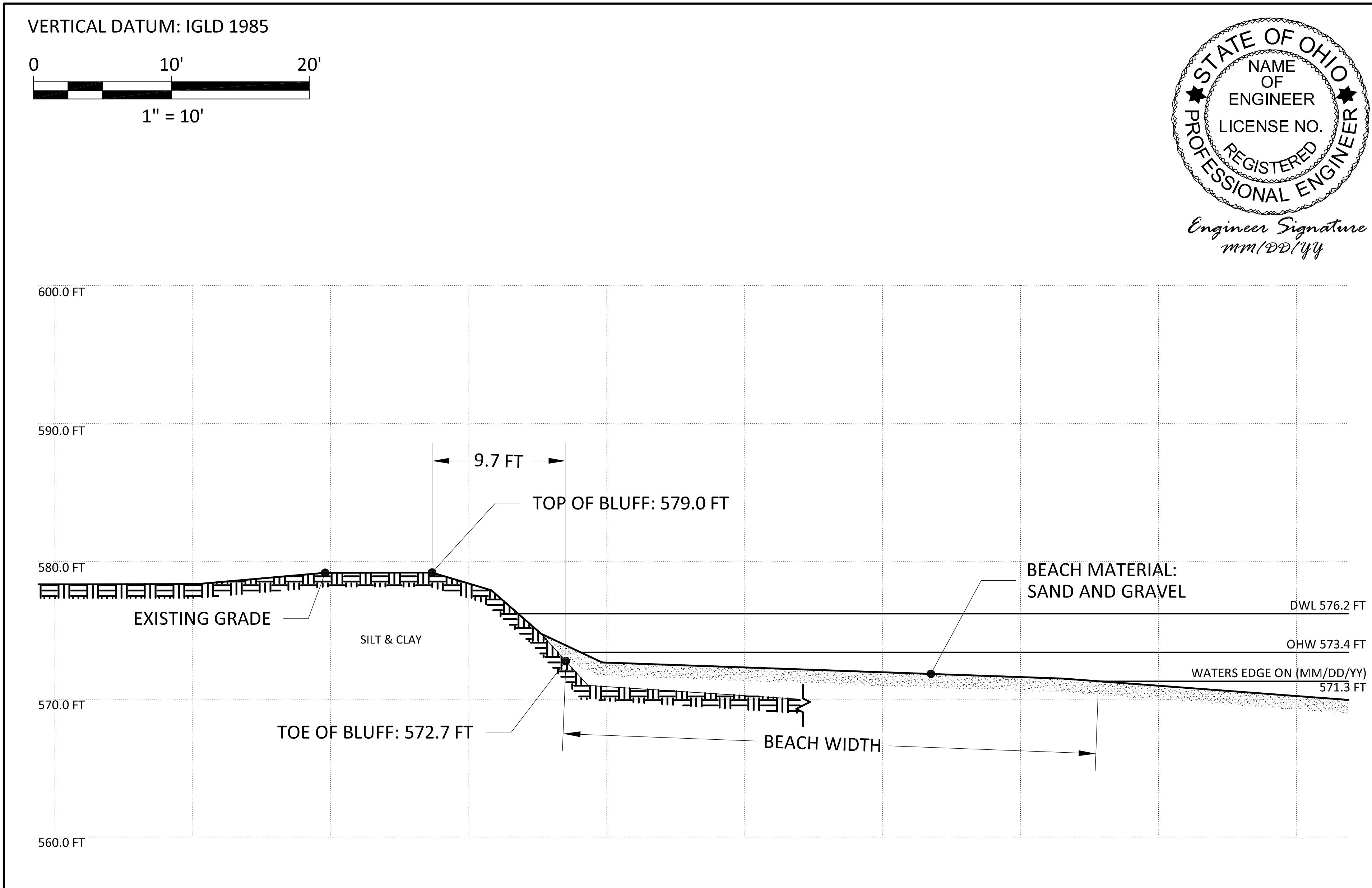


Engineer Signature
MM/DD/YY

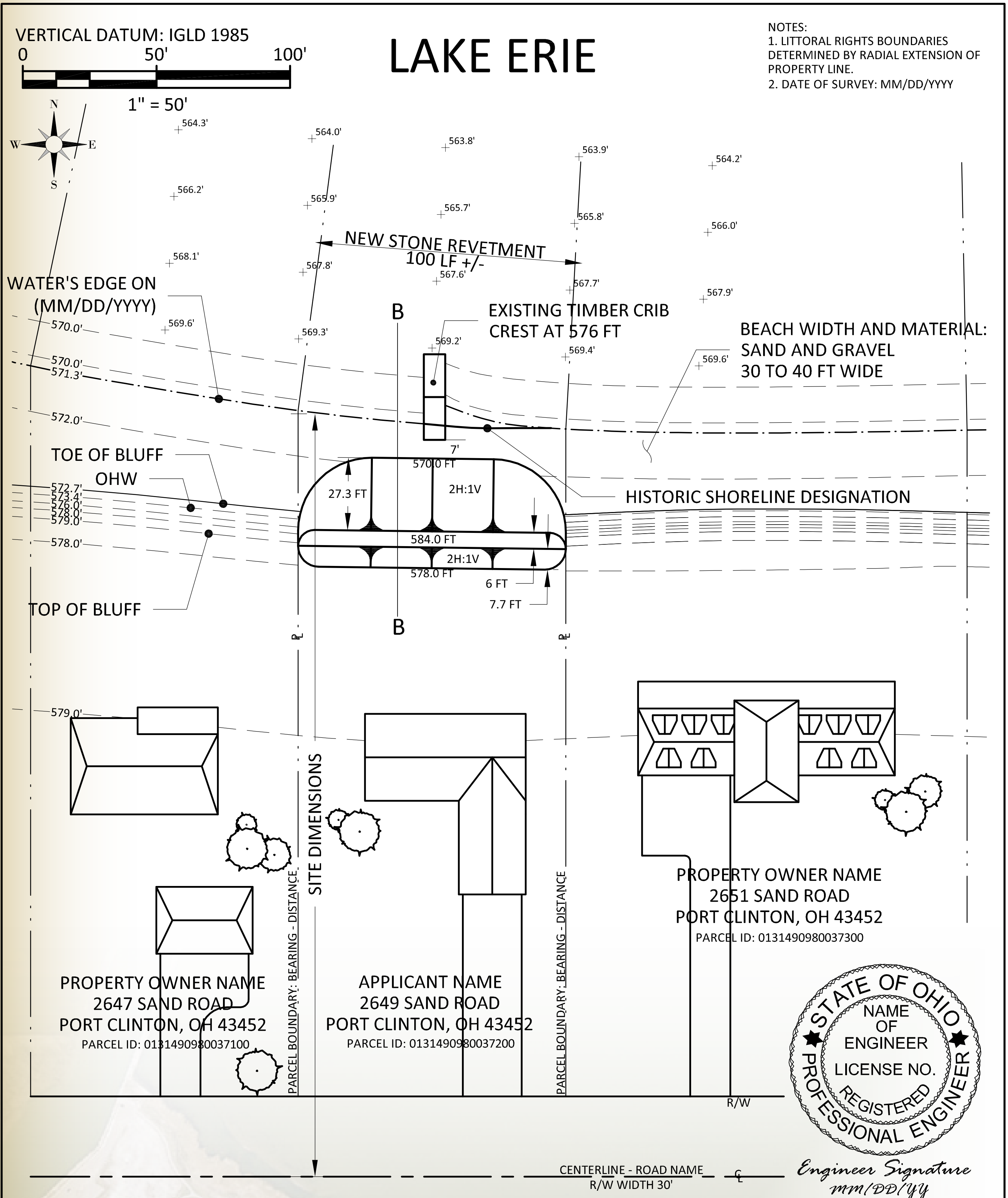


PROJECT: ARMOR STONE REVETMENT	TITLE: VICINITY MAP	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 1 OF 5	DATE: 02/01/11

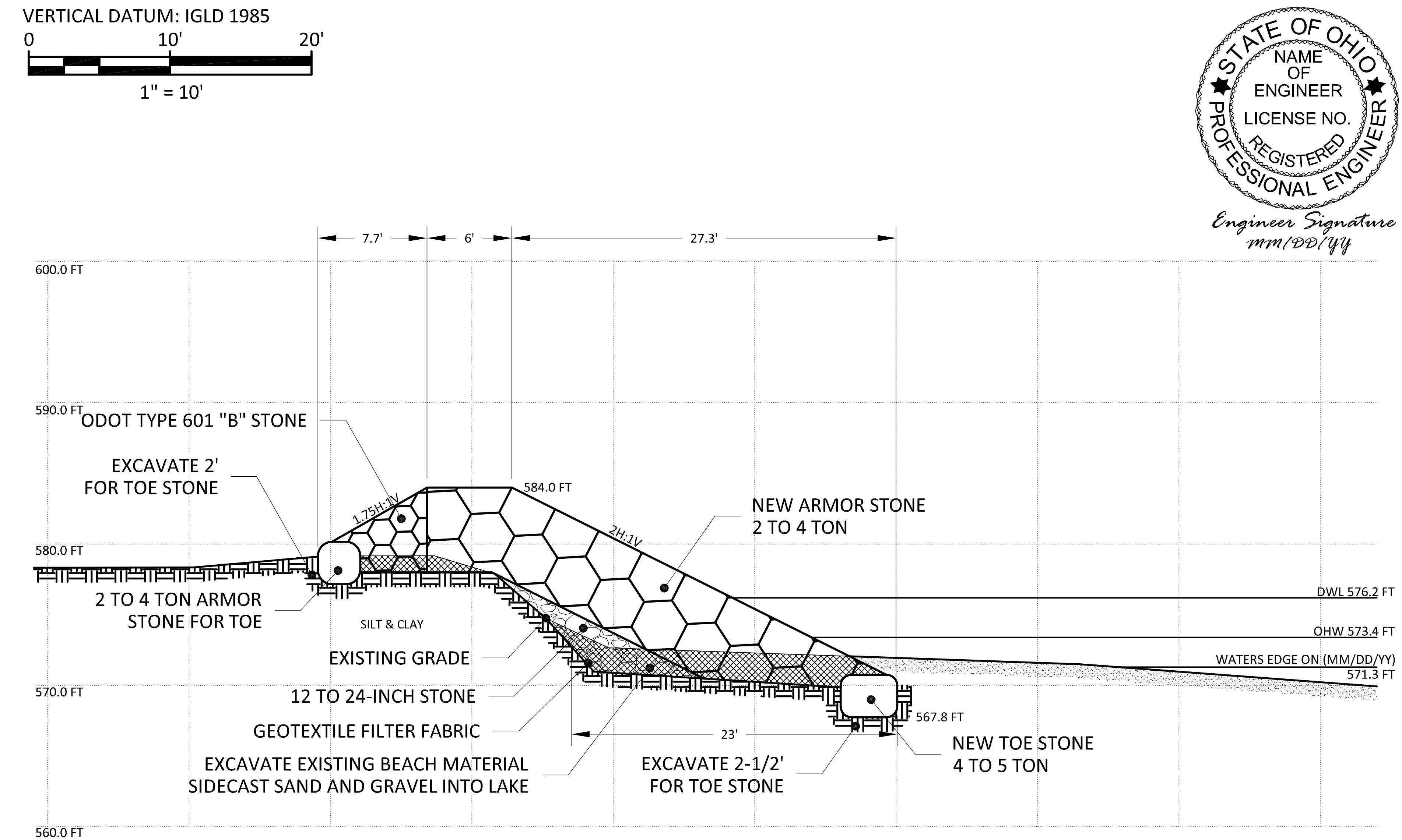

PLAT OF SURVEY
PART OF FRACTIONAL SECTION 35, TOWNSHIP 7 NORTH, RANGE 17 EAST,
NORTH AND EAST OF THE FIRST PRINCIPAL MERIDIAN,
CATAWBA ISLAND TOWNSHIP, OTTAWA COUNTY, OHIO
SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO THE NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)
LAKE ERIE
LITTORAL PARTITION BOUNDARY
EXISTING TIMBER CRIB
HISTORIC NATURAL SHORELINE (1956)
S 83° 59' 35" E
45.90' (M)
A
WATER'S EDGE ON (MM/DD/YYYY)
N 84° 58' 02" W
8.03' (M)
S 88° 13' 49" E
46.38' (M)
N
S
E
W
BASIS OF BEARING:
OSPC 3401
NAD 83 (2007)
564.3'
564.0'
563.8'
563.9'
566.2'
565.9'
565.7'
565.8'
568.1'
567.8'
567.6'
567.7'
567.9'
569.6'
569.3'
569.2'
569.4'
569.6'
570.0'
570.0'
571.3'
572.0'
572.7'
573.4'
576.0'
578.0'
579.0'
578.0'
579.0'
WEST ADJOINER
2647 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
UPLAND PROPERTY OWNER
2649 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
0.6463 ACRES
EAST ADJOINER
2651 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
N 0° 00' 00" E 285.91' (M)
191.52' (M)
S 0° 00' 00" W 278.97' (M)
189.55' (M)
STATE OF OHIO
NAME OF SURVEYOR
LICENSE NO.
REGISTERED
PROFESSIONAL SURVEYOR
Surveyor Signature
MM/DD/YYYY
0
50'
100'
1" = 50'
R/W
SAND ROAD (60' R/W)
30.00' (M)
30.00' (M)
100.00' (M) & (R)
100.00' (M) & (R)
S 90° 00' 00" W 270.11' (M)
SPRING VALLEY DR. (50' R/W)
LEGEND
5/8" IRON PIN SET
5/8" IRON PIN FOUND
PK NAIL SET
MEASURED (M)
RECORD (R)
PROJECT:
ARMOR STONE REVETMENT
TITLE:
EXISTING SITE PLAN
PREPARED BY:
SAMPLE SURVEYING AND
ENGINEERING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJOINER
2647 SAND ROAD, PORT CLINTON, OH 43452
EASTERN ADJOINER
2651 SAND ROAD, PORT CLINTON, OH 43452
APPLICANT:
APPLICANT
2649 SAND ROAD
PORT CLINTON, OH 43452
SHEET:
2 OF 5
DATE:
02/01/2011



PROJECT:	TITLE:	PREPARED BY:	
ARMOR STONE REVETMENT	SECTION A-A: EXISTING SITE	SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 3 OF 5	DATE: 02/01/11



PROJECT: ARMOR STONE REVETMENT	TITLE: PROPOSED SITE PLAN	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 4 OF 5 / DATE: 02/01/11



NOTES:

1. ARMOR LAYER CONSISTS OF ROUGH, ANGULAR QUARRY STONE (LIMESTONE).
2. STONES SHALL BE PLACED INDIVIDUALLY TO MAXIMIZE CONTACT AREA BETWEEN STONES AND MINIMIZE VOIDS. STONES SHOULD NOT BE DROPPED.
3. FILTER LAYER CONSISTS OF 12 INCH TO 24 INCH STONE.
4. EXCAVATE EXISTING BEACH TO SHALE BEDROCK OR STIFF CLAY. DEPOSIT EXCAVATED SAND & GRAVEL LAKEWARD OF PROJECT. NO SAND OR GRAVEL SHOULD BE TRAPPED UNDER REVETMENT.
5. EXCAVATE TOE TRENCH 2-1/2 FT (MINIMUM) INTO STIFF CLAY OR LIMESTONE BEDROCK.

PROJECT: ARMOR STONE REVETMENT	TITLE: SECTION B-B	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 5 OF 5	DATE: 02/01/11

Lake Erie Submerged Lands Legal Description
Adjacent to 2649 Sand Road, Port Clinton

Situate in the State of Ohio and located within the waters of Lake Erie, County of Ottawa, Catawba Island Township, Town 7 North, Range 17 East, North and East of the First Principal Meridian, adjacent to a portion of fractional Section 35 conveyed to (NAME OF UPLAND OWNER) by Deed Volume (XXX), Page (XXXX), of the deed records of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin found at the intersection of the centerline of sixty (60) foot Sand Road and the centerline of fifty (50) foot Spring Valley Drive, said point also being the southwest corner of (NAME OF WEST ADJOINER) parcel as conveyed by Deed Volume (XXX), Page (XXXX);

Thence along the centerline of sixty (60) foot Sand Road and the south line of said (NAME OF WEST ADJOINER), North 90 degrees, 00 minutes, 00 seconds East, 99.79 feet to a P-K nail set at the southeast corner of said (NAME OF WEST ADJOINER) parcel, also being the southwest corner of said (NAME OF UPLAND OWNER);

Thence along the west line of said (NAME OF UPLAND OWNER) parcel and the east line of said (NAME OF WEST ADJOINER), North 00 degrees, 00 minutes, 00 seconds East, 285.91 feet, and passing for reference, a 5/8 inch solid iron pin set at 30.00 feet on the north right-of-way of Sand Road and a 5/8 inch solid iron pin found at 221.52 feet to the location of the natural shoreline of Lake Erie present in (1956) as determined by the Ohio Department of Natural Resources, also being the northwest corner of said (NAME OF UPLAND OWNER);

Thence along the north line of said (NAME OF UPLAND OWNER), also being said natural shoreline, South 83 degrees, 59 minutes, 35 seconds East, 45.90 feet to a point not monumented due to the location on the submerged lands of Lake Erie, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said (NAME OF UPLAND OWNER) parcel, across the open waters of Lake Erie, North 00 degrees, 00 minutes, 00 seconds East, 25.65 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, North 87 degrees, 27 minutes, 17 seconds East, 8.01 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 00 degrees, 00 minutes, 24 seconds West, 26.71 feet to a 5/8 inch solid iron pin set on the north line of said (NAME OF UPLAND OWNER), also being said natural shoreline;

Thence along said natural shoreline, North 84 degrees, 58 minutes, 02 seconds West, 8.03 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 209 square feet (0.0048 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: The alignment of the centerline of Sand Road (North 90 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

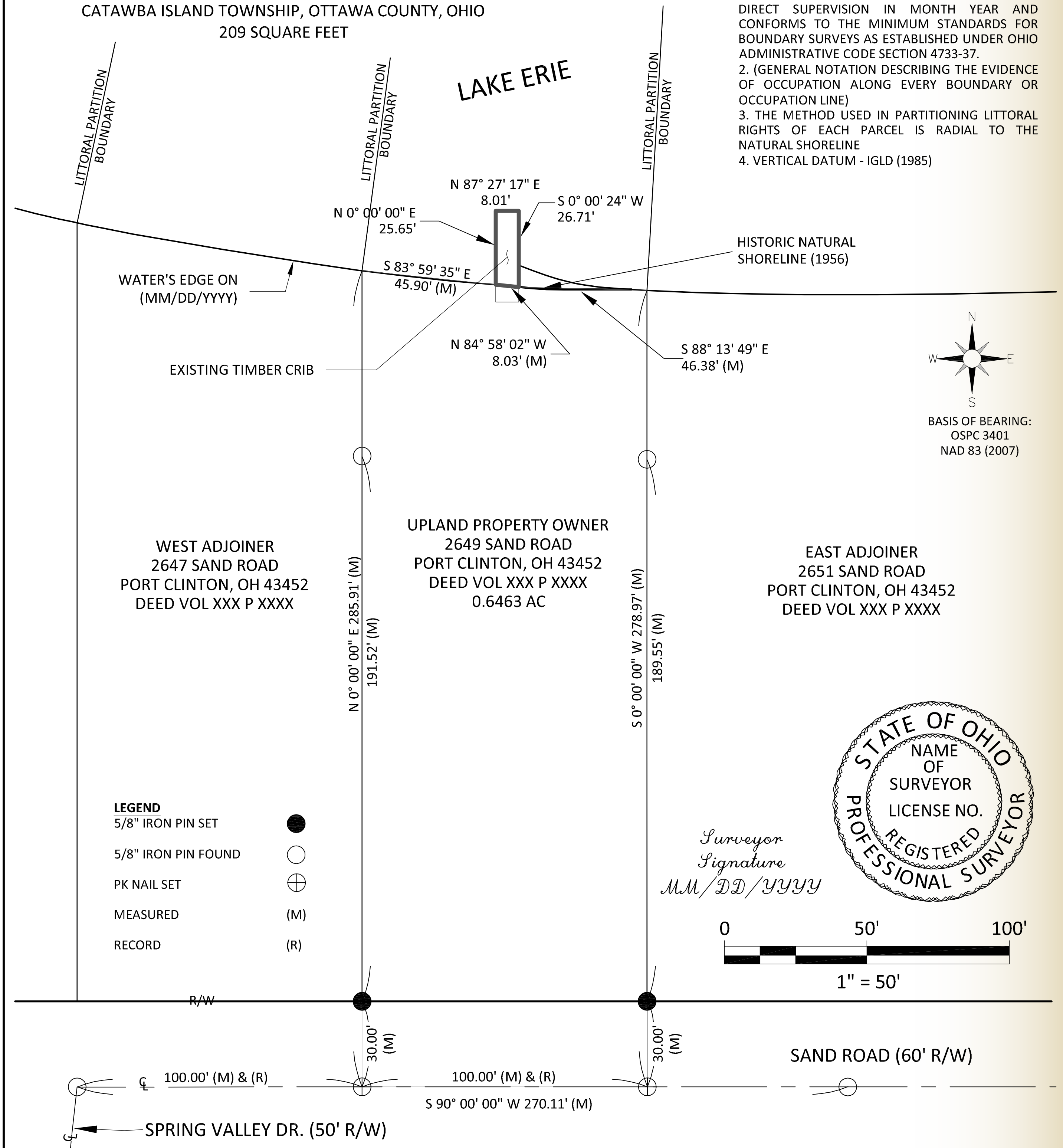
SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)

SUBMERGED LANDS LEASE PLAT OF SURVEY

SUBMERGED LANDS ADJACENT TO
FRACTIONAL SECTION 35, TOWNSHIP 7 NORTH, RANGE 17 EAST,
NORTH AND EAST OF THE FIRST PRINCIPAL MERIDIAN,
CATAWBA ISLAND TOWNSHIP, OTTAWA COUNTY, OHIO
209 SQUARE FEET

SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO THE NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)



PROJECT:	TITLE:	PREPARED BY:
ARMOR STONE REVETMENT	SUBMERGED LANDS PLAT	SAMPLE SURVEYING AND ENGINEERING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WEST ADJOINER 2647 SAND ROAD, PORT CLINTON, OH 43452 EAST ADJOINER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: APPLICANT 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 1 OF 1 — DATE: 02/01/2011

Ch 4.5 Design Example D: Concrete Block Seawall

Design Example D

The following example demonstrates the design of a concrete block seawall as erosion protection at a site with low (0 to 15 foot high) bluffs along the shore. The design is demonstrated using the same project site as the low bluff revetment Design Example C. This example illustrates a design alternative to the low bluff revetment. The project site is fictitious but similar to the coastal features common along the south coast of Lake Erie's western basin.

Project Purpose

The purpose of Example Project D is to protect the toe of the silt and clay bluff from erosion due to wave action and to provide access to the waters of Lake Erie. In this case a concrete block seawall is selected to best achieve the project purpose.

Site Description

The description of this project site is the same as Example C.

The project site is located along the shore of Lake Erie in Ottawa County, between Port Clinton and Catawba Island. The shore in this area is oriented from west to east, and is irregular in shape with small bays and headlands. The predominant direction of sediment transport in the littoral zone is from northeast to southwest.

The shore at the project site consists of a 30 to 40-foot wide sand and gravel beach in front of a 6-foot high bluff (embankment). The bluff extends from a toe elevation of 572.7 feet to 579.0 feet at the crest as referenced to the International Great Lakes Datum of 1985 (IGLD 1985). A timber crib pier is present at the center of the site property and is trapping a small amount of sediment on its east edge. The crib pier is made up of two 16-foot long by 8-foot wide timber cribs with a crest elevation of 576.0 IGLD 1985.

The bluff is composed primarily of silt and clay with a thin layer of topsoil. A 2 to 4-foot thick layer of sand covers till in the nearshore zone and is distributed in a bar system. Limestone bedrock is present at an unknown depth. The nearshore slopes at approximately 4 degrees for the first 100 feet then levels to approximately 1 degree.

The site is exposed to storm waves from west-northwest to north directions but is partially protected by Catawba Island and the Bass Islands from northeast waves. A review of historic wave information results in a significant wave height of 1.6 feet at a period of 3.4 seconds. The most frequent wave direction was from the southwest. The largest wave recorded over the 32 year study was 6.9 feet with a 7.0 second period. The average direction of the largest waves was from the northeast. Wave data was measured at WIS station E04 located approximately 3.5 miles north of the project site in 20-foot deep water.

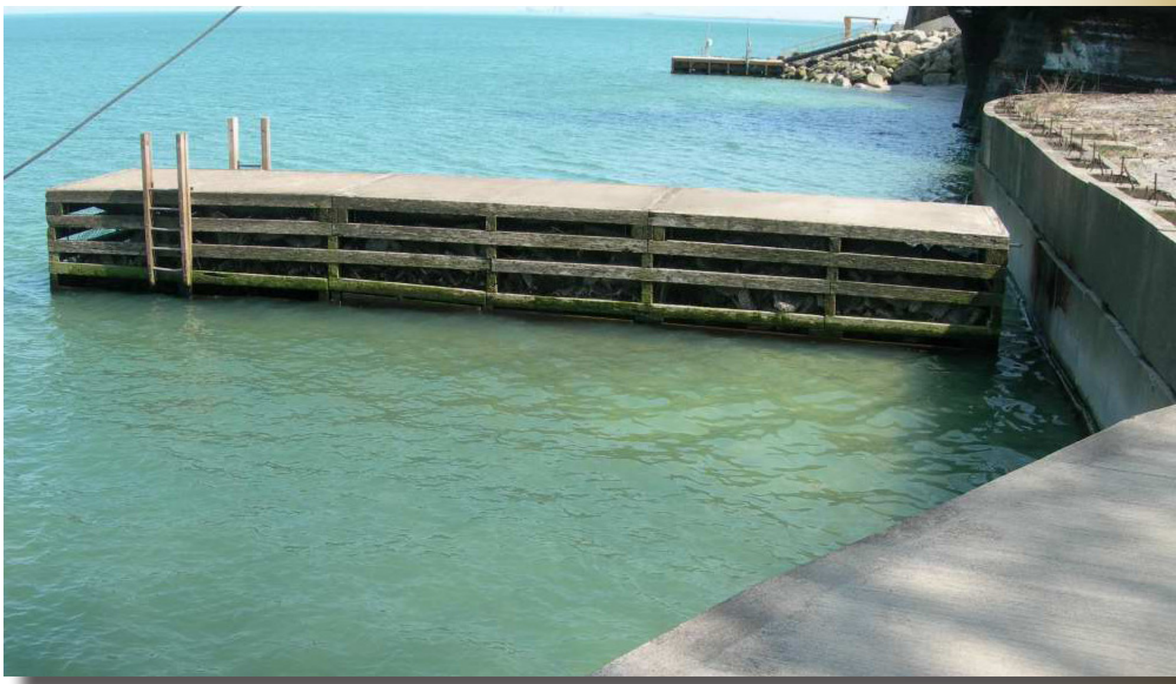
The expected erosion rate at the project site is 0.0 feet over 30 years based on the 2010 Coastal Erosion Area maps. The site is not located in a designated Coastal Erosion Area. There are no existing drainage measures causing localized erosion at the project site.

The eastern and western adjoining properties are similar to the project site in bluff elevation and upland topography. The beach width varies from 30 to 40 feet on both the eastern and western adjoining properties. There are no existing shore structures on either adjoining property.

Field Survey

The upland parcel is located within the Congress Lands district north and east of the First Principal Meridian of the Public Lands Survey System more specifically part of Fractional Section 35, Town 7 North, Range 17 East. Being within Catawba Island Township, and outside of any incorporated municipal boundaries, the parcel boundary extends to the centerline of the county road with a 60-foot right of way reservation for public ingress and egress centered on said centerline.

Horizontal control was established for this site by evaluating the location of published monumentation through the National Geodetic Survey (NGS) website: *www.ngs.noaa.gov*. The closest station to this site was determined to be "Clintport AZ MK" (PID MC1546) which is approximately 1.5 kilometers east. Based upon the NGS datasheet, the horizontal accuracy of the station is reported as a Cooperative Base Network Control Station with reports that attempts to recover the station were successful in 1995. Therefore this station was used within the horizontal control network. A closed traverse was performed between station "Clintport AZ MK" and the inter-visible station "Clintport" (PID MC1541) with intermediate stations located close to the project site. A least squares adjustment was made to generate resultant coordinates based upon Ohio State Plane 3401(NAD 83).



Vertical control was established for this site by evaluating the location of published monumentation through the NGS website. The closest station to this site was determined to be "J 317" (PID MC0994) which is approximately three (3) kilometers southwest. Based upon the NGS datasheet, the vertical accuracy of the station is First Order Class II with reports that attempts to recover the station were successful in 2004 and 2009. The NGS stainless steel rod, established in 1980, has a reported dynamic height of 585.05 feet at 45 degrees latitude. NGS Vertical Datum Transformation software (VDatum) was used to adjust for the hydraulic corrections for the project location based upon the latitude and longitude positions in the NGS datasheet for station "J 317." The resultant adjusted elevations provided by a closed level circuit were utilized for the project after confirming the elevation, relative to IGLD85, of the control stations by benching into the water level on a calm day with minimal wave activity and comparing that value to the water level station data retrieved from NOAA's Great Lakes Online website: *www.glakesonline.nos.noaa.gov/monitor.html* for station #9063079 (Marblehead).

With the horizontal and vertical control network established, recovery of boundary evidence was performed. Monumentation found and held as controlling stations included 5/8" iron pins at the intersecting centerlines of sixty (60) foot Sand Road and fifty (50) foot Spring Valley Road and along the centerline of Sand Road. A topographic survey was performed that located the cultural (i.e. buildings, survey monuments, coastal structures) and natural (i.e. top and toe of bluff) features on the subject parcel and adjoiners. Notwithstanding the presence of the timber crib pier along the shore and centered on the upland parcel, the natural shoreline appears to be unaltered by artificially placed fill material.

A technical assistance request was made to the ODNR Office of Coastal Management to help in identifying the location of the natural shoreline prior to the artificial placement of the concrete material. A drawing was provided to the consultant that depicted the location of the natural shoreline on the May 1956 aerial photograph. This location was transferred to the site and compared to the descriptions within the current and previous title deeds. The natural shoreline was slightly adjusted based upon the description within the 1993 limited warranty deed for the subject parcel.

Analysis

Parcel data provided by the Ottawa County Auditor's Office was imported into the computer-aided design (CAD) drawing to establish a general orientation of the shoreline for a reach of approximately 1.5 kilometers. Methodology for partitioning the boundaries between the littoral adjoiners was examined including extending the upland parcel boundary lakeward without deflection and a radial projection from the general alignment of the 1.5 kilometers reach of shore from the intersection of the natural shoreline and the parcel sidelines. The radial projection method provided the most equitable distribution between the subject parcel and the east and west adjoiners.

A base map was provided to the engineering consultant that depicted the locations of the existing site improvements relative to the established parcel boundaries and littoral partitions. A general statement that the survey and plat were prepared that conforms to Ohio Administrative Code (A.C.) Section 4733-37 was included and the Ohio registered professional surveyor's signature and seal were affixed to the plat of survey (see Existing Site Plan "C").

Design

Design specifications and details are identified on the following design example drawings and supported by the included design calculations.

A critical component of the design of a seawall is its placement with respect to lake levels, the bluff, and geologic features. In this case, the controlling element of the design process is the beach in front of the seawall. When waves interact with an impermeable vertical structure, the motion of the water particles influenced by the waves has a scouring effect on sediments at the base of the structure. This effect is often amplified by the reflection of wave energy off the structure. To reduce the risk of the beach eroding, the seawall should be placed as far up the beach profile as possible. In this example, the base of the seawall is placed at the toe of the bluff at an elevation of 570.8 feet IGLD 1985. This elevation is selected because it is the natural boundary between the sand and clay layers at the project site.

Even with adequate structural connections it is generally not recommended to use concrete blocks stacked more than 3 units high. If 3-foot tall by 4-foot wide by 5-foot long precast concrete blocks are specified, the maximum recommended height is 9-feet tall. In this example, a 9-inch thick reinforced concrete cap is specified which brings the crest elevation to 580.5 feet IGLD 1985. In some cases a lower crest elevation may be required if a seawall is to be used for watercraft access. However, this is not a consideration for this design due to the wide beach at the project site.

The existing bluff and beach profile must be excavated in the area of the seawall, and all sand and gravel must be sidecast into the lake. A second row of concrete blocks are added to the design to increase the overall weight of the gravity structure and help prevent sliding failures. The concrete blocks should be connected with rebar installed in predrilled holes and set with grout.

The project site is in the Locust Point to Marblehead reach of the "Revised Report on Great Lakes Open Coast Flooding" (USACE 1988) and has a 30-year return period design water level of 576.2 feet IGLD 1985.

An initial 3.7-foot structure depth can be calculated from the beach profile elevation at the base of the structure and the design water level. Based on the breaking wave equation, a design wave height of 2.9 feet can be calculated for the initial case. If the beach profile in front of the structure is completely scoured away, the water depth at the base of the structure would increase to 5.4 feet. In this case, the design wave height would increase to 4.2 feet.

In order to confirm the external stability of the seawall it must be checked for both sliding and overturning. The seawall is to be placed above the average lake level and will, at most times, be completely dry. In this case, the seawall acts as a retaining structure. When design storm conditions are present, the seawall may be subjected to hydrostatic and hydrodynamic forces from 5.4 feet of water depth and up to 4.2-foot waves. In this example, a second design case is necessary.

In both design cases it is assumed that the ground water level is below the lake level. This requires that hydrostatic forces be considered on the structure (in the second design case) and leads to a more conservative design.

Case 1 – Low Water:

In this case the following forces will act on the structure:

- Gravity
- Earth forces
- Reactive forces
- Friction

The force of gravity is the total weight of the structure cross section. A total of 5.0 tons was calculated for a 1-foot section of the seawall (concrete blocks, cap, backfill, etc). In the absence of other vertical forces the normal reactive force is equal to the structure weight. If a minimum angle of internal friction of 35 degrees is assumed, friction forces can be estimated at 3.5 tons per linear foot of structure.

In most cases, soil borings are suggested to determine actual physical properties at the project site. For this design example it is assumed that the till beneath the seawall is sufficient to support the wall. A 110 lb/ft^3 unit weight is assumed for the backfill. An active earth pressure of 0.27 is calculated from the internal angle of friction using the Rankine Method. Earth forces are estimated at 0.7 tons per foot of structure.

In this case, the earth force is the only anti-stabilizing force and friction is the only stabilizing force to induce or resist sliding. The factor of safety for sliding stability is the ratio of stabilizing to anti-stabilizing forces. A factor of safety of 5.0 was calculated for the low water case.

To verify the seawall will be stable against overturning, moments are calculated about the structure toe. A 4-foot moment arm was assumed for the center of gravity and a 3.2-foot moment arm was assumed for the center of pressure for the earth forces. This results in a 20.0 ft-tons stabilizing moment per linear foot of structure and a 2.2 ft-tons per linear foot anti-stabilizing moment. A factor of safety of 9.0 was calculated for the low water case.

Case 2 – Design Water Level and Wave Height

In this case the following forces will act on the structure:

- gravity
- earth forces
- normal reactive forces
- friction
- wave uplift
- hydrostatic forces
- horizontal wave forces

The force of gravity was determined in the same method as the low water case. In this case, the normal reactive force will be reduced by the vertical wave uplift forces; therefore, wave forces on the seawall must be estimated next.

Several methods are commonly used to predict the forces due to waves. In this design example, a method described in the USACE Coastal Engineering Manual was used. Wave forces are calculated based on the Goda Formula for irregular waves modified to include impulsive forces from head on breaking waves. This method was adapted to the geometry of the proposed seawall. In particular the calculations have been simplified based on the exclusion of a rubble foundation in the design and the assumptions that Bm = 0 and hs = d = h' (water depth at toe of structure is the same as water depth in front of structure).

This method predicts a free surface height 6.3 feet above the design water level at the wave crest. Wave pressures are calculated at 216 lb/ft^2 at the base of the structure, 250 lb/ft^2 at the design water level, and 80 lb/ft^2 at the crest of the structure. Wave uplift pressures are also estimated at 213 lb/ft^2.

Notice that this calculation predicts that the structure will be slightly overtopped in design storm conditions. For this design, the reinforced concrete cap extending over the top of the low bluff will be sufficient to resist overtopping forces.

Based on these pressures, the total horizontal wave force is estimated to be approximately 0.9 tons per linear foot of structure, and the wave uplift force is estimated to be approximately 0.3 tons per linear foot of structure. Horizontal hydrostatic forces are predicted to be 0.5 tons per linear foot of structure.

Using the Rankine Method, a passive earth pressure coefficient of 3.69 was calculated. A 110 lb/ft3 unit weight is also assumed for the backfill. Earth forces are estimated at 9.5 tons per foot of structure.

stabilizing forces = (friction + earth forces)

anti-stabilizing forces = (wave + hydrostatic forces)

The resultant normal force is the difference between the structure weight and wave uplift forces (4.7 tons/ft). Friction was estimated at 3.3 tons per linear foot assuming a 35 degree internal angle of friction.

A total of 12.8 tons per foot of stabilizing forces (friction + earth forces) and 1.3 tons per foot of anti-stabilizing forces (wave + hydrostatic forces) were calculated. This results in a factor of safety of 9.6 against sliding.

To verify the seawall will be stable against overturning, moments are calculated about the structure heel. Assuming a 4-foot moment arm for the center of gravity and a 3.2-foot moment arm for the center of pressure for the earth forces, a total stabilizing moment of 50.6 ft-tons per linear foot of structure was calculated. Assuming a 3.6-foot moment arm for the center of pressure of the horizontal wave forces, a 5.3-foot moment arm for the center of pressure of the wave uplift force and a 1.8-foot moment arm for the center of pressure of the hydrostatic forces results in a total anti-stabilizing moment of 5.7 ft-tons per linear foot of structure. A factor of safety of 8.8 is calculated for overturning stability.

Discussion

Although the entire structure is located on the beach area above the water level at the time of the survey, an appropriate design still considers minimization of the overall project footprint. The seawall in this example will extend lakeward a maximum of 5.6 feet from the toe of the existing bluff. Comparing this design to the revetment design at the same site, the seawall would be the alternative with the minimal impact to littoral drift. A final design selection would need to weigh the risk of beach scour at the project site as well as wave reflection on adjoining properties. The advantages of each alternative should be considered as well as the property owner's beach/ lake access requirements.

Similar to the revetment, this seawall design is intended to prevent erosion of the existing bluff and will therefore decrease the amount of material added to the littoral system. Any sand or gravel in the footprint of the revetment must be excavated and sidecast into the lake prior to construction to prevent sediment from being permanently removed from the littoral system.

A row of toe stones is often included lakeward of a seawall. The toe stones both protect the base of the seawall from scour and dissipate wave energy. In some cases, the recreational purposes of the seawall precludes the use of toe stone because the reduced water depth at the base of the structure limits its use for watercraft access. In this case, the row of toe stones was not included in order to reduce the overall footprint of the structure and preserve the largest possible width of beach lakeward of the structure.

Observing and measuring changes to the beach over time should be part of the routine inspection of the structure's performance in the years following construction. A beach monitoring plan should be developed to quantify and mitigate long-term effects of the structure.

Final Survey Products

Based upon the design from the Ohio registered PE, a plat that depicted the boundaries of the submerged lands lease has been prepared. The proposed design of the armor stone revetment locates its occupation landward of the natural shoreline and therefore is not included in any lease parcel. The existing occupation of the timber crib pier is bisected by the location of the natural shoreline, and therefore the lease parcel only includes the area lakeward of said natural shoreline (see Submerged Lands Plat).

A metes and bounds description has been written for the area depicted on the plat of survey with direct relationship to the upland parcel boundaries as required in Ohio Revised Code Section 1506.11(B) (see Submerged Lands Lease description for the parcel).

Moment arm: In a rigid system, the distance between a reference point and the point at which a force is exerted on the system (torque).

Torque: A shorthand definition might be "force times distance."

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SHEET NO.: 1 OF 9
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SCALE:

SEAWALL DESIGN

A. DESIGN WATER LEVEL

30 YEAR DESIGN WATER LEVEL = 576.2 FT IGLD 1985
REFERENCE: "REVISED REPORT ON GREAT LAKES OPEN COAST FLOODING" USACE, 1988.

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE
LAKE BOTTOM ELEVATION = 572.5 FEET IGLD 1985
STRUCTURE DEPTH = ds = 576.2 FT - 572.5 FT = 3.7 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 3.7 FT = 2.9 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED
TOE OF STRUCTURE = 570.8 FEET IGLD 1985
STRUCTURE DEPTH = ds = 576.2 FT - 570.8 FT = 5.4 FT IGLD 1985
BREAKING WAVE HEIGHT = Hb = 0.78 x ds = 0.78 x 5.4 FT = 4.2 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

C. CONCRETE CAP HEIGHT/OVERTOPPING

INITIAL DESIGN CASE
WAVE CREST ELEVATION = DWL + 0.7 Hb
= 576.2 FT + 0.7 (2.9 FT) = 578.2 FT IGLD 1985
CONSERVATIVE CASE, IF TOE OF STRUCTURE IS SCOURED
WAVE CREST ELEVATION = DWL + 0.7 Hb
= 576.2 FT + 0.7 (4.2 FT) = 579.1 FT IGLD 1985

CONSERVATIVE DESIGN: SET SEAWALL CREST ELEVATION AT 580.5 FT IGLD 1985

D. EXTERNAL STABILITY

CONSIDER 2 DESIGN CASES:
1. WATER AT MEAN LOW LEVEL
2. DESIGN WATER LEVEL AND WAVE HEIGHT

CASE 1: LOW WATER (WATER LEVEL AT 569.2 FT IGLD 1985)

DETERMINE FORCES:
I STRUCTURE CROSS SECTION WEIGHT
II NORMAL FORCE
III FRICTION
IV EARTH FORCES

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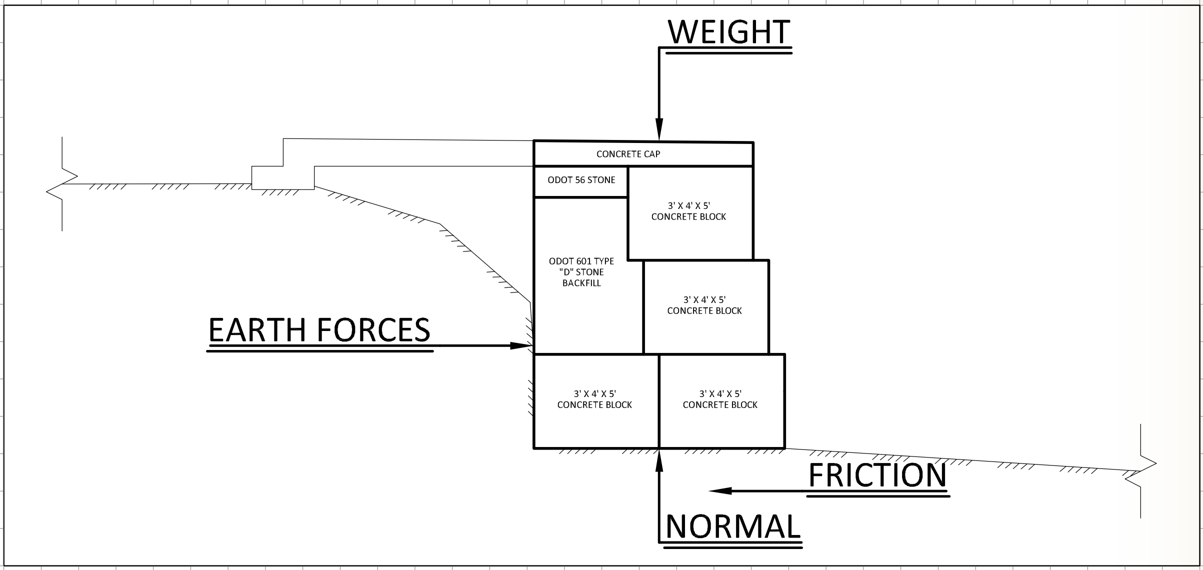
SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 1



I STRUCTURE CROSS SECTION WEIGHT

COMPONENT	L (FT)	H (FT)	AREA (FT^2)	UNIT WT. (PCF)	NO.	WEIGHT/FT (LB/FT)
CONCRETE CAP	7	0.75	5.25	145	1	761
CONCRETE BLOCKS	4	3	12	145	4	6960
ODOT "D" FILL			16.5	110	1	1815
ODOT 56 FILL			3	120	1	360
REINFORCEMENT					1	120
					TOTAL	10016

WEIGHT PER LINEAR FOOT = 10016 LB/FT = 5.0 TON/FT

II NORMAL FORCE = WEIGHT = 10016 LB/FT = 5.0 TON/FT

III FRICTION

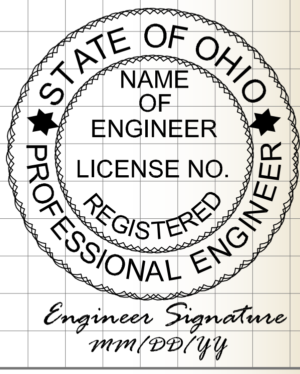
ANGLE OF INTERNAL FRICTION, α = 35 DEGREES (FROM SOIL SAMPLES)
COEFFICIENT OF STATIC FRICTION, $\mu = \tan \alpha = 0.7$

FRICTION = N μ = (10016 LB/FT)(0.7) = 7011 LB/FT = 3.5 TON/FT

IV EARTH FORCES

$FE = \frac{1}{2} \gamma h_w^2 K_a \cos \beta$

β = SLOPE OF BACKFILL = 0 DEGREES
hw = OVERALL HEIGHT OF STRUCTURE = 9.7 FT



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SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 1

γ = UNIT WEIGHT OF BACKFILL = 110 LB/FT³ (FROM SOIL SAMPLES)
ϕ = ANGLE OF INTERNAL FRICTION OF BACKFILL = 35 DEGREES (FROM SOIL SAMPLES)

Ka = ACTIVE EARTH COEFFICIENT

$Ka = TAN^2 (45-\phi/2)$ RANKINE THEORY FOR LEVEL BACKFILL ($\beta = 0°$)

REFERENCE: "USS STEEL SHEET PILING DESIGN MANUAL" US STEEL, 1984.

$Ka = TAN^2 (45-(35°/2)) = 0.27$

$FE = \frac{1}{2} (110\ LB/FT^3) (9.7\ FT)^2 (0.27) (COS\ 0) = 1397\ LB/FT = 0.7\ TON/FT$

SLIDING STABILITY

STABILIZING FORCES = FRICTION = 7011 LB/FT

ANTI-STABILIZING FORCES = EARTH FORCES = 1397 LB/FT

FACTOR OF SAFETY = STABILIZING FORCES / ANTI-STABILIZING FORCES

FACTOR OF SAFETY = (7013 LB/FT) / (1397 LB/FT) = 5.0

OVERTURNING STABILITY - CALCULATE MOMENTS ABOUT STRUCTURE TOE

STABILIZING MOMENTS

STRUCTURE WEIGHT = 10016 LB/FT
MOMENT ARM = 4 FT
STABILIZING MOMENT = 40064 FT-LB/FT = 20.0 FT-TON/FT

ANTI-STABILIZING MOMENTS

EARTH FORCES = 1397 LB/FT
MOMENT ARM = 3.2 FT
ANTI-STABILIZING MOMENT = 4470 FT-LB/FT = 2.2 FT-TON/FT

FACTOR OF SAFETY = STABILIZING / ANTI-STABILIZING

FACTOR OF SAFETY = (40064 FT-LB/FT) / (4470 FT-LB/FT) = 9.0

STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER

Engineer Signature
MM/DD/YY

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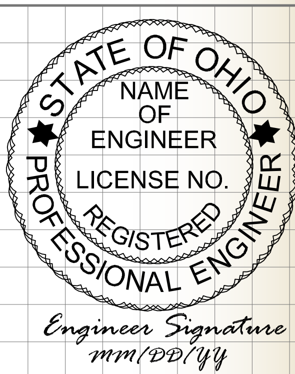


SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

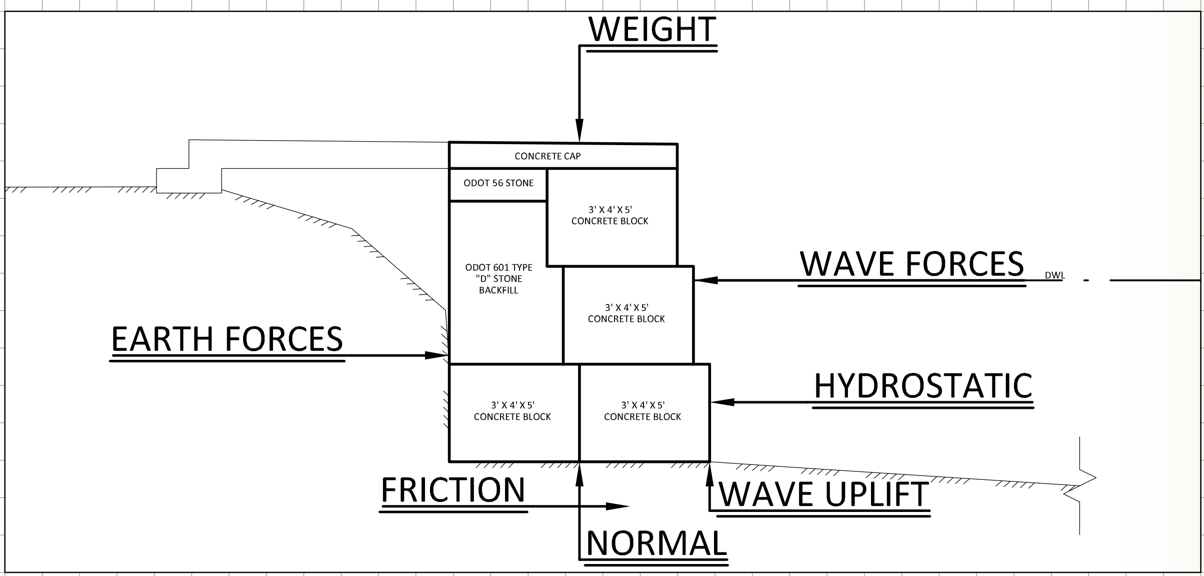
CASE 2: DESIGN WATER LEVEL AND WAVE HEIGHT

DETERMINE FORCES:

I STRUCTURE CROSS SECTION WEIGHT
II WAVE FORCES
III EARTH FORCES
IV HYDROSTATIC (BUOYANT) FORCES
V NORMAL FORCE (RESULTANT)
VI FRICTION

DESIGN ASSUMPTIONS:

- FOR CONSERVATIVE DESIGN ASSUME HIGH LAKE WATER LEVEL AND LOW GROUND WATER LEVEL (SEPARATED BY SEAWALL). HYDROSTATIC FORCES MUST BE CONSIDERED.



I STRUCTURE WEIGHT

TOTAL STRUCTURE WEIGHT = 10016 LB/FT = 5.0 TON/FT (PREVIOUSLY CALCULATED)

II WAVE FORCES

WAVE FORCE CALCULATION BASED ON GODA FORMULA FOR IRREGULAR WAVES MODIFIED TO INCLUDE IMPULSIVE FORCES FROM HEAD ON BREAKING WAVES AND ADAPTED TO THE GEOMETRY OF THE PROPOSED SEAWALL.
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 1996, TABLES VI-5-53, 54 & 55.

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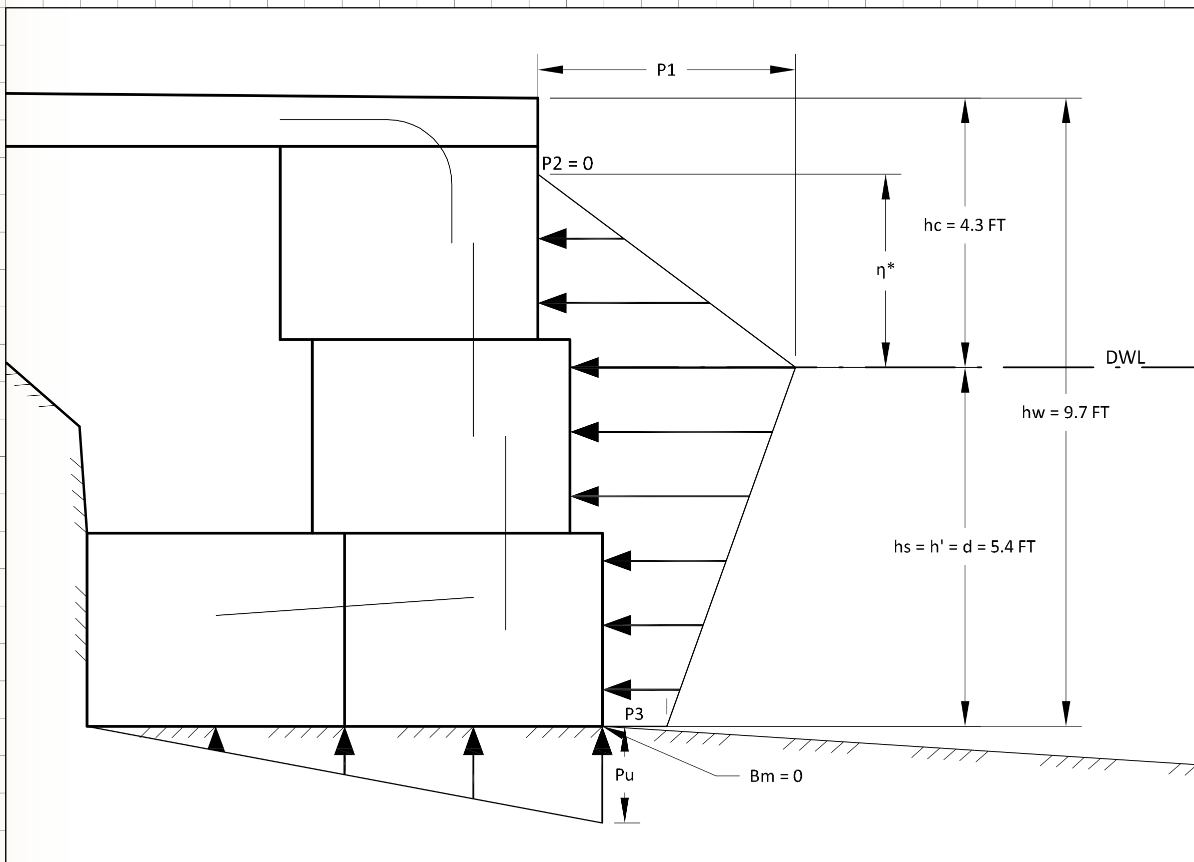
SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2



DEFINITIONS:

P1 = WAVE PRESSURE AT DESIGN WATER LEVEL
P2 = WAVE PRESSURE AT WAVE/SEAWALL CREST HEIGHT
P3 = WAVE PRESSURE AT BASE OF SEAWALL
Pu = WAVE UPLIFT PRESSURE AT BASE OF SEAWALL
η* = WAVE CREST HEIGHT
hs = DEPTH OF STRUCTURE TOE = 5.4 FT
d = WATER DEPTH AT TOE OF STRUCTURE = 5.4 FT
h' = TOTAL DEPTH OF STRUCTURE = 5.4 FT
β = ANGLE OF INCIDENCE OF DESIGN WAVES = 0 DEGREES
Hdesign = DESIGN WAVE HEIGHT = Hb = 4.2 FT
hw = OVERALL HEIGHT OF STRUCTURE = 9.7 FT
hc = HEIGHT OF STRUCTURE ABOVE DWL = 4.3 FT
Bm = WIDTH OF RUBBLE FOUNDATION = 0
Ts = WAVE PERIOD = 4.5 SECONDS (ASSUMED FOR 4.2 FT WAVE)
Ts = WAVE PERIOD = 4.5 SECONDS (ASSUMED FOR 4.2 FT WAVE)

STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
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SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

hb = WATER DEPTH AT A DISTANCE 5 X Hdesign FROM SEAWALL
= hs +5 X Hdesign X TAN ϕ = 5.4 FT + 5 X 4.2 FT X TAN (1°) = 5.8 FT

L = WAVELENGTH AT WATER DEPTH hb = Ts $\sqrt{g\ hb}$ = (4.5 S) $\sqrt{(32.2\ FT/S^2 \times 5.8\ FT)}$ = 61.5 FT

DETERMINE MODIFICATIONS TO GODA FORMULA

$$\delta 22 = -0.36\left(\frac{Bm}{L} - 0.12\right) + 0.93\left(\frac{hs - d}{hs} - 0.6\right) = -0.51$$

$$\delta 2 = \begin{cases} 4.9 \times \delta 22 & \text{FOR } \delta 22 \le 0 \\ 3 \times \delta 22 & \text{FOR } \delta 22 > 0 \end{cases} \qquad \delta 2 = 4.9 \times -0.51 = -2.52$$

$$\delta 11 = 0.93\left(\frac{Bm}{L} - 0.12\right) + 0.36\left(\frac{hs - d}{hs} - 0.6\right) = -0.33$$

$$\delta 1 = \begin{cases} 20 \times \delta 11 & \text{FOR } \delta 11 \le 0 \\ 15 \times \delta 11 & \text{FOR } \delta 11 > 0 \end{cases} \qquad \delta 1 = 20 \times -0.33 = -6.55$$

$$\alpha 11 = \begin{cases} \text{COS } \delta 2 / \text{COSH } \delta 1 & \text{FOR } \delta 2 \le 0 \\ 1/(\text{COSH } \delta 1 \times \sqrt{\text{COSH } \delta 2}) & \text{FOR } \delta 2 > 0 \end{cases} \qquad \alpha 11 = 0.018$$

$$\alpha 10 = \begin{cases} \text{Hdesign} / d & \text{FOR Hdesign} / d \le 2 \\ 2.0 & \text{FOR Hdesign} / d > 2 \end{cases} \qquad \alpha 10 = 0.78$$

$\alpha 1 = \alpha 10 \times \alpha 11 = 0.014$

$$\alpha 2 = \text{SMALLER OF: } \frac{hb - d}{3hb}\left(\frac{\text{Hdesign}}{d}\right)^2 = 0.013 \quad \text{AND} \quad \frac{2d}{\text{Hdesign}} = 2.56, \qquad \alpha 2 = 0.013$$

α^* = LARGER OF $\alpha 1$ AND $\alpha 2$ = 0.014

STRUCTURE TYPE MODIFICATION FACTORS

$\lambda 1 = \lambda 2 = \lambda 3 = 1.0$ FOR CONVENTIONAL VERTICAL WALL STRUCTURES

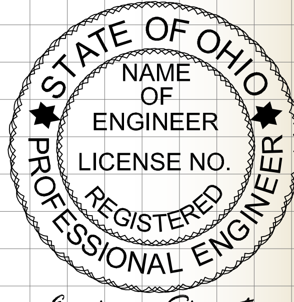
DETERMINE PRESSURE COEFFICIENTS FOR GODA FORMULA

$\alpha^* = 0.014$ (MODIFIED α^* FOR IMPULSIVE FORCES)

$$\alpha 1 = 0.6 + 0.5\left(\frac{4\pi\ hs / L}{\text{SINH } (4\pi\ hs / L)}\right)^2 = 0.94$$

$\alpha 2 = 0.013$ (SAME AS ABOVE)

$$\alpha 3 = 1 - \frac{hw - hc}{hs}\left(1 - \frac{1}{\text{COSH } (2\pi\ hs / L)}\right) = 0.86$$



Engineer Signature
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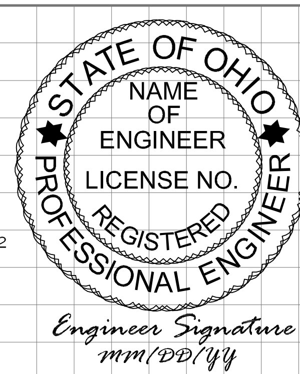
SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2



CALCULATE WAVE PRESSURES

$\eta^* = 0.75\,(1+\cos\beta)\,\lambda_1\,H_{design} = 6.3$ FT

$P_1 = 0.5\,(1+\cos\beta)\,(\lambda_1\alpha_1 + \lambda_2\alpha^*\cos^2\beta)\,\rho_w\,g\,H_{design} = 250$ LB/FT²

$P_2 = \begin{cases} (1 - h_c/\eta^*)\,P_1 & \text{FOR } \eta^* > h_c \\ 0 & \text{FOR } \eta^* \le h_c \end{cases}$ $\quad P_2 = 80$ LB/FT²

$P_3 = \alpha_3 P_1 = 216$ LB/FT²

$P_U = 0.5\,(1+\cos\beta)\,\lambda_3\,\alpha_1\,\alpha_3\,\rho_w\,g\,H_{design} = 213$ LB/FT²

DETERMINE LEVELS OF UNCERTAINTY
FOR HORIZONTAL FORCE, UFH = 0.90
FOR UPLIFT FORCE, UFU = 0.77
FOR HORIZONTAL MOMENT, UMH = 0.81
FOR UPLIFT MOMENT, UMU = 0.72

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-55.

CALCULATE WAVE FORCES PER LINEAR FOOT OF STRUCTURE

HORIZONTAL WAVE FORCE, $F_H = U_{FH}\left(\tfrac{1}{2}(P_1+P_2)h_c + \tfrac{1}{2}(P_1+P_3)h'\right) = 1772$ LB/FT = 0.9 TON/FT

WAVE UPLIFT FORCE, $F_U = U_{FU} \times \tfrac{1}{2}P_U \times B = 656$ LB/FT = 0.3 TON/FT
B = 10 FT WIDTH OF STRUCTURE CROSS SECTION

III EARTH FORCES

$F_E = \tfrac{1}{2}\,\gamma\,h_w^2\,K_p\cos\beta$

β = SLOPE OF BACKFILL = 0 DEGREES
h_w = OVERALL HEIGHT OF STRUCTURE = 9.7 FT
γ = UNIT WEIGHT OF BACKFILL = 110 LB/FT³ (FROM SOIL SAMPLES)
ϕ = ANGLE OF INTERNAL FRICTION OF BACKFILL = 35 DEGREES (FROM SOIL SAMPLES)

K_p = PASSIVE EARTH COEFFICIENT

$K_p = \tan^2(45+\phi/2)$ RANKINE THEORY FOR LEVEL BACKFILL ($\beta = 0°$)
REFERENCE: "USS STEEL SHEET PILING DESIGN MANUAL" US STEEL, 1984.

$K_p = \tan^2(45+(35°/2)) = 3.69$

$F_E = \tfrac{1}{2}\,(110 \text{ LB/FT}^3)\,(9.7 \text{ FT})^2\,(3.69)\,(\cos 0) = 19096$ LB/FT = 9.5 TON/FT

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE D - BLOCK SEAWALL
SHEET NO. 8 OF 9
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

IV HYDROSTATIC FORCES

$F_{hydro} = \frac{1}{2} \gamma_w h^2$

γ_w = UNIT WEIGHT OF WATER = 62.4 LB/FT^3
h = WATER DEPTH AT TOE OF STRUCTURE = 5.4 FT

Fhydro = 910 LB/FT = 0.5 TON/FT

V RESULTANT NORMAL FORCE

RESULTANT VERTICAL FORCE, N = WEIGHT - WAVE UPLIFT

N = 10016 LB/FT - 656 LB/FT = 9360 LB/FT = 4.7 TON/FT

VI FRICTION
ANGLE OF INTERNAL FRICTION, α = 35 DEGREES (FROM SOIL SAMPLES)
COEFFICIENT OF STATIC FRICTION, $\mu = \tan \alpha = 0.7$

FRICTION = N μ = (9360 LB/FT)(0.7) = 6552 LB/FT = 3.3 TON/FT

SLIDING STABILITY

STABILIZING FORCES = FRICTION + EARTH FORCES
STABILIZING = 6552 LB/FT + 19096 LB/FT = 25648 LB/FT = 12.8 TON/FT

ANTI-STABILIZING FORCES = WAVE FORCES + HYDROSTATIC FORCES
ANTI-STABILIZING FORCES = 1772 LB/FT + 910 LB/FT = 2682 LB/FT = 1.3 TON/FT

FACTOR OF SAFETY = STABILIZING FORCES / ANTI-STABILIZING FORCES
FACTOR OF SAFETY = (25648 LB/FT) / (2682 LB/FT) = 9.6

OVERTURNING STABILITY - CALCULATE MOMENTS ABOUT STRUCTURE HEEL

STABILIZING MOMENTS

STRUCTURE WEIGHT = 10016 LB/FT
MOMENT ARM = 4 FT
STABILIZING MOMENT = 40064 FT-LB/FT = 20.0 FT-TON/FT

EARTH FORCES = 19096 LB/FT
MOMENT ARM = 3.2 FT
STABILIZING MOMENT = 61107 FT-LB/FT = 30.6 FT-TON/FT

Engineer Signature
mm/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE D - BLOCK SEAWALL
SHEET NO. 9 OF 9
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

TOTAL STABILIZING MOMENT = 101171 FT-LB/FT

ANTI-STABILIZING MOMENTS

HORIZONTAL WAVE FORCE = FH = 1772 LB/FT
MOMENT ARM = 3.6 FT
ANTI-STABILIZING MOMENT = 6379 FT-LB/FT = 3.2 FT-TON/FT

WAVE UPLIFT FORCE = FU = 656 LB/FT
MOMENT ARM = 5.3 FT
ANTI-STABILIZING MOMENT = 3477 FT-LB/FT = 1.7 FT-TON/FT

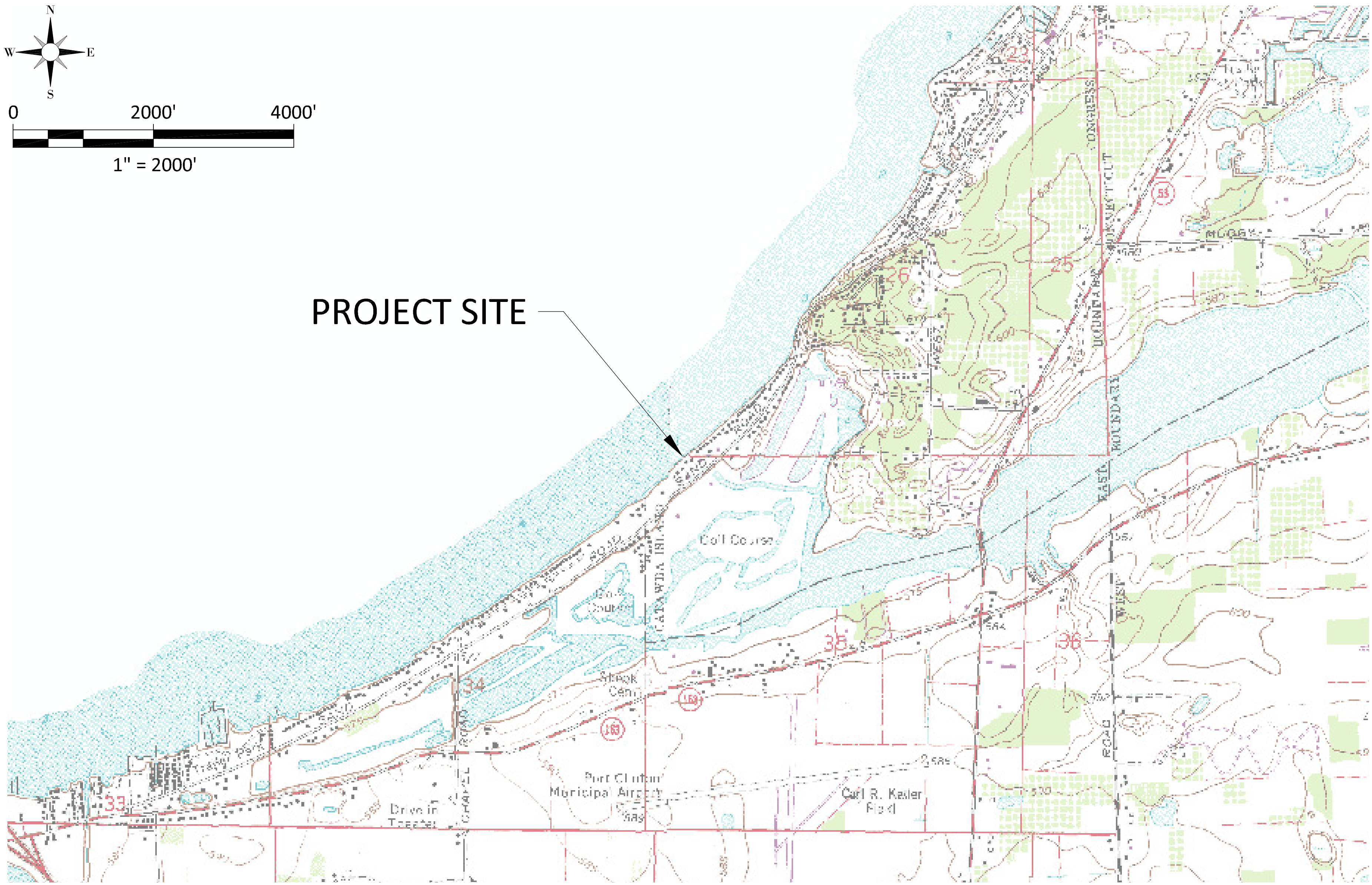
HYDROSTATIC FORCE = 910 LB/FT
MOMENT ARM = 1.8 FT
ANTI-STABILIZING MOMENT = 1638 FT-LB/FT = 0.8 FT-TON/FT

TOTAL ANTI-STABILIZING MOMENT = 11494 FT-LB/FT = 5.7 FT-TON/FT

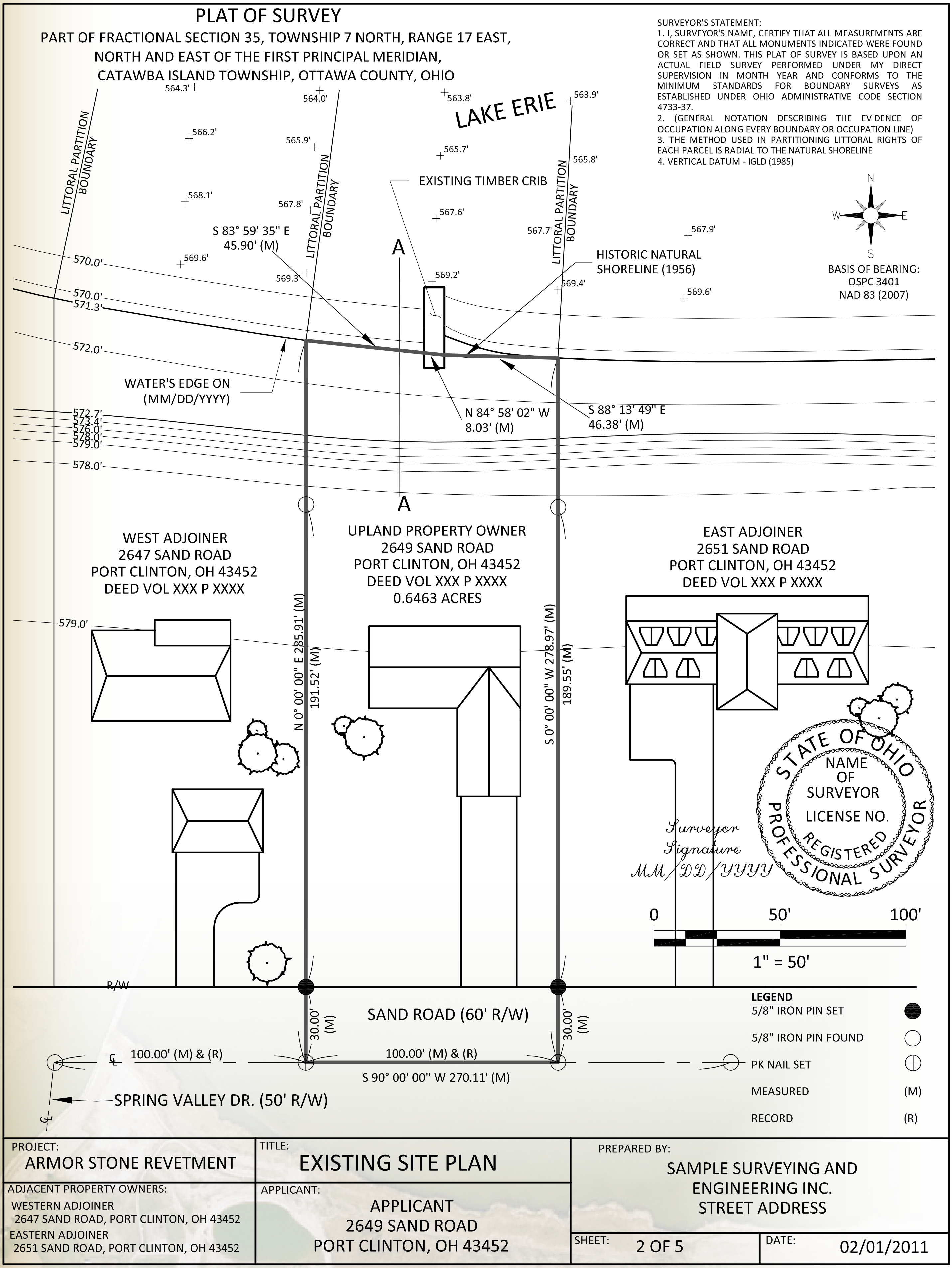
FACTOR OF SAFETY = STABILIZING / ANTI-STABILIZING

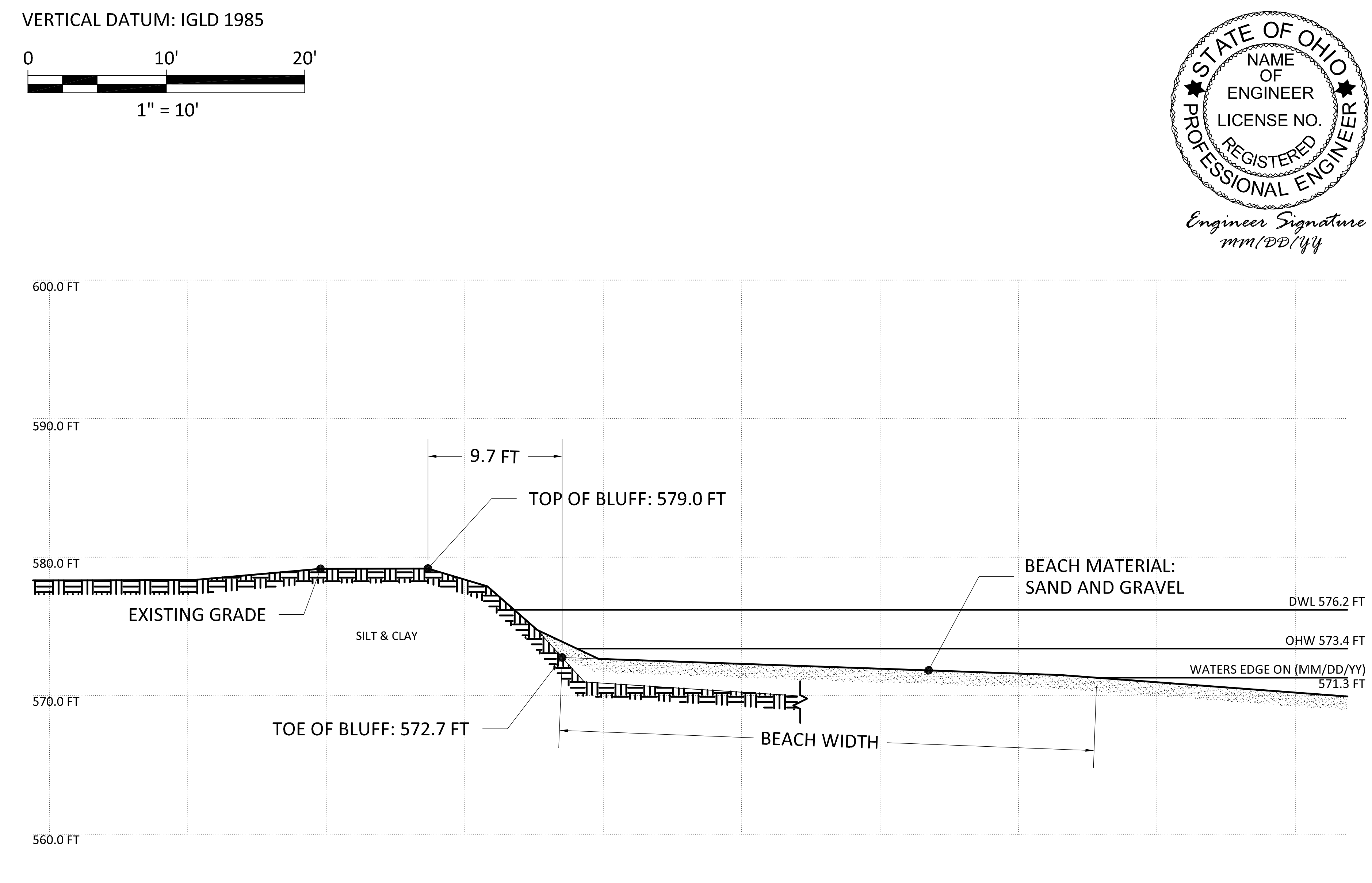
FACTOR OF SAFETY = 101171 FT-LB/FT / 11494 FT-LB/FT = 8.8

*NOTE: THE CALCULATIONS INCLUDED IN THIS EXAMPLE WERE ORIGINALLY COMPUTED USING EXCEL SPREADSHEETS. THE SOFTWARE DISPLAYS A SPECIFIED NUMBER OF SIGNIFICANT FIGURES BUT RETAINS THE ORIGINAL NUMBER FOR OPERATIONS. AS A RESULT SMALL ROUNDING ERRORS ARE INTRODUCED IN TRANSCRIBING THE STEP-BY-STEP CALCULATIONS. THESE ERRORS ARE ACCEPTABLE CONSIDERING THE OVERALL ACCURACY OF THE CALCULATION METHODS AND THE PURPOSE OF THIS DESIGN MANUAL.

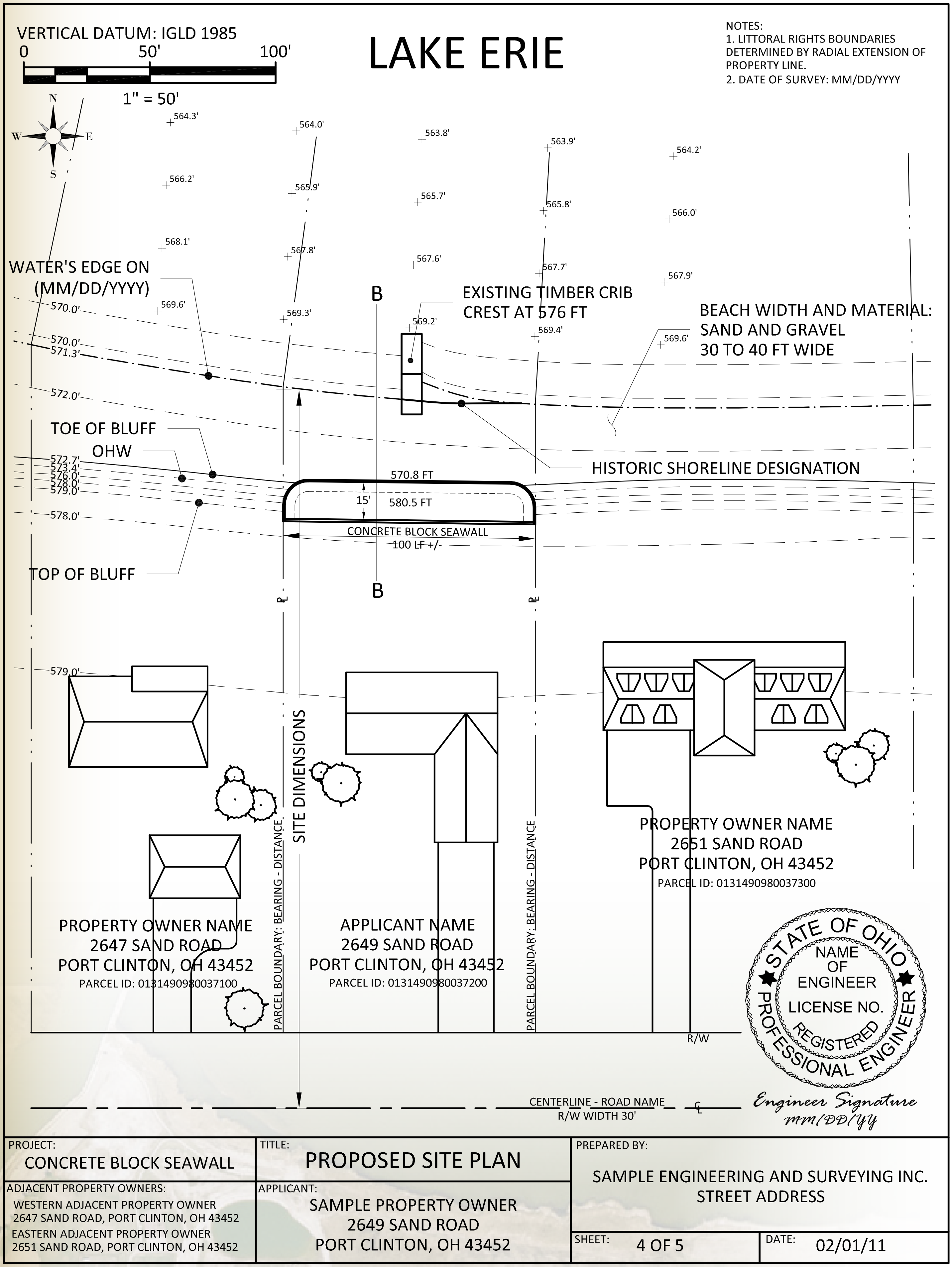


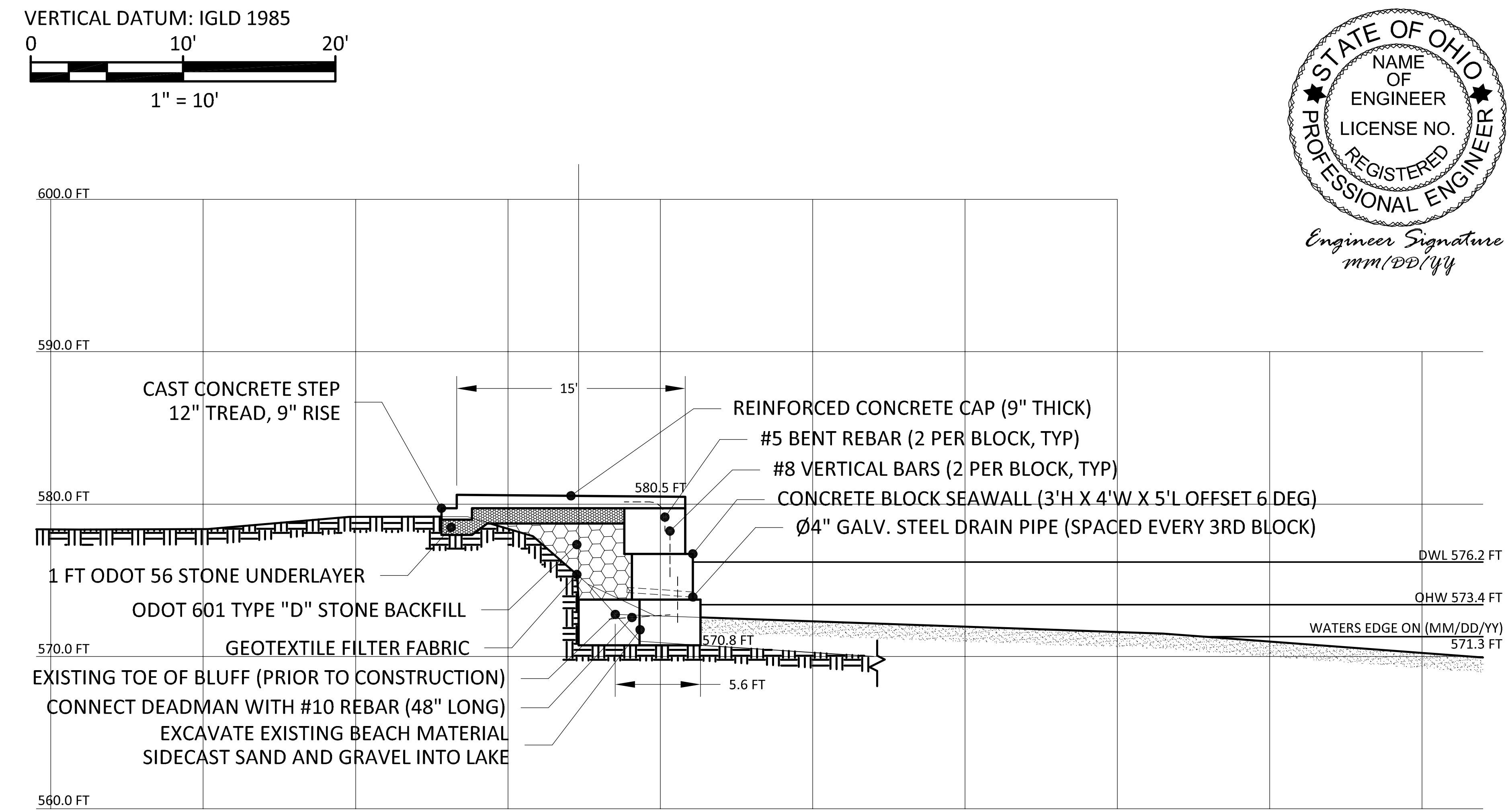
PROJECT: CONCRETE BLOCK SEAWALL	TITLE: VICINITY MAP	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 1 OF 5 DATE: 02/01/11


PLAT OF SURVEY
PART OF FRACTIONAL SECTION 35, TOWNSHIP 7 NORTH, RANGE 17 EAST,
NORTH AND EAST OF THE FIRST PRINCIPAL MERIDIAN,
CATAWBA ISLAND TOWNSHIP, OTTAWA COUNTY, OHIO
SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO THE NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)
LAKE ERIE
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
564.3'
564.0'
563.8'
563.9'
566.2'
565.9'
565.7'
565.8'
568.1'
567.8'
567.6'
567.7'
567.9'
569.6'
569.3'
569.2'
569.4'
569.6'
EXISTING TIMBER CRIB
S 83° 59' 35" E
45.90' (M)
A
HISTORIC NATURAL SHORELINE (1956)
N
W
E
S
BASIS OF BEARING:
OSPC 3401
NAD 83 (2007)
570.0'
570.0'
571.3'
572.0'
WATER'S EDGE ON (MM/DD/YYYY)
N 84° 58' 02" W
8.03' (M)
S 88° 13' 49" E
46.38' (M)
572.7'
573.4'
576.0'
578.0'
579.0'
578.0'
A
WEST ADJOINER
2647 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
UPLAND PROPERTY OWNER
2649 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
0.6463 ACRES
EAST ADJOINER
2651 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
579.0'
N 0° 00' 00" E 285.91' (M)
191.52' (M)
S 0° 00' 00" W 278.97' (M)
189.55' (M)
STATE OF OHIO
NAME OF SURVEYOR
LICENSE NO.
REGISTERED
PROFESSIONAL SURVEYOR
Surveyor Signature
MM/DD/YYYY
0
50'
100'
1" = 50'
R/W
SAND ROAD (60' R/W)
30.00' (M)
30.00' (M)
100.00' (M) & (R)
100.00' (M) & (R)
S 90° 00' 00" W 270.11' (M)
SPRING VALLEY DR. (50' R/W)
LEGEND
5/8" IRON PIN SET
5/8" IRON PIN FOUND
PK NAIL SET
MEASURED (M)
RECORD (R)
PROJECT:
ARMOR STONE REVETMENT
TITLE:
EXISTING SITE PLAN
PREPARED BY:
SAMPLE SURVEYING AND ENGINEERING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJOINER
2647 SAND ROAD, PORT CLINTON, OH 43452
EASTERN ADJOINER
2651 SAND ROAD, PORT CLINTON, OH 43452
APPLICANT:
APPLICANT
2649 SAND ROAD
PORT CLINTON, OH 43452
SHEET: 2 OF 5
DATE: 02/01/2011



PROJECT: CONCRETE BLOCK SEAWALL	TITLE: SECTION A-A: EXISTING SITE	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 3 OF 5	DATE: 02/01/11


VERTICAL DATUM: IGLD 1985
0
50'
100'
1" = 50'
N
W
E
S
LAKE ERIE
NOTES:
1. LITTORAL RIGHTS BOUNDARIES DETERMINED BY RADIAL EXTENSION OF PROPERTY LINE.
2. DATE OF SURVEY: MM/DD/YYYY
564.3'
564.0'
563.8'
563.9'
564.2'
566.2'
565.9'
565.7'
565.8'
566.0'
568.1'
567.8'
567.6'
567.7'
567.9'
569.6'
569.3'
569.2'
569.4'
569.6'
WATER'S EDGE ON (MM/DD/YYYY)
B
EXISTING TIMBER CRIB CREST AT 576 FT
BEACH WIDTH AND MATERIAL: SAND AND GRAVEL 30 TO 40 FT WIDE
570.0'
570.0'
571.3'
572.0'
TOE OF BLUFF
OHW
HISTORIC SHORELINE DESIGNATION
572.7'
573.4'
576.0'
578.0'
579.0'
570.8 FT
15'
580.5 FT
578.0'
CONCRETE BLOCK SEAWALL
100 LF +/-
TOP OF BLUFF
B
579.0'
SITE DIMENSIONS
PARCEL BOUNDARY: BEARING - DISTANCE
PARCEL BOUNDARY: BEARING - DISTANCE
PROPERTY OWNER NAME
2651 SAND ROAD
PORT CLINTON, OH 43452
PARCEL ID: 0131490980037300
PROPERTY OWNER NAME
2647 SAND ROAD
PORT CLINTON, OH 43452
PARCEL ID: 0131490980037100
APPLICANT NAME
2649 SAND ROAD
PORT CLINTON, OH 43452
PARCEL ID: 0131490980037200
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
R/W
CENTERLINE - ROAD NAME
R/W WIDTH 30'
Engineer Signature
MM/DD/YY
PROJECT:
CONCRETE BLOCK SEAWALL
TITLE:
PROPOSED SITE PLAN
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
2647 SAND ROAD, PORT CLINTON, OH 43452
EASTERN ADJACENT PROPERTY OWNER
2651 SAND ROAD, PORT CLINTON, OH 43452
APPLICANT:
SAMPLE PROPERTY OWNER
2649 SAND ROAD
PORT CLINTON, OH 43452
SHEET:
4 OF 5
DATE:
02/01/11



NOTES:

1. PROVIDE 1 DEGREE OF SLOPE ON CONCRETE CAP FOR DRAINAGE
2. CONCRETE CAP SHALL HAVE 28 DAY COMPRESSIVE STRENGTH OF 4 KSI WITH CONTROL JOINTS SPACED EVERY 10 FEET.
3. REINFORCE CAP WITH #5 60 KSI DEFORMED BARS SPACED AT 16 INCHES IN LONGITUDINAL AND TRANSVERSE DIRECTION.
4. REINFORCE NOSE OF STEP TREAD WITH #5 REBAR.
5. PROVIDE MINIMUM OF 2 INCHES OF COVER OVER ALL REBAR.
6. EXCAVATE EXISTING BEACH TO STIFF CLAY. DEPOSIT EXCAVATED SAND & GRAVEL LAKEWARD OF PROJECT. NO SAND OR GRAVEL SHOULD BE TRAPPED UNDER SEAWALL.

PROJECT: CONCRETE BLOCK SEAWALL	TITLE: SECTION B-B: PROPOSED SITE	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 2647 SAND ROAD, PORT CLINTON, OH 43452 EASTERN ADJACENT PROPERTY OWNER 2651 SAND ROAD, PORT CLINTON, OH 43452	APPLICANT: SAMPLE PROPERTY OWNER 2649 SAND ROAD PORT CLINTON, OH 43452	SHEET: 5 OF 5 — DATE: 02/01/11

Lake Erie Submerged Lands Legal Description
Adjacent to 2649 Sand Road, Port Clinton

Situate in the State of Ohio and located within the waters of Lake Erie, County of Ottawa, Catawba Island Township, Town 7 North, Range 17 East, North and East of the First Principal Meridian, adjacent to a portion of fractional Section 35 conveyed to (NAME OF UPLAND OWNER) by Deed Volume (XXX), Page (XXXX), of the deed records of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin found at the intersection of the centerline of sixty (60) foot Sand Road and the centerline of fifty (50) foot Spring Valley Drive, said point also being the southwest corner of (NAME OF WEST ADJOINER) parcel as conveyed by Deed Volume (XXX), Page (XXXX);

Thence along the centerline of sixty (60) foot Sand Road and the south line of said (NAME OF WEST ADJOINER), North 90 degrees, 00 minutes, 00 seconds East, 99.79 feet to a P-K nail set at the southeast corner of said (NAME OF WEST ADJOINER) parcel, also being the southwest corner of said (NAME OF UPLAND OWNER);

Thence along the west line of said (NAME OF UPLAND OWNER) parcel and the east line of said (NAME OF WEST ADJOINER), North 00 degrees, 00 minutes, 00 seconds East, 285.91 feet, and passing for reference, a 5/8 inch solid iron pin set at 30.00 feet on the north right-of-way of Sand Road and a 5/8 inch solid iron pin found at 221.52 feet to the location of the natural shoreline of Lake Erie present in (1956) as determined by the Ohio Department of Natural Resources, also being the northwest corner of said (NAME OF UPLAND OWNER);

Thence along the north line of said (NAME OF UPLAND OWNER), also being said natural shoreline, South 83 degrees, 59 minutes, 35 seconds East, 45.90 feet to a point not monumented due to the location on the submerged lands of Lake Erie, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said (NAME OF UPLAND OWNER) parcel, across the open waters of Lake Erie, North 00 degrees, 00 minutes, 00 seconds East, 25.65 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, North 87 degrees, 27 minutes, 17 seconds East, 8.01 feet to a point not monumented due to location on submerged lands of Lake Erie;

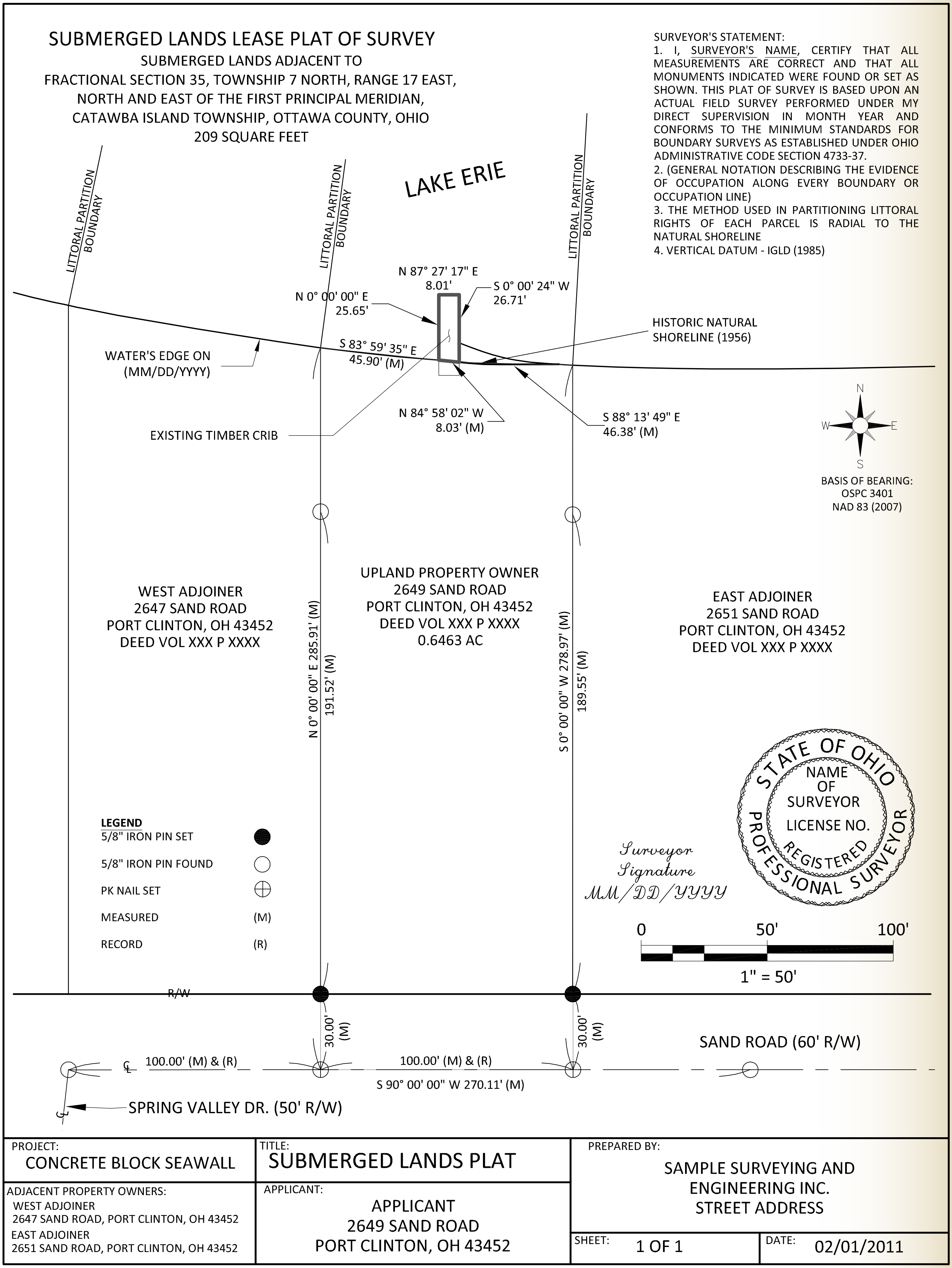
Thence continuing across the open waters of Lake Erie, South 00 degrees, 00 minutes, 24 seconds West, 26.71 feet to a 5/8 inch solid iron pin set on the north line of said (NAME OF UPLAND OWNER), also being said natural shoreline;

Thence along said natural shoreline, North 84 degrees, 58 minutes, 02 seconds West, 8.03 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 209 square feet (0.0048 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: The alignment of the centerline of Sand Road (North 90 degrees, 00 minutes, 00 seconds East) as determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)


SUBMERGED LANDS LEASE PLAT OF SURVEY
SUBMERGED LANDS ADJACENT TO
FRACTIONAL SECTION 35, TOWNSHIP 7 NORTH, RANGE 17 EAST,
NORTH AND EAST OF THE FIRST PRINCIPAL MERIDIAN,
CATAWBA ISLAND TOWNSHIP, OTTAWA COUNTY, OHIO
209 SQUARE FEET
SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO THE NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)
LAKE ERIE
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
N 87° 27' 17" E 8.01'
N 0° 00' 00" E 25.65'
S 0° 00' 24" W 26.71'
HISTORIC NATURAL SHORELINE (1956)
WATER'S EDGE ON (MM/DD/YYYY)
S 83° 59' 35" E 45.90' (M)
N 84° 58' 02" W 8.03' (M)
S 88° 13' 49" E 46.38' (M)
EXISTING TIMBER CRIB
N
W
E
S
BASIS OF BEARING: OSPC 3401 NAD 83 (2007)
WEST ADJOINER
2647 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
UPLAND PROPERTY OWNER
2649 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
0.6463 AC
EAST ADJOINER
2651 SAND ROAD
PORT CLINTON, OH 43452
DEED VOL XXX P XXXX
N 0° 00' 00" E 285.91' (M)
191.52' (M)
S 0° 00' 00" W 278.97' (M)
189.55' (M)
STATE OF OHIO
NAME OF SURVEYOR
LICENSE NO.
REGISTERED
PROFESSIONAL SURVEYOR
Surveyor Signature MM/DD/YYYY
LEGEND
5/8" IRON PIN SET
5/8" IRON PIN FOUND
PK NAIL SET
MEASURED (M)
RECORD (R)
0
50'
100'
1" = 50'
R/W
30.00' (M)
30.00' (M)
SAND ROAD (60' R/W)
℄
100.00' (M) & (R)
100.00' (M) & (R)
S 90° 00' 00" W 270.11' (M)
SPRING VALLEY DR. (50' R/W)
PROJECT:
CONCRETE BLOCK SEAWALL
TITLE:
SUBMERGED LANDS PLAT
PREPARED BY:
SAMPLE SURVEYING AND ENGINEERING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WEST ADJOINER
2647 SAND ROAD, PORT CLINTON, OH 43452
EAST ADJOINER
2651 SAND ROAD, PORT CLINTON, OH 43452
APPLICANT:
APPLICANT
2649 SAND ROAD
PORT CLINTON, OH 43452
SHEET: 1 OF 1
DATE: 02/01/2011

Ch 4.5 Design Example E: Stone Filled Crib Seawall

Design Example E

The following example demonstrates the design of a stone filled crib seawall as erosion protection at a site with medium (20 to 30-foot high) bluffs along the shore. The design is demonstrated using the same fictitious project site as the medium bluff revetment Design Example B. In this case, the revetment designed in the medium bluff example has already been constructed. Later the property owners decide they would like to improve their access to the lake for swimming and small watercraft while maintaining the functionality of erosion control.

Project Purpose

The purpose of Example Project E is to provide access to the waters of Lake Erie while still providing adequate protection to the bluff from wave based erosion. The replacement of a portion of the armor stone revetment with a steel crib seawall is proposed.

Site Description

The project site is located along the shore of Lake Erie in Vermilion, Erie County, approximately 3.5 miles west of the Vermilion River. The shore in this area is oriented from west to east. The predominant direction of sediment transport in the littoral zone is from east to west.

The shore at the project site is irregular in shape due to the installation of the shore perpendicular structures. The site property is oriented in a slight northwest to southeast direction. The project site spans two parcels and is approximately 200 feet wide. At the east end of the property there is a small embayment suggesting increased erosion in this area.

The bluffs in this area are 15 to 20 feet in height and have been partially regraded to an approximately 1.7 horizontal to 1 vertical slope. The bluffs are composed primarily of till overlain with gaciolacustrine silts and clays. In the nearshore zone, shale makes up the bottom. Sand and a nearshore bar system are located as far as 700 feet offshore near the site location. The bottom slope from 100 to 1500 feet offshore is approximately 100 horizontal to 1 vertical.

An armor stone revetment has been constructed on the site as erosion protection. The revetment extends from an elevation of 567.5 feet as referenced to the International Great Lakes Datum of 1985 (IGLD 1985) at the base of the toe to 582 ft IGLD 1985 at the crest. The revetment is constructed with a double layer of 2 to 4 ton armor stone over stone filter layer consisting of 12 to 24-inch stone. 4 to 5 ton armor stone entrenched 2.5 feet into bedrock is specified as toe protection. An ODOT 601 Type “B” stone splash apron extends from the revetment crest to 585 feet IGLD 1985. Above the splash apron the bluff has been regraded to the top of the bluff at approximately 589 feet IGLD 1985.

The site is exposed to storm waves from west-southwest to east-northeast. A review of historic wave information results in a significant wave height of 2.3 feet at a period of 3.6 seconds. The most frequent wave direction was from 180 degrees (referenced to 0/360 degrees north). The largest wave recorded over the 32 year study was 11.8 feet with a 9.0 second period. The average direction of the largest waves was 11.0 degrees. Wave data was measured at WIS station E06 located approximately 4.5 miles north of the project site in 33-foot deep water.

The project site is not located in a designated Coastal Erosion Area based on the 2010 mapping, but has an expected erosion rate of 0.1 to 0.8 feet over 30 years. There are no existing drainage measures causing localized erosion at the project site.

The eastern and western adjoining properties are similar to the project site in bluff elevation and upland topography. The western adjoining property is undeveloped and includes no shore protection. A 15 to 20-foot wide sand and gravel beach is present at the toe of the bluff. The eastern adjoining property includes an existing structure for erosion protection in the form of a revetment. The structure is in poor condition due to undersized concrete rubble being fractured and displaced by wave action.

Field Survey

The upland parcel is located within the Firelands portion of the Connecticut Western Reserve district of Ohio's Public Lands Survey System, specifically part of Original Lot (O.L.) 34, Town 13 North, Range 20 West. Being within the incorporated boundaries of the city of Vermilion, the parcel boundary extends north of the sixty (60) foot dedicated right of way centered on said centerline.

Horizontal control was established for this site by evaluating the location of published monumentation through the National Geodetic Survey (NGS) website: *www.ngs.noaa.gov*. The closest station to this site was determined to be "A 319" (PID MC0927) which is approximately 2.5 kilometers east. Based upon the NGS datasheet, the horizontal accuracy of the station is reported as a Cooperative Base Network Control Station with reports that attempts to recover the station were successful in 2003, 2004 and 2009. Therefore, this station was used within the horizontal control network. An open traverse was performed between "A 319" and a Third Order station "Ceylon" (PID MC1118) with intermediate stations located close to the project site. No adjustment was made to the resultant coordinates.

Vertical control was established for this site by evaluating the location of published monumentation through the NGS website. The closest station to this site was determined to be "Z 318" (PID MC0928) which is approximately 0.1 kilometers south. Based upon the NGS datasheet the vertical accuracy of the station is First Order Class II with reports that attempts to recover the station were successful in 2004. The NGS stainless steel rod, established in 1980, has a reported dynamic height of 597.99 feet at 45 degrees latitude. NGS Vertical Datum Transformation software (VDatum) was used to adjust for the hydraulic corrections for the project location based upon the latitude and longitude positions in the NGS datasheet for station "A 319". Confirmation of the elevation, relative to IGLD 1985, of the control stations was performed by benching into the water level on a calm day with minimal wave activity and comparing that value to the water level station data retrieved from NOAA's Great Lakes Online website: *www.glakesonline.nos.noaa.gov/monitor.html* for station #9063063 (Cleveland).

With the horizontal and vertical control network established, recovery of boundary evidence was performed. Monumentation found and held as controlling stations included a 5/8- inch iron pin at the southwest corner of Sub Lot 5 and another at the southeast corner of Sub Lot 6. Subsequent points were located along the north right of way of West Lake Road within the Water's Edge Subdivision, and proration of any surplus was calculated and applied to the subject parcels in the final determination of the boundary lines. A topographic survey was performed that located the cultural (i.e. buildings, survey monuments, coastal structures) and natural (i.e. top and toe of bluff) features on the subject parcel and adjoiners. Notwithstanding the presence of random rubble along the shore on the east portion of the upland parcel, the natural shoreline appears to be unaltered by artificially placed fill material.

Analysis

Parcel data provided by the Erie County Auditor's Office was imported into the computer-aided design (CAD) drawing to establish a general orientation of the shoreline for a reach of approximately 1.5 kilometers. Methodology for partitioning the boundaries between the littoral adjoiners was examined including extending the upland parcel boundary lakeward without deflection and a radial projection from the general alignment of the 1.5 kilometer reach of shore from the intersection of the natural shoreline and the parcel sidelines. The radial projection method provided the most equitable distribution between the subject parcel and the east and west adjoiners.

A base map was provided to the engineering consultant that depicted the locations of the existing site improvements relative to the established parcel boundaries and littoral partitions. A general statement that the survey and plat were prepared t in conformity with Ohio Administrative Code (OAC.) Section 4733-37 was included and the Ohio registered professional surveyor's signature and seal were affixed to the plat of survey (see Existing Site Plan "A").

Design

Design specifications and details are identified on the following design example drawings and supported by the included design calculations.

In order to improve lake access at the project site while still providing adequate shore protection a portion of the existing armor stone revetment is to be removed and replaced with a seawall constructed with stone filled cribbing. The existing revetment spans both parcels of the site property and is approximately 208 linear feet long. Four steel crib units are proposed. Each crib will be 16 feet long and 10 feet wide. The cribs are to be placed just west of the center of the project site with 3 cribs on the west parcel and 1 on the east parcel.

The proposed seawall is intended to maintain existing erosion protection while providing access to the waters of Lake Erie for swimming and small watercraft. Therefore the cap elevation of the seawall is to be set at 576 feet IGLD 1985 based on the structure's recreational function rather than wave run up and overtopping. The structure will be placed on bedrock at an elevation of 569.8 feet IGLD 1985. The cribs are to be placed as far into the revetment as possible to minimize the overall footprint of the structure. In this case, the cribs are recessed into the revetment so that the seawall cap meets the armor layer. The armor stone removed from the revetment will be retained and used as fill for the cribs.

The steel cribs will replace the toe stone and must be large enough to prevent sliding failures in the armor layer of the revetment. The trench left from excavating the revetment toe stone will be filled with ODOT 601 Type "B" stone as scour protection for the seawall. The vertical piles of the crib are to be set 1.5 feet into bedrock and grouted in place. In the area of the toe stone, the pile will be set 1.5 feet below the toe trench.

The 30-year return period design water level for this site is 575.5 feet IGLD 1985 as listed in the "Revised Report on Great Lakes Open Coast Flooding" (USACE 1988). At the 30-year design water level the water depth at the base of the seawall will be 5.7 feet. Based on the breaking wave equation, a design wave height of 4.4 feet can be calculated.

With the design water level just 0.3 feet below the seawall cap elevation, it is clear that the seawall will be severely overtopped by 4.4-foot waves. The intended use of the seawall for lake access necessitates the low crest elevation of the structure. Overtopping during storm conditions is acceptable as the recreational intent of the structure limits its use during severe storms. The risk of overtopping is minimal as the existing 2 to 4 ton armor stone revetment continues behind the seawall to an elevation of 582 feet IGLD 1985. Additionally, the existing ODOT 601 Type "B" stone splash apron extends to an elevation of 585 feet IGLD 1985. A 10-inch thick reinforced concrete cap is specified for the seawall to withstand overtopping forces.

In order to confirm the external stability of the seawall it must be checked for both sliding and overturning. Due to the variable water levels and wave forces expected at the site, a minimum of two design cases must be considered for the steel crib. In this example, the stability is assessed both at low water with no waves and at the design water level with the design wave height. This ensures the design is acceptable as a retaining structure for the armor stone revetment and is capable of withstanding significant hydrodynamic loads.

It is assumed that the stone filled crib and revetment are porous structures and that water passes through. In this case hydrostatic forces are the same on all sides of the structure and the resultant hydrostatic force is limited to the buoyancy of the submerged portion of the structure.

Case 1 – Low Water

In this case, the following forces will act on the structure: gravity, earth forces, reactive forces, and friction.

The force of gravity is determined by estimating the total weight of the structure's cross section. A total of 56.3 tons was calculated for each 16-foot long by 10-foot wide crib. A structure weight of 3.5 tons per foot will be used in the design. The assumed low water level of 569.2 feet IGLD 1985 is below the base of the structure. Hydrostatic and buoyant forces will not affect this design case.

In the absence of other vertical forces the normal reactive force is equal to the structure weight. If a minimum angle of internal friction of 35 degrees is assumed, friction forces can be estimated at 2.5 tons per linear foot of structure.

In most cases soil borings are suggested to determine actual physical properties at the test site. For this design example, the bedrock beneath the revetment and seawall is assumed to be capable of supporting the structures with minimal settling. A 110 lb/ft3 unit weight is assumed for the backfill. Based on the 26.6 degree revetment slope and 35 degree angle of internal friction, an active pressure coefficient of 0.43 is calculated. Earth forces are estimated at 0.4 tons per foot of structure.

The pile resistance to sheer load is estimated using the rigid analysis described in International Building Code 1805.72. This method results in a minimal estimate for pile resistive forces and provides a more conservative design than balancing active and passive earth forces on a steel pile fixed in bedrock. The rigid pile analysis conservatively estimates pile resistance at 13 lbs per linear foot of structure.

The earth force due to retaining the existing revetment is the only anti-stabilizing force. Friction and the resistance on the pile are stabilizing forces in this design case. The factor of safety for sliding stability is the ratio of stabilizing to anti-stabilizing forces. A factor of safety of 6.1 was calculated for the low water case.

To verify the seawall will be stable against overturning, moments are calculated about the structure toe. A 5-foot moment arm was assumed for the center of gravity and a 2.1-foot moment arm was assumed for the center of pressure for the earth forces. Friction and pile resistance forces were

assumed to act at the base of the structure with zero moment arms. This results in a 17.6 ft-tons stabilizing moment per linear foot of structure and a 0.9 ft-tons per linear foot anti-stabilizing moment. A factor of safety of 20.6 was calculated for the low water case.

The ability of the steel crib to retain the revetment can also easily be checked by comparing the weight of the steel crib to the weight of the existing revetment toe stone. The steel crib weighs approximately 3.5 ton per linear foot. The 4 to 5 ton toe stone will be approximately 4 to 4.5 feet in diameter weighing only 1.25 tons per linear foot.

Case 2 – Design Water Level and Wave Height

In this case, the following forces will act on the structure: gravity, earth forces, normal reactive forces, friction, wave uplift, and horizontal wave forces.

The force of gravity is determined in the same method as the low water case (3.5 tons per linear foot of structure). However, in this case the normal reactive force will be reduced by buoyancy and the vertical wave uplift forces. Based on the 5.9-foot structure depth, 10-foot structure width and assuming 30 percent porosity, 1.2 tons per linear foot of buoyant force is estimated.

Several methods are commonly used to predict the forces due to waves. In this design example, a method described in the USACE Coastal Engineering Manual is used. Wave forces are calculated based on the Goda Formula for irregular waves modified to include impulsive forces from breaking waves. This method was adapted to the geometry of the proposed seawall. In particular the calculations have been simplified based on the exclusion of a rubble foundation in the design and the assumptions that Bm = 0 and hs = d = h' (water depth at toe of structure is the same as water depth in front of structure).

It should be noted that this method assumes a vertical impermeable structure. It does not take into account the dissipation of wave energy within the matrix of the stone inside the crib or the transmission of wave energy through the crib to the existing revetment. This method will provide a considerably conservative design.

The Goda method predicts a free surface height 6.7 feet above the design water level at the wave crest. Wave pressures are calculated at 225 lb/ft2 at the base of the structure, 262 lb/ft2 at the design water level and 242 lb/ft2 at the crest of the structure. Wave uplift pressures are also estimated at 221 lb/ft2. Based on these pressures, the total horizontal wave force is estimated to be approximately 0.7 tons per linear foot of structure and the wave uplift force is estimated to be approximately 0.4 tons per linear foot of structure.

The 26.6 degree revetment slope and 35 degree angle of internal friction is used to calculate a passive earth pressure coefficient of 2.34 for the backfill. Earth forces are estimated at 1.7 tons per foot of structure. Pile resistive forces are estimated to be similar to the low water design case: 13 lbs per linear foot of structure.

The resultant normal force is calculated from the structure weight, buoyancy and wave uplift forces (1.8 tons/ft). Friction is estimated at 1.3 tons per linear foot assuming a 35 degree internal angle of friction.

A total of 3.0 tons per foot of stabilizing forces (friction + earth forces + pile resistance) and 0.7 tons per foot of anti-stabilizing (wave) forces were calculated. This results in a factor of safety of 4.5 against sliding.

To verify overturning, stability moments are calculated about the structure heel. Assuming a 5-foot moment arm for the center of gravity and a 2.1-foot moment arm for the center of pressure for the earth forces results in a total stabilizing moment of 21.3 ft-tons per linear foot of structure. Assuming a 3.8-foot moment arm for the center of pressure of the horizontal wave forces and a 6.7-foot moment arm for the center of pressure of the wave uplift force results in a total anti-stabilizing moment of 5.4 ft-tons per linear foot of structure. A factor of safety of 3.9 is calculated for overturning stability.

The steel crib should be designed to ensure it has sufficient flexural strength to resist the forces expected in its design life. The design should be checked using Load and Resistance Factor Design methods (AISC Manual of Steel Construction).

Discussion

The proposed steel crib seawall will extend approximately 28 feet from the pre-revetment location of the bluff toe. The proposed seawall will extend nearly to the toe of the existing revetment but will result in a slight reduction of the overall structure footprint.

Generally, vertical structures increase the wave energy in the nearshore zone due to wave reflection. The use of stone filled cribbing will limit the reflection of energy as a significant portion of the wave energy will be dissipated within the crib or allowed to pass over the crib to the revetment. The placement of the crib completely within the footprint of the existing revetment effectively isolates the new construction and will limit its effect on adjacent properties.

Final Survey Products

Based upon the design from the Ohio registered professional engineer, a plat that depicted the boundaries of the submerged lands lease was prepared. The project site includes two separate parcels, but a lot consolidation has not been planned by the parcel owner. Therefore, two separate lease parcels are depicted using the location of the water's edge on the date of the field survey as the natural shoreline (see Submerged Lands Plat "B").

Two metes and bounds descriptions have been written for the areas depicted on the plat of survey with direct relationship to the upland parcel boundaries as required in Ohio Revised Code Section 1506.11(B) (see Submerged Lands Lease Descriptions for Parcel "A" and "B").

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO. 1 OF 10
CALCULATED BY MPC DATE 02/01/11
CHECKED BY DLB DATE 02/01/11
SCALE

SEAWALL DESIGN

A. DESIGN WATER LEVEL

30 YEAR DESIGN WATER LEVEL = 575.5 FT IGLD 1985
REFERENCE: "REVISED REPORT ON GREAT LAKES OPEN COAST FLOODING" USACE, 1988.

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE
LAKE BOTTOM ELEVATION = 569.8 FEET IGLD 1985
STRUCTURE DEPTH = d_s = 575.5 FT - 569.8 FT = 5.7 FT IGLD 1985
BREAKING WAVE HEIGHT = $H_b = 0.78 \times d_s = 0.78 \times 5.7$ FT = 4.4 FT
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, PAGE II-4-3.

C. CONCRETE CAP HEIGHT/OVERTOPPING

WAVE CREST ELEVATION = DWL + 0.7 H_b
= 575.5 FT + 0.7 (4.4 FT) = 578.6 FT IGLD 1985

SET CONCRETE CAP ELEVATION TO 576.0 FT IGLD 1985 TO PROVIDE ACCESS TO THE WATERS OF LAKE ERIE. THE INTENDED USE OF THE CRIB REQUIRES A LOW CREST ELEVATION. OVERTOPPING DURING STORM CONDITIONS IS ACCEPTABLE AS THE RECREATIONAL INTENT OF THE STRUCTURE LIMITS ITS USE DURING SEVERE STORMS.

OVERTOPPING WILL BE ACCOMMODATED WITH EXISTING ARMOR STONE REVETMENT ABOVE THE SEAWALL CREST ELEVATION.

D. EXTERNAL STABILITY

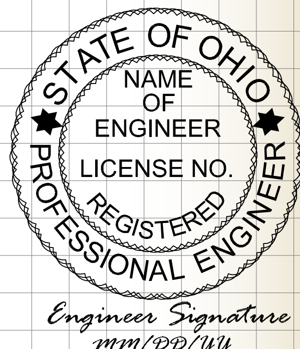
CONSIDER 2 DESIGN CASES:

1. WATER AT MEAN LOW LEVEL
2. DESIGN WATER LEVEL AND WAVE HEIGHT

CASE 1: LOW WATER (WATER LEVEL AT 569.2 FT IGLD 1985)

DETERMINE FORCES:

I STRUCTURE CROSS SECTION WEIGHT
II EARTH FORCES
III NORMAL FORCE
IV FRICTION



Engineer Signature
MM/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
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JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO.: 2 OF 10
CALCULATED BY: MPC DATE: 02/01/11
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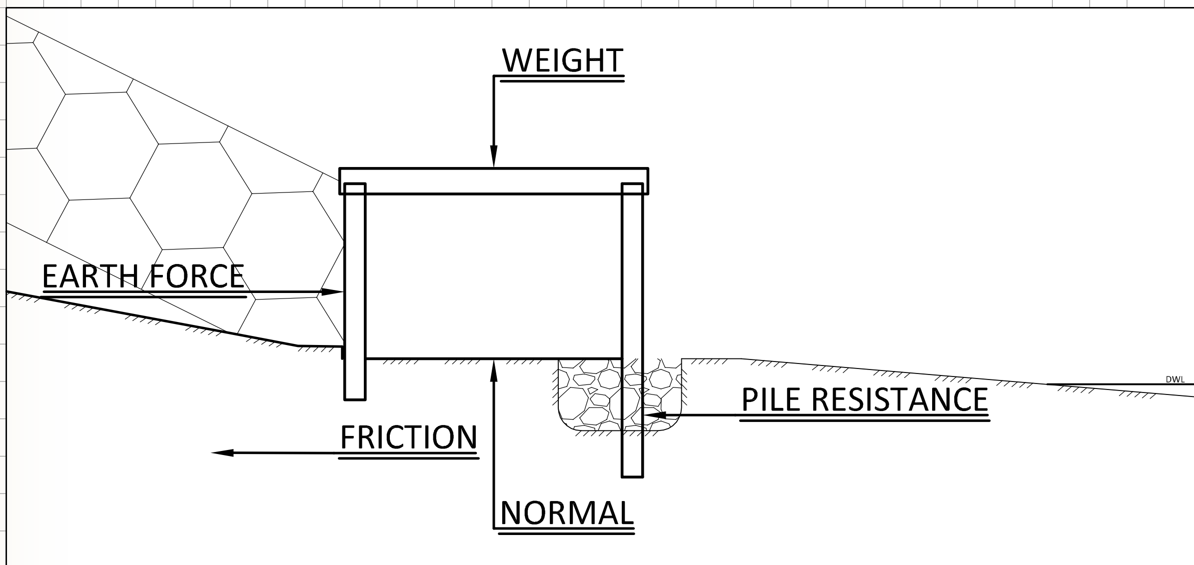
SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 1



1 STRUCTURE CROSS SECTION WEIGHT

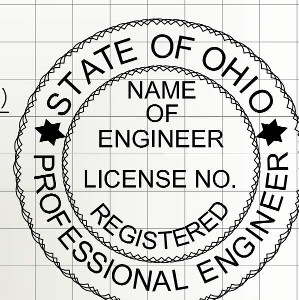
COMPONENT	L (FT)	W/L (LB/FT)	WEIGHT (LB)	NO.	WEIGHT (LB)
LONG PILES	9.5	20	190	2	380
SHORT PILES	7	20	140	2	280
COLUMN TUBES	7	37.6	263	4	1053
TRANS. FRAMES	8.3	20	167	4	667
LONG. FRAMES	14.7	20	293	4	1173
TRANS. RIBS	8.3	12.2	102	6	610
LONG. RIBS	14.7	12.2	179	6	1074
FLOORS	9.0	7.3	65	7	455
CROSS BRACES	8.7	9.7	85	4	339
BRACKETS	1.3	14.9	20	2	40

COMPONENT	L (FT)	W/L (LB/FT)	WEIGHT (LB)	NO.	WEIGHT (LB)
TRANS. REBAR	9.7	1.0	10	32	323
LONG. REBAR	15.7	1.0	16	20	327

COMPONENT	L (FT)	W (FT)	H (FT)	V (FT^3)	S (LB/FT^3)	WEIGHT (LB)
CONC. CAP	16	10	0.8	133	145	19333
STONE FILL*	16	10	5.3	256	145	86613

*FILL VOLUME INCLUDES 30 PERCENT REDUCTION FOR POROSITY

TOTAL STRUCTURE WEIGHT = 112666 LB = 56.3 TON
WEIGHT PER LINEAR FOOT = 7042 LB/FT = 3.5 TON/FT



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SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 1

II EARTH FORCES

$FE = \frac{1}{2} \gamma \, hw^2 \, Ka \, COS \, \beta$

β = SLOPE OF BACKFILL = 26.6 DEGREES
hw = OVERALL HEIGHT OF STRUCTURE = 6.2 FT
γ = UNIT WEIGHT OF BACKFILL = 110 LB/FT^3 (FROM SOIL SAMPLES)
ϕ = ANGLE OF INTERNAL FRICTION OF BACKFILL = 35 DEGREES (FROM SOIL SAMPLES)

Ka = ACTIVE EARTH COEFFICIENT

$$Ka = COS\,\beta \left(\frac{COS\,\beta - \sqrt{COS^2\beta - COS^2\phi}}{COS\,\beta + \sqrt{COS^2\beta - COS^2\phi}}\right)$$ RANKINE THEORY

REFERENCE: "USS STEEL SHEET PILING DESIGN MANUAL" US STEEL, 1984.

$$Ka = COS\,(26.6°) \left(\frac{COS\,(26.6°) - \sqrt{COS^2(26.6°) - COS^2(35°)}}{COS\,(26.6°) + \sqrt{COS^2(26.6°) - COS^2(35°)}}\right) = 0.43$$

$FE = \frac{1}{2}$ (110 LB/FT^3) (6.2 FT)^2 (0.43) (COS 26.6) = 813 LB/FT = 0.4 TON/FT

PILE RESISTANCE TO SHEAR LOAD

USE RIGID ANALYSIS (REFERENCE: INTERNATIONAL BUILDING CODE 1805.7.2)

Dmin, Z = DEPTH OF EMBEDMENT = 1.5 FT
S3 = ALLOWABLE SOIL PRESSURE = 400Z = 600 LB/FT^2
B = DIAMETER (WIDTH) OF FOUNDATION = 0.5 FT
H = DISTANCE TO SHEAR LOAD = 3 FT (ASSUMED 1/2 CRIB HEIGHT)
V = Dmin^2*S3*B / 4.25*H = 53 LB PER PILE

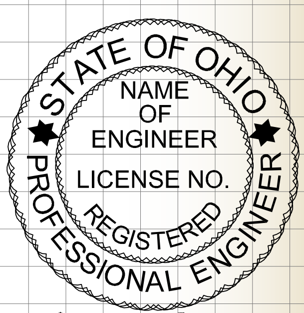
AVERAGE SHEAR LOAD / FOOT OF STRUCTURE = (53 LB/PILE * 4 PILES)/16 FEET = 13 LB/FT

III NORMAL FORCE = WEIGHT = 7042 LB/FT = 3.5 TON/FT

IV FRICTION

ANGLE OF INTERNAL FRICTION, α = 35 DEGREES (FROM SOIL SAMPLES)
COEFFICIENT OF STATIC FRICTION, μ = TAN α = 0.7

FRICTION = N μ = (7042 LB/FT)(0.7) = 4929 LB/FT = 2.5 TON/FT



Engineer Signature
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SAMPLE ENGINEERING AND SURVEYING INC.
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JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO. 4 OF 10
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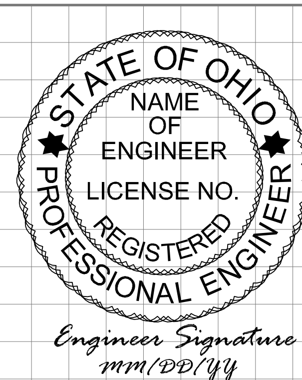

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 1

SLIDING STABILITY

STABILIZING FORCES = FRICTION + PILE RESISTANCE = 4942 LB/FT

ANTI-STABILIZING FORCES = EARTH FORCES = 813 LB/FT

FACTOR OF SAFETY = STABILIZING FORCES / ANTI-STABILIZING FORCES

FACTOR OF SAFETY = (4942 LB/FT) / (813 LB/FT) = 6.1

OVERTURNING STABILITY - CALCULATE MOMENTS ABOUT STRUCTURE TOE

STABILIZING MOMENTS

STRUCTURE WEIGHT = 7042 LB/FT
MOMENT ARM = 5 FT
STABILIZING MOMENT = 35210 FT-LB/FT = 17.6 FT-TON/FT

ANTI-STABILIZING MOMENTS

EARTH FORCES = 813 LB/FT
MOMENT ARM = 2.1 FT
ANTI-STABILIZING MOMENT = 1707 FT-LB/FT = 0.9 FT-TON/FT

FACTOR OF SAFETY = STABILIZING / ANTI-STABILIZING

FACTOR OF SAFETY = (35210 FT-LB/FT) / (1707 FT-LB/FT) = 20.6

CASE 2: DESIGN WATER LEVEL AND WAVE HEIGHT

DETERMINE FORCES:
I STRUCTURE CROSS SECTION WEIGHT
II WAVE FORCES
III EARTH FORCES
IV HYDROSTATIC (BUOYANT) FORCES
V NORMAL FORCE (RESULTANT)
VI FRICTION

DESIGN ASSUMPTIONS:

- WATER LEVEL IS CONSTANT THROUGH CRIB, HYDROSTATIC FORCES = 0
- RESULTANT STRUCTURE WEIGHT IS REDUCED BY BUOYANCY.

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JOB EXAMPLE E - CRIB SEAWALL
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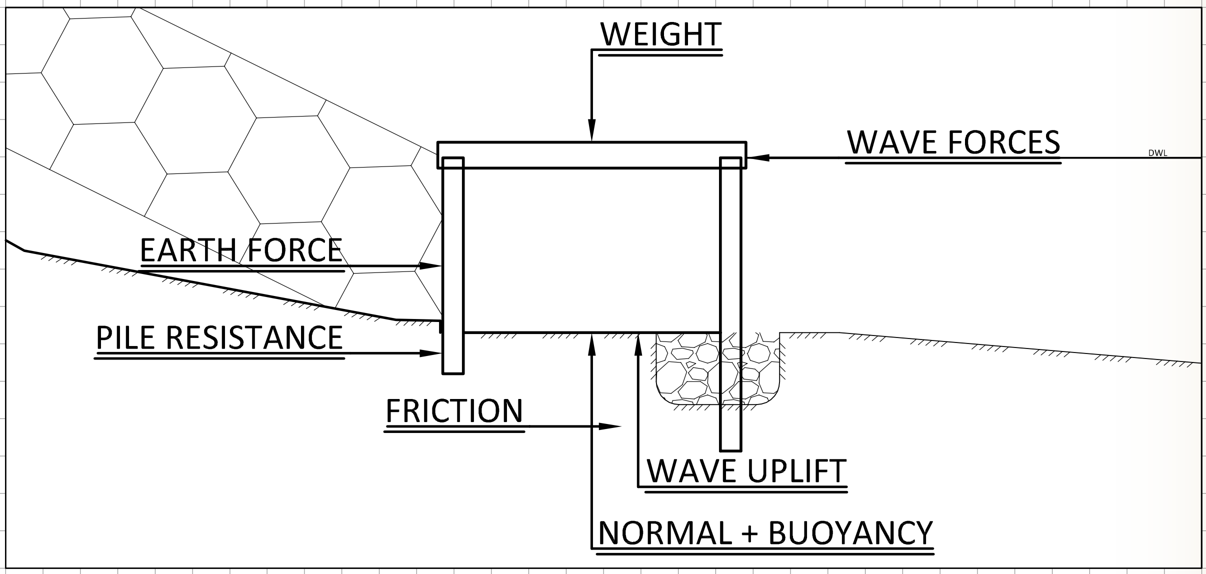
SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2



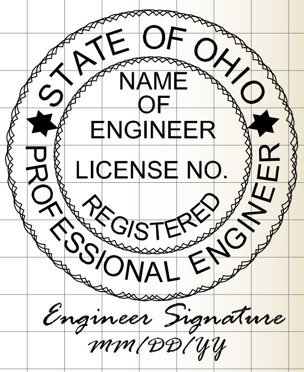
I STRUCTURE WEIGHT

TOTAL STRUCTURE WEIGHT = 7042 LB/FT = 3.5 TON/FT (PREVIOUSLY CALCULATED)

II WAVE FORCES

WAVE FORCE CALCULATION BASED ON GODA FORMULA FOR IRREGULAR WAVES MODIFIED TO INCLUDE IMPULSIVE FORCES FROM HEAD ON BREAKING WAVES AND ADAPTED TO THE GEOMETRY OF THE PROPOSED SEAWALL.
REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 1996, TABLES VI-5-53, 54 & 55.

DEFINITIONS:
P1 = WAVE PRESSURE AT DESIGN WATER LEVEL
P2 = WAVE PRESSURE AT WAVE/SEAWALL CREST HEIGHT
P3 = WAVE PRESSURE AT BASE OF SEAWALL
Pu = WAVE UPLIFT PRESSURE AT BASE OF SEAWALL
η^* = WAVE CREST HEIGHT
hs = DEPTH OF STRUCTURE TOE = 5.7 FT
d = WATER DEPTH AT TOE OF STRUCTURE = 5.7 FT
h' = TOTAL DEPTH OF STRUCTURE = 5.7 FT
β = ANGLE OF INCIDENCE OF DESIGN WAVES = 0 DEGREES
Hdesign = DESIGN WAVE HEIGHT = Hb = 4.4 FT
hw = OVERALL HEIGHT OF STRUCTURE = 6.2 FT
hc = HEIGHT OF STRUCTURE ABOVE DWL = 0.5 FT
Bm = WIDTH OF RUBBLE FOUNDATION = 0
Ts = WAVE PERIOD = 4.5 SECONDS (ASSUMED FOR 4.4 FT WAVE)



SAMPLE ENGINEERING AND SURVEYING INC.
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JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO.: 6 OF 10
CALCULATED BY: MPC DATE: 02/01/11
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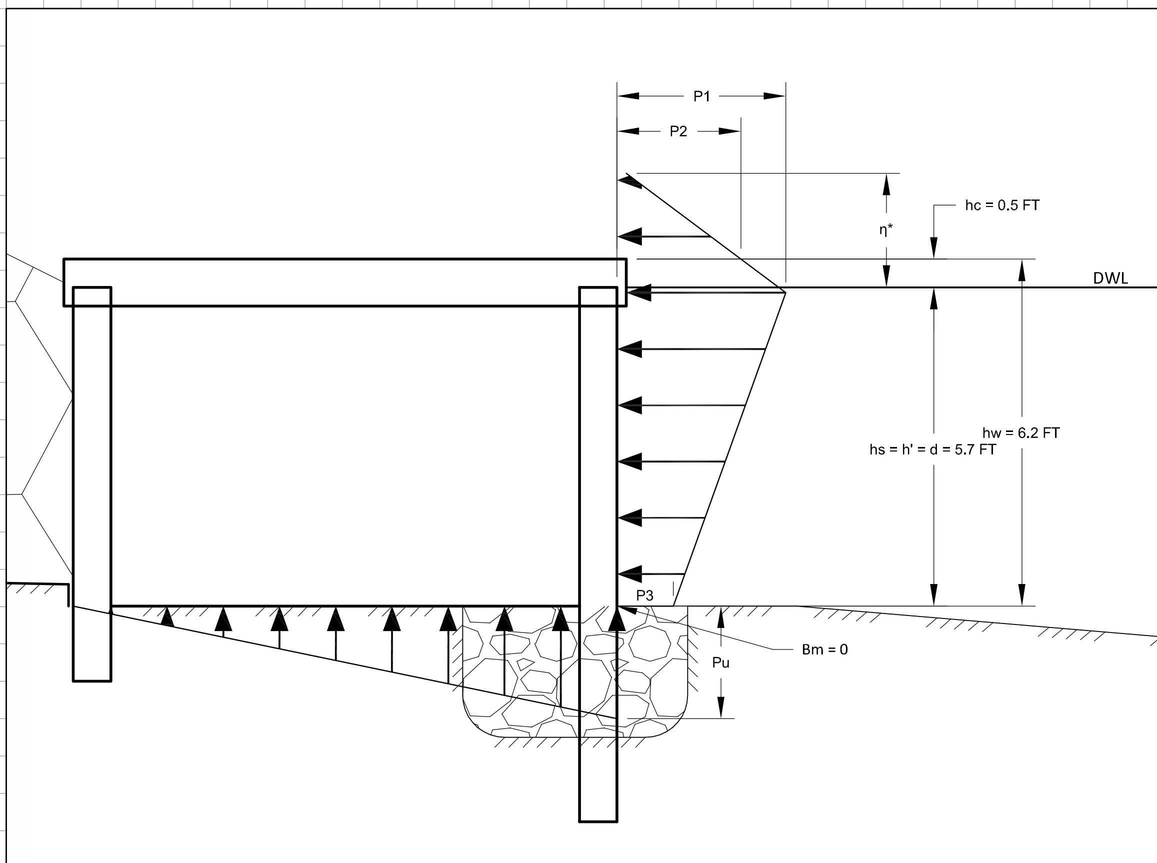
SCALE:

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2



hb = WATER DEPTH AT A DISTANCE 5 X Hdesign FROM SEAWALL

$= hs + 5 \times H_{design} \times \tan\phi = 5.7\text{ FT} + 5 \times 4.4\text{ FT} \times \tan(1°) = 6.1\text{ FT}$

L = WAVELENGTH AT WATER DEPTH hb $= T_s\sqrt{g\,hb} = (4.5\text{ S})\sqrt{(32.2\text{ FT/S}^2 \times 6.1\text{ FT})} = 63.1\text{ FT}$

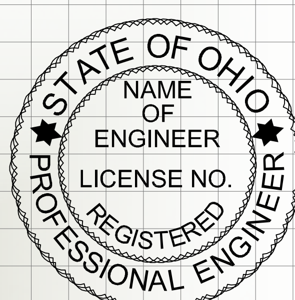
DETERMINE MODIFICATIONS TO GODA FORMULA

$$\delta 22 = -0.36\left(\frac{Bm}{L} - 0.12\right) + 0.93\left(\frac{hs - d}{hs} - 0.6\right) = -0.51$$

$$\delta 2 = \begin{cases} 4.9 \times \delta 22 & \text{FOR } \delta 22 \le 0 \\ 3 \times \delta 22 & \text{FOR } \delta 22 > 0 \end{cases} \qquad \delta 2 = 4.9 \times -0.51 = -2.52$$

$$\delta 11 = 0.93\left(\frac{Bm}{L} - 0.12\right) + 0.36\left(\frac{hs - d}{hs} - 0.6\right) = -0.33$$

$$\delta 1 = \begin{cases} 20 \times \delta 11 & \text{FOR } \delta 11 \le 0 \\ 15 \times \delta 11 & \text{FOR } \delta 11 > 0 \end{cases} \qquad \delta 1 = 20 \times -0.33 = -6.55$$



Engineer Signature
MM/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO. 7 OF 10
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SCALE

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

$$\alpha 11 = \begin{cases} \cos\delta 2 / \cosh\delta 1 & \text{FOR } \delta 2 \le 0 \\ 1/(\cosh\delta 1 \times \sqrt{\cosh\delta 2}) & \text{FOR } \delta 2 > 0 \end{cases}$$

$\alpha 11 = 0.018$

$$\alpha 10 = \begin{cases} H_{design} / d & \text{FOR } H_{design} / d \le 2 \\ 2.0 & \text{FOR } H_{design} / d > 2 \end{cases}$$

$\alpha 10 = 0.78$

$\alpha 1 = \alpha 10 \times \alpha 11 = 0.014$

$\alpha 2$ = SMALLER OF:

$\alpha 2 = 0.013$

$$\frac{h_b - d}{3h_b}\left(\frac{H_{design}}{d}\right)^2 = 0.013$$

AND

$$\frac{2d}{H_{design}} = 2.56$$

α^* = LARGER OF $\alpha 1$ AND $\alpha 2$ = 0.014

STRUCTURE TYPE MODIFICATION FACTORS

$\lambda 1 = \lambda 2 = \lambda 3 = 1.0$ FOR CONVENTIONAL VERTICAL WALL STRUCTURES

DETERMINE PRESSURE COEFFICIENTS FOR GODA FORMULA

$\alpha^* = 0.014$ (MODIFIED α^* FOR IMPULSIVE FORCES)

$$\alpha 1 = 0.6 + 0.5\left(\frac{4\pi h_s / L}{\sinh(4\pi h_s / L)}\right)^2 = 0.93$$

$\alpha 2 = 0.013$ (SAME AS ABOVE)

$$\alpha 3 = 1 - \frac{h_w - h_c}{h_s}\left(1 - \frac{1}{\cosh(2\pi h_s / L)}\right) = 0.86$$

CALCULATE WAVE PRESSURES

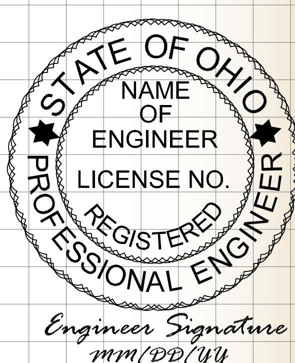
$\eta^* = 0.75\,(1 + \cos\beta)\,\lambda 1\, H_{design} = 6.7$ FT

$P1 = 0.5\,(1 + \cos\beta)\,(\lambda 1 \alpha 1 + \lambda 2\, \alpha^* \cos^2\beta)\,\rho_w\, g\, H_{design} = 262$ LB/FT²

$$P2 = \begin{cases} (1 - h_c/\eta^*)\, P1 & \text{FOR } \eta^* > h_c \\ 0 & \text{FOR } \eta^* \le h_c \end{cases}$$

P2 = 242 LB/FT²

$P3 = \alpha 3\, P1 = 225$ LB/FT²



$PU = 0.5\,(1 + \cos\beta)\,\lambda 3\, \alpha 1\, \alpha 3\, \rho_w\, g\, H_{design} = 221$ LB/FT²

SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	JOB	EXAMPLE E - CRIB SEAWALL	
	SHEET NO. 8	OF 10	
	CALCULATED BY MPC	DATE 02/01/11	
	CHECKED BY DLB	DATE 02/01/11	
	SCALE		

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

DETERMINE LEVELS OF UNCERTAINTY

FOR HORIZONTAL FORCE, UFH = 0.90

FOR UPLIFT FORCE, UFU = 0.77

FOR HORIZONTAL MOMENT, UMH = 0.81

FOR UPLIFT MOMENT, UMU = 0.72

REFERENCE: "COASTAL ENGINEERING MANUAL" USACE, 2006, TABLE VI-5-55.

CALCULATE WAVE FORCES PER LINEAR FOOT OF STRUCTURE

HORIZONTAL WAVE FORCE, $FH = UFH\left(\frac{1}{2}(P1+P2)hc + \frac{1}{2}(P1+P3)h'\right) = 1362$ LB/FT = 0.7 TON/FT

WAVE UPLIFT FORCE, $FU = UFU \times \frac{1}{2}PU \times B = 853$ LB/FT = 0.4 TON/FT

B = 10 FT WIDTH OF STRUCTURE CROSS SECTION

III EARTH FORCES

$$FE = \frac{1}{2}\gamma hc^2 Kp \cos\beta$$

β = SLOPE OF BACKFILL = 26.6 DEGREES

ϕ = ANGLE OF INTERNAL FRICTION OF BACKFILL = 35 DEGREES (FROM SOIL SAMPLES)

Kp = PASSIVE EARTH COEFFICIENT

$$Kp = \cos\beta\left(\frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}\right)$$ RANKINE THEORY

REFERENCE: "USS STEEL SHEET PILING DESIGN MANUAL" US STEEL, 1984.

$$Kp = \cos(26.6°)\left(\frac{\cos(26.6°) + \sqrt{\cos^2(26.6°) - \cos^2(35°)}}{\cos(26.6°) - \sqrt{\cos^2(26.6°) - \cos^2(35°)}}\right) = 2.34$$

ABOVE DESIGN WATERLINE

γ = UNIT WEIGHT OF BACKFILL = 110 LB/FT^3

hc = HEIGHT OF STRUCTURE ABOVE DWL = 0.5 FT

$FE\,1 = \frac{1}{2}(110\text{ LB/FT}^3)(0.5\text{ FT})^2(2.34)(\cos 26.6) = 29$ LB/FT

BELOW DESIGN WATERLINE

γ = UNIT WEIGHT OF BACKFILL = 101 LB/FT^3 (SATURATED)

hs = DEPTH OF STRUCTURE TOE = 5.7 FT

$FE\,2 = \frac{1}{2}(101\text{ LB/FT}^3)(5.7\text{ FT})^2(2.34)(\cos 26.6) = 3433$ LB/FT

PILE RESISTANCE TO SHEAR LOAD (PREVIOUSLY CALCULATED)

AVERAGE SHEAR LOAD PER FOOT OF STRUCTURE = 13 LB/FT

TOTAL EARTH FORCES = 3475 LB/FT = 1.7 TON/FT

Engineer Signature
mm/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB EXAMPLE E - CRIB SEAWALL
SHEET NO. 9 OF 10
CALCULATED BY MPC DATE 02/01/11
CHECKED BY DLB DATE 02/01/11
SCALE

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

IV HYDROSTATIC (BUOYANT) FORCES

Fbuoyant = γw hs B (1-P)

γw = UNIT WEIGHT OF WATER = 62.4 LB/FT^3
hs = WATER DEPTH AT TOE OF STRUCTURE = 5.7 FT
B = WIDTH OF STRUCTURE = 10 FT
P = POROSITY = 0.3

Fbuoyant = 2490 LB/FT = 1.2 TON/FT

IV RESULTANT NORMAL FORCE

RESULTANT VERTICAL FORCE, N = WEIGHT - WAVE UPLIFT - BUOYANCY

N = 7042 LB/FT - 853 LB/FT - 2490 LB/FT = 3699 LB/FT = 1.8 TON/FT

VI FRICTION
ANGLE OF INTERNAL FRICTION, α = 35 DEGREES (FROM SOIL SAMPLES)
COEFFICIENT OF STATIC FRICTION, μ = TAN α = 0.7

FRICTION = N μ = (3699 LB/FT)(0.7) = 2590 LB/FT = 1.3 TON/FT

SLIDING STABILITY

STABILIZING FORCES = FRICTION + TOTAL EARTH FORCES
STABILIZING = 2590 LB/FT + 3475 LB/FT = 6065 LB/FT = 3.0 TON/FT

ANTI-STABILIZING FORCES = WAVE FORCES = 1362 LB/FT = 0.7 TON/FT

FACTOR OF SAFETY = STABILIZING FORCES / ANTI-STABILIZING FORCES

FACTOR OF SAFETY = (6065 LB/FT) / (1362 LB/FT) = 4.5

OVERTURNING STABILITY - CALCULATE MOMENTS ABOUT STRUCTURE HEEL

STABILIZING MOMENTS

STRUCTURE WEIGHT = 7042 LB/FT
MOMENT ARM = 5 FT
STABILIZING MOMENT = 35210 FT-LB/FT = 17.6 FT-TON/FT

STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER

Engineer Signature
MM/DD/YY

SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS

JOB: EXAMPLE E - CRIB SEAWALL
SHEET NO.: 10 OF: 10
CALCULATED BY: MPC DATE: 02/01/11
CHECKED BY: DLB DATE: 02/01/11
SCALE:

SEAWALL DESIGN (CONT.) - EXTERNAL STABILITY CASE 2

EARTH FORCES = 3475 LB/FT
MOMENT ARM = 2.1 FT
STABILIZING MOMENT = 7298 FT-LB/FT = 3.6 FT-TON/FT

TOTAL STABILIZING MOMENT = 42508 FT-LB/FT = 21.3 FT-TON/FT

ANTI-STABILIZING MOMENTS

HORIZONTAL WAVE FORCE = FH = 1362 LB/FT
MOMENT ARM = 3.8 FT
ANTI-STABILIZING MOMENT = 5176 FT-LB/FT = 2.6 FT-TON/FT

WAVE UPLIFT FORCE = FU = 853 LB/FT
MOMENT ARM = 6.7 FT
ANTI-STABILIZING MOMENT = 5715 FT-LB/FT = 2.9 FT-TON/FT

TOTAL ANTI-STABILIZING MOMENT = 10891 FT-LB/FT = 5.4 FT-TON/FT

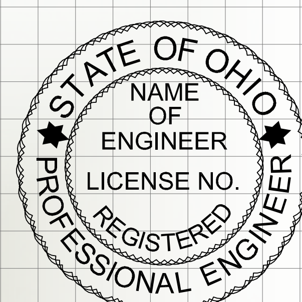
FACTOR OF SAFETY = STABILIZING / ANTI-STABILIZING

FACTOR OF SAFETY = 42508 FT-LB/FT / 10891 FT-LB/FT = 3.9

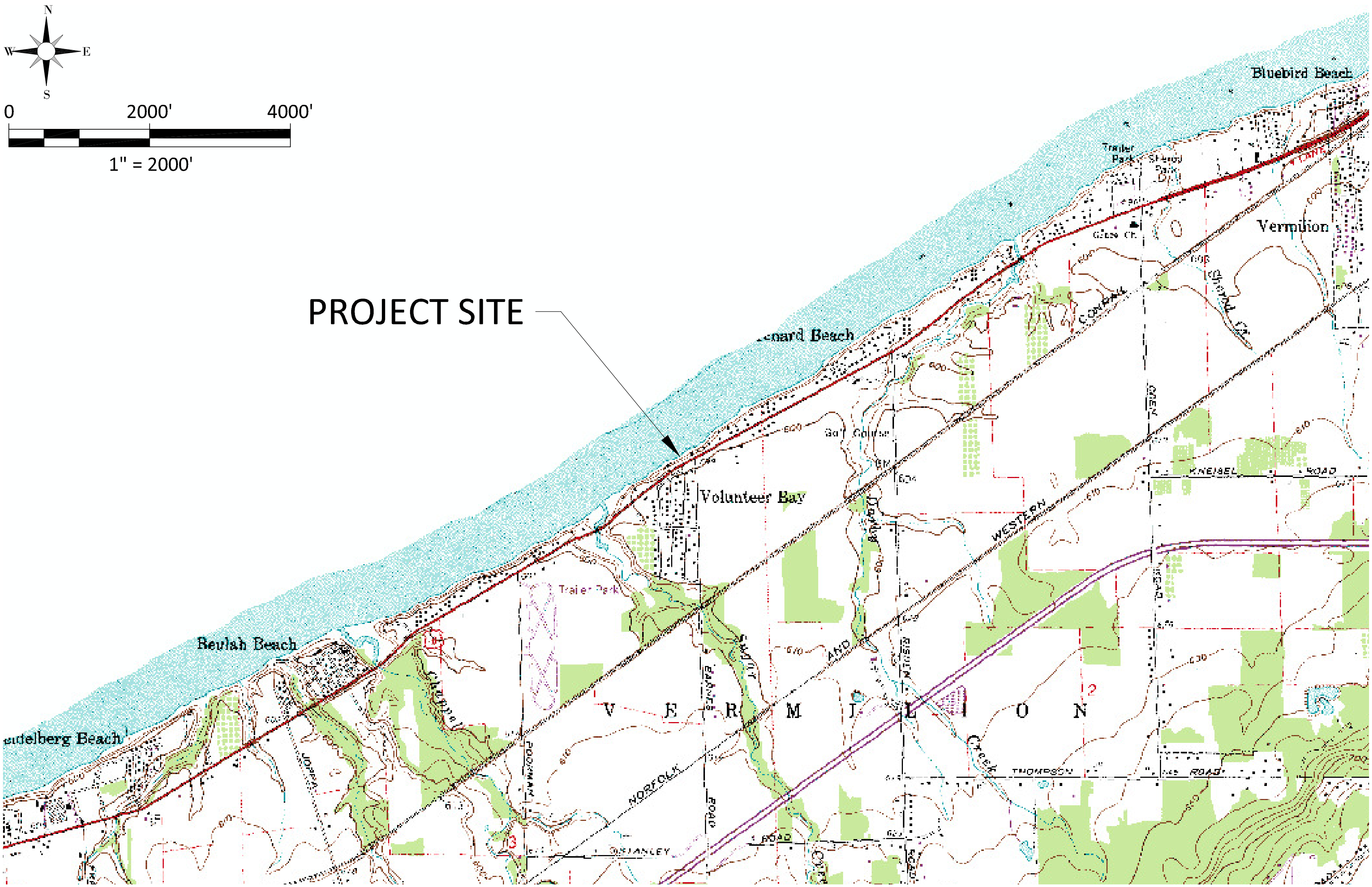
E. INTERNAL STABILITY

CHECK CRIB STRUCTURAL MEMBERS BASED ON LOAD AND RESISTANCE FACTOR DESIGN
PLEASE REFER TO AISC MANUAL OF STEEL CONSTRUCTION

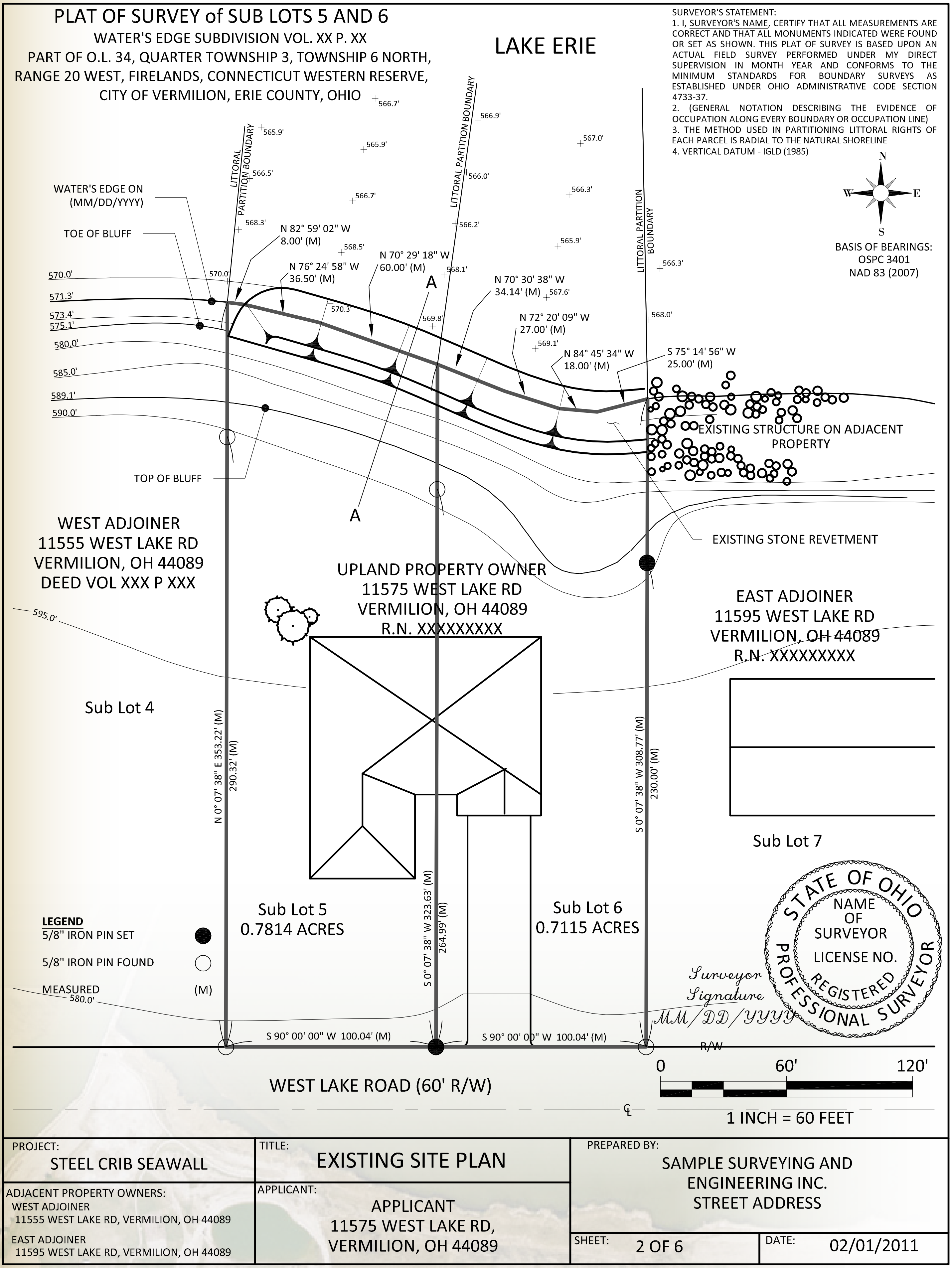
*NOTE: THE CALCULATIONS INCLUDED IN THIS EXAMPLE WERE ORIGINALLY COMPUTED USING EXCEL SPREADSHEETS. THE SOFTWARE DISPLAYS A SPECIFIED NUMBER OF SIGNIFICANT FIGURES BUT RETAINS THE ORIGINAL NUMBER FOR OPERATIONS. AS A RESULT SMALL ROUNDING ERRORS ARE INTRODUCED IN TRANSCRIBING THE STEP-BY-STEP CALCULATIONS. THESE ERRORS ARE ACCEPTABLE CONSIDERING THE OVERALL ACCURACY OF THE CALCULATION METHODS AND THE PURPOSE OF THIS DESIGN MANUAL.

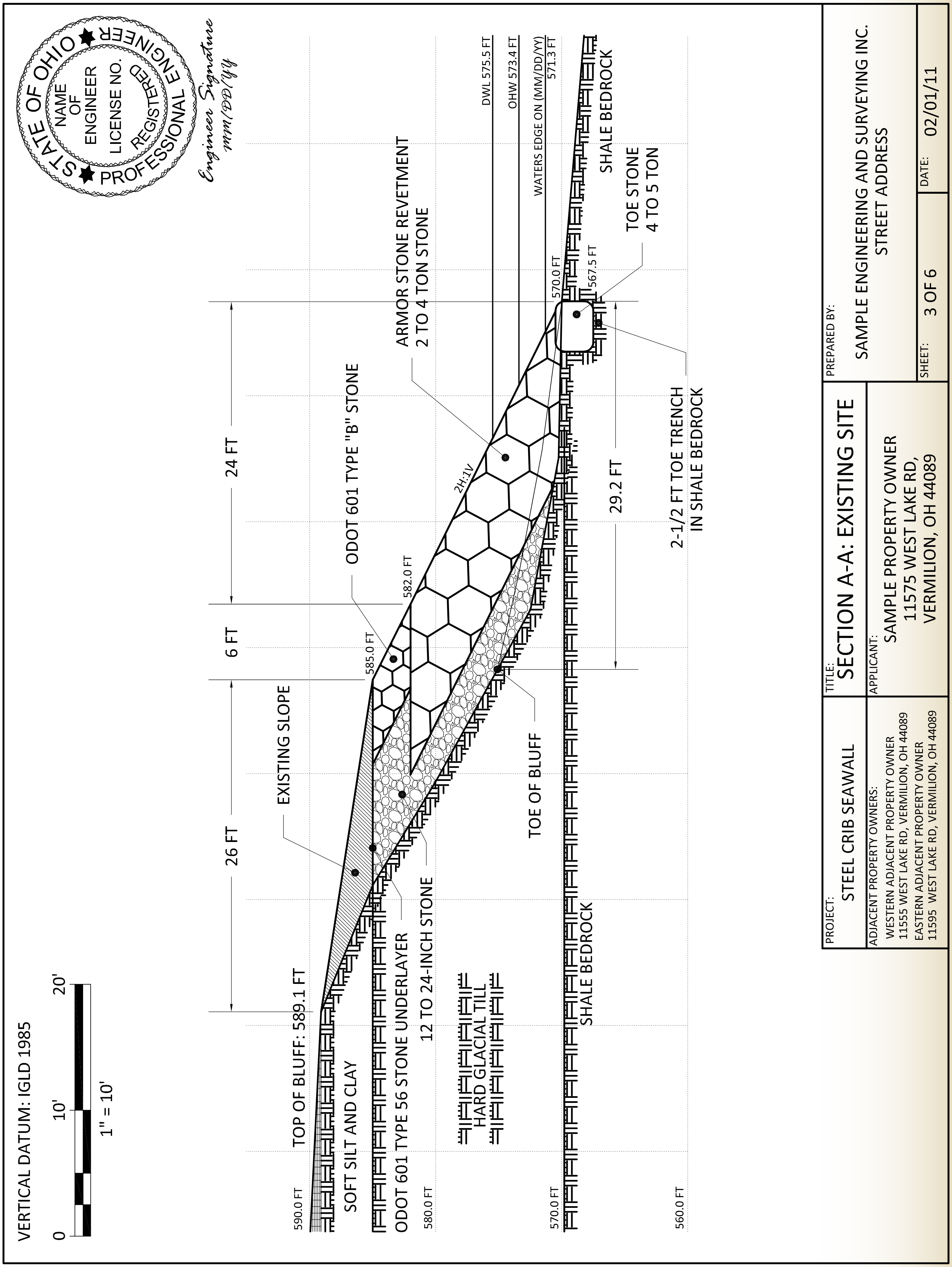


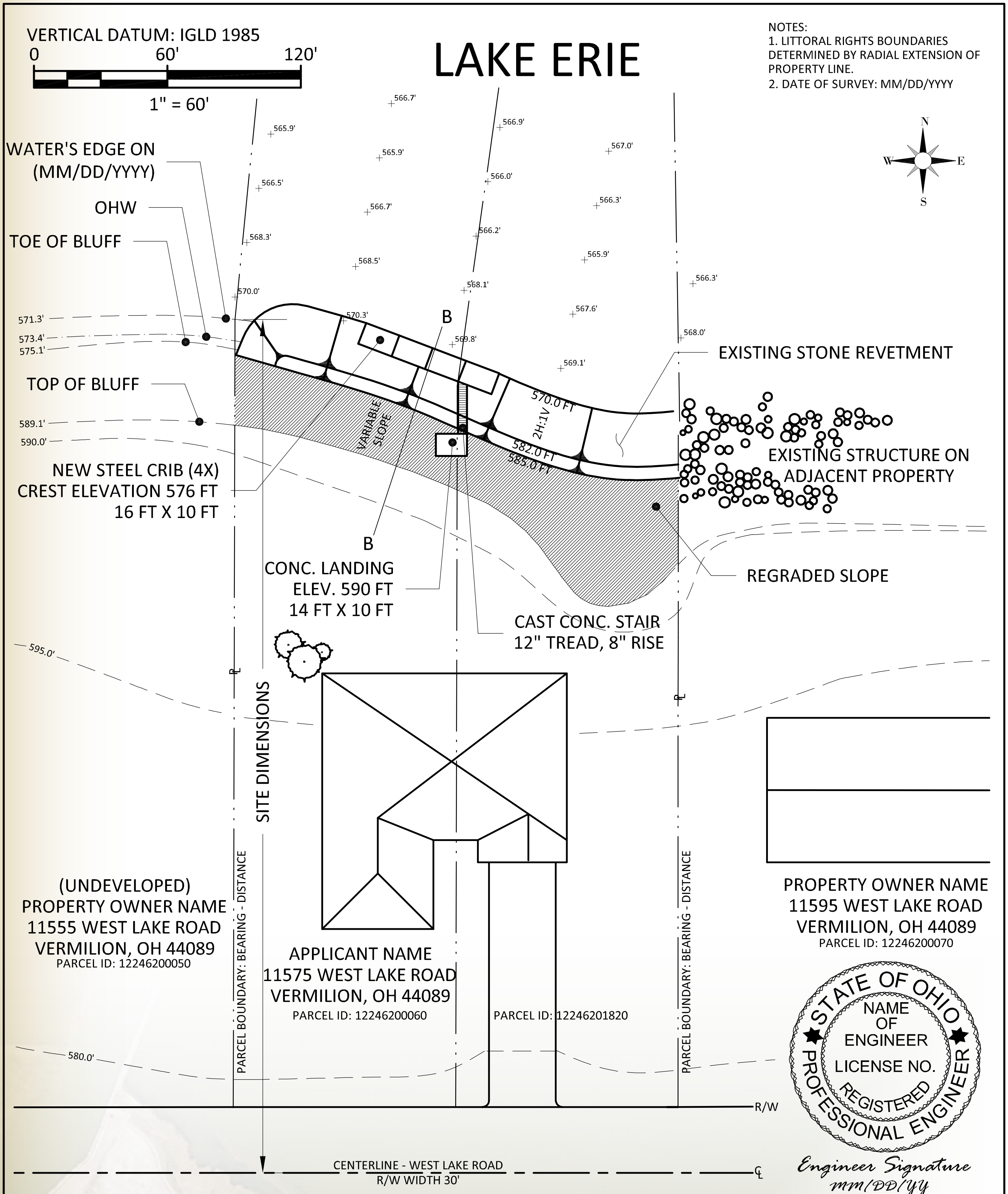
Engineer Signature
MM/DD/YY



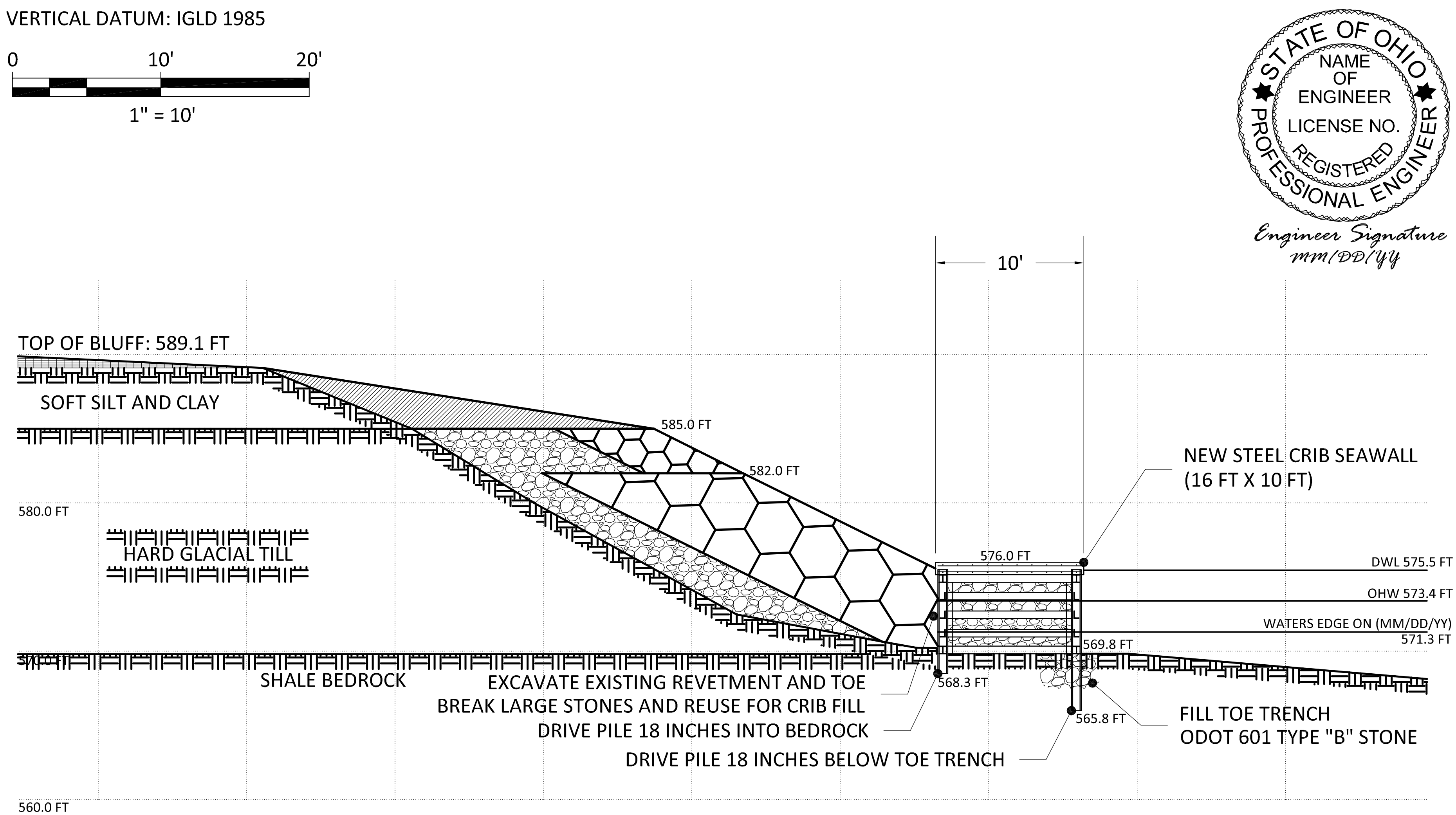
PROJECT: STEEL CRIB SEAWALL	TITLE: VICINITY MAP	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS	
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 1 OF 6	DATE: 02/01/11


PLAT OF SURVEY of SUB LOTS 5 AND 6
WATER'S EDGE SUBDIVISION VOL. XX P. XX
PART OF O.L. 34, QUARTER TOWNSHIP 3, TOWNSHIP 6 NORTH,
RANGE 20 WEST, FIRELANDS, CONNECTICUT WESTERN RESERVE,
CITY OF VERMILION, ERIE COUNTY, OHIO
LAKE ERIE
SURVEYOR'S STATEMENT:
1. I, SURVEYOR'S NAME, CERTIFY THAT ALL MEASUREMENTS ARE CORRECT AND THAT ALL MONUMENTS INDICATED WERE FOUND OR SET AS SHOWN. THIS PLAT OF SURVEY IS BASED UPON AN ACTUAL FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION IN MONTH YEAR AND CONFORMS TO THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS ESTABLISHED UNDER OHIO ADMINISTRATIVE CODE SECTION 4733-37.
2. (GENERAL NOTATION DESCRIBING THE EVIDENCE OF OCCUPATION ALONG EVERY BOUNDARY OR OCCUPATION LINE)
3. THE METHOD USED IN PARTITIONING LITTORAL RIGHTS OF EACH PARCEL IS RADIAL TO THE NATURAL SHORELINE
4. VERTICAL DATUM - IGLD (1985)
N
W
E
S
BASIS OF BEARINGS:
OSPC 3401
NAD 83 (2007)
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
LITTORAL PARTITION BOUNDARY
566.7'
565.9'
565.9'
566.9'
567.0'
566.5'
566.0'
566.7'
566.3'
568.3'
566.2'
565.9'
568.5'
568.1'
566.3'
570.0'
570.3'
567.6'
569.8'
568.0'
569.1'
WATER'S EDGE ON (MM/DD/YYYY)
TOE OF BLUFF
N 82° 59' 02" W 8.00' (M)
N 76° 24' 58" W 36.50' (M)
N 70° 29' 18" W 60.00' (M)
N 70° 30' 38" W 34.14' (M)
N 72° 20' 09" W 27.00' (M)
N 84° 45' 34" W 18.00' (M)
S 75° 14' 56" W 25.00' (M)
A
A
570.0'
571.3'
573.4'
575.1'
580.0'
585.0'
589.1'
590.0'
EXISTING STRUCTURE ON ADJACENT PROPERTY
TOP OF BLUFF
EXISTING STONE REVETMENT
WEST ADJOINER
11555 WEST LAKE RD
VERMILION, OH 44089
DEED VOL XXX P XXX
UPLAND PROPERTY OWNER
11575 WEST LAKE RD
VERMILION, OH 44089
R.N. XXXXXXXXX
EAST ADJOINER
11595 WEST LAKE RD
VERMILION, OH 44089
R.N. XXXXXXXXX
595.0'
Sub Lot 4
N 0° 07' 38" E 353.22' (M)
290.32' (M)
S 0° 07' 38" W 308.77' (M)
230.00' (M)
Sub Lot 7
S 0° 07' 38" W 323.63' (M)
264.99' (M)
Sub Lot 5
0.7814 ACRES
Sub Lot 6
0.7115 ACRES
STATE OF OHIO
NAME OF SURVEYOR
LICENSE NO.
REGISTERED
PROFESSIONAL SURVEYOR
Surveyor Signature
MM/DD/YYYY
LEGEND
5/8" IRON PIN SET
5/8" IRON PIN FOUND
MEASURED (M)
580.0'
S 90° 00' 00" W 100.04' (M)
S 90° 00' 00" W 100.04' (M)
R/W
0
60'
120'
WEST LAKE ROAD (60' R/W)
℄
1 INCH = 60 FEET
PROJECT:
STEEL CRIB SEAWALL
TITLE:
EXISTING SITE PLAN
PREPARED BY:
SAMPLE SURVEYING AND ENGINEERING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WEST ADJOINER
11555 WEST LAKE RD, VERMILION, OH 44089
EAST ADJOINER
11595 WEST LAKE RD, VERMILION, OH 44089
APPLICANT:
APPLICANT
11575 WEST LAKE RD,
VERMILION, OH 44089
SHEET:
2 OF 6
DATE:
02/01/2011


VERTICAL DATUM: IGLD 1985
0
10'
20'
1" = 10'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
MM/DD/YY
590.0 FT
580.0 FT
570.0 FT
560.0 FT
TOP OF BLUFF: 589.1 FT
SOFT SILT AND CLAY
ODOT 601 TYPE 56 STONE UNDERLAYER
12 TO 24-INCH STONE
HARD GLACIAL TILL
SHALE BEDROCK
26 FT
6 FT
24 FT
EXISTING SLOPE
TOE OF BLUFF
585.0 FT
582.0 FT
ODOT 601 TYPE "B" STONE
ARMOR STONE REVETMENT
2 TO 4 TON STONE
2H:1V
29.2 FT
2-1/2 FT TOE TRENCH
IN SHALE BEDROCK
570.0 FT
567.5 FT
TOE STONE
4 TO 5 TON
SHALE BEDROCK
DWL 575.5 FT
OHW 573.4 FT
WATERS EDGE ON (MM/DD/YY)
571.3 FT
PROJECT:
STEEL CRIB SEAWALL
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
11555 WEST LAKE RD, VERMILION, OH 44089
EASTERN ADJACENT PROPERTY OWNER
11595 WEST LAKE RD, VERMILION, OH 44089
TITLE:
SECTION A-A: EXISTING SITE
APPLICANT:
SAMPLE PROPERTY OWNER
11575 WEST LAKE RD,
VERMILION, OH 44089
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
SHEET:
3 OF 6
DATE:
02/01/11

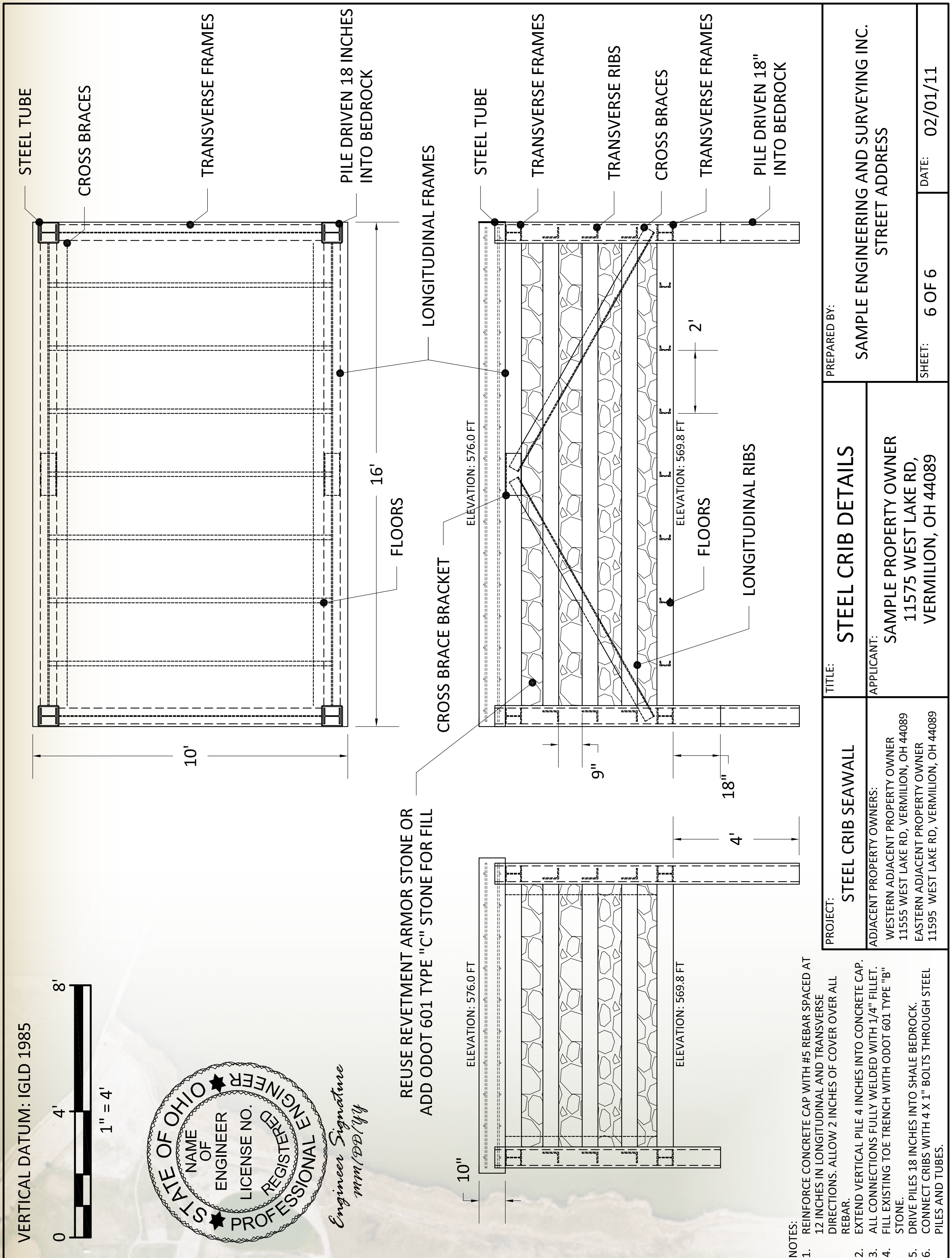


PROJECT: STEEL CRIB SEAWALL	TITLE: PROPOSED SITE PLAN	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 4 OF 6 / DATE: 02/01/11



NOTES:
1. REINFORCE CONCRETE CAP WITH #5 REBAR SPACED AT 12 INCHES IN LONGITUDINAL AND TRANSVERSE DIRECTIONS. ALLOW 2 INCHES OF COVER OVER ALL REBAR.
2. EXTEND VERTICAL PILE 4 INCHES INTO CONCRETE CAP.
3. ALL CONNECTIONS FULLY WELDED WITH 1/4" FILLET.
4. FILL EXISTING TOE TRENCH WITH ODOT 601 TYPE "B" STONE.
5. DRIVE PILES 18 INCHES INTO SHALE BEDROCK.
6. CONNECT CRIBS WITH 4 X 1" BOLTS THROUGH STEEL PILES AND TUBES.

PROJECT: STEEL CRIB SEAWALL	TITLE: SECTION B-B: PROPOSED SITE	PREPARED BY: SAMPLE ENGINEERING AND SURVEYING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WESTERN ADJACENT PROPERTY OWNER 11555 WEST LAKE RD, VERMILION, OH 44089 EASTERN ADJACENT PROPERTY OWNER 11595 WEST LAKE RD, VERMILION, OH 44089	APPLICANT: SAMPLE PROPERTY OWNER 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 5 OF 6 DATE: 02/01/11


VERTICAL DATUM: IGLD 1985
0
4'
8'
1" = 4'
STATE OF OHIO
NAME OF ENGINEER
LICENSE NO.
REGISTERED
PROFESSIONAL ENGINEER
Engineer Signature
mm/dd/yy
STEEL TUBE
CROSS BRACES
TRANSVERSE FRAMES
PILE DRIVEN 18 INCHES INTO BEDROCK
LONGITUDINAL FRAMES
FLOORS
16'
10'
STEEL TUBE
TRANSVERSE FRAMES
TRANSVERSE RIBS
CROSS BRACES
TRANSVERSE FRAMES
PILE DRIVEN 18" INTO BEDROCK
2'
ELEVATION: 576.0 FT
ELEVATION: 569.8 FT
CROSS BRACE BRACKET
FLOORS
LONGITUDINAL RIBS
9"
18"
REUSE REVETMENT ARMOR STONE OR ADD ODOT 601 TYPE "C" STONE FOR FILL
4'
10"
ELEVATION: 576.0 FT
ELEVATION: 569.8 FT
NOTES:
1. REINFORCE CONCRETE CAP WITH #5 REBAR SPACED AT 12 INCHES IN LONGITUDINAL AND TRANSVERSE DIRECTIONS. ALLOW 2 INCHES OF COVER OVER ALL REBAR.
2. EXTEND VERTICAL PILE 4 INCHES INTO CONCRETE CAP.
3. ALL CONNECTIONS FULLY WELDED WITH 1/4" FILLET.
4. FILL EXISTING TOE TRENCH WITH ODOT 601 TYPE "B" STONE.
5. DRIVE PILES 18 INCHES INTO SHALE BEDROCK.
6. CONNECT CRIBS WITH 4 X 1" BOLTS THROUGH STEEL PILES AND TUBES.
PROJECT:
STEEL CRIB SEAWALL
TITLE:
STEEL CRIB DETAILS
PREPARED BY:
SAMPLE ENGINEERING AND SURVEYING INC.
STREET ADDRESS
ADJACENT PROPERTY OWNERS:
WESTERN ADJACENT PROPERTY OWNER
11555 WEST LAKE RD, VERMILION, OH 44089
EASTERN ADJACENT PROPERTY OWNER
11595 WEST LAKE RD, VERMILION, OH 44089
APPLICANT:
SAMPLE PROPERTY OWNER
11575 WEST LAKE RD,
VERMILION, OH 44089
SHEET:
6 OF 6
DATE:
02/01/11

Lake Erie Submerged Lands Legal Description Parcel "A"
Adjacent to 11575 West Lake Road, Vermilion

Situate in the State of Ohio and located within the waters of Lake Erie, County of Erie, City of Vermilion, part of Original Lot 34, Quarter Township 3, Township 6 North, Range 20 West of the Firelands portion of the Connecticut Western Reserve, adjacent to the Water's Edge Subdivision, Sub Lot 5 as recorded in Plat Volume (XX), Page (XX) of said county records and being adjacent to a parcel of land conveyed to (NAME OF UPLAND OWNER) by Record Number (XXXXXXXXX) of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin set at the southeast corner of Sub Lot 5 of Water's Edge Subdivision, said point also being the southwest corner of Sub Lot 6 conveyed to (NAME OF EAST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the east line of said Sub Lot 5, also being the west line of Sub Lot 6, North 00 degrees, 07 minutes, 38 seconds East, 323.63 feet to a point on the natural shoreline as determined by a field survey on (DATE) not monumented due to the location on the submerged lands of Lake Erie, and passing for reference a 5/8 inch solid iron pin found at 264.99 feet, also being the northeast corner of said Sub Lot 5 and the northwest corner of said Sub Lot 6, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said Sub Lot 5, across the open waters of Lake Erie, along the littoral partition boundary between said Sub Lot 5 and said Sub Lot 6 as determined by radial means, North 07 degrees, 57 minutes, 10 seconds East, 12.50 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence across the open waters of Lake Erie, North 70 degrees, 32 minutes, 59 seconds West, 79.34 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 69 degrees, 03 minutes, 43 seconds West, 16.00 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 41 degrees, 49 minutes, 55 seconds West, 6.00 feet to a point not monumented due to location on submerged lands of Lake Erie, also being the location of said natural shoreline;

Thence along said natural shoreline, South 76 degrees, 24 minutes, 58 seconds East, 36.50 feet to a point not monumented due to location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, South 70 degrees, 29 minutes, 18 seconds East, 60.00 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 1135 square feet (0.0260 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: Determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)

Lake Erie Submerged Lands Legal Description Parcel "B"
Adjacent to 11575 West Lake Road, Vermilion

Situate in the State of Ohio and located within the waters of Lake Erie, County of Erie, City of Vermilion, part of Original Lot 34, Quarter Township 3, Township 6 North, Range 20 West of the Firelands portion of the Connecticut Western Reserve, adjacent to the Water's Edge Subdivision, Sub Lot 6 as recorded in Plat Volume (XX), Page (XX) of said county records and being adjacent to a parcel of land conveyed to (NAME OF UPLAND OWNER) by Record Number (XXXXXXXXX) of said county and being more particularly described as follows:

Commencing at a 5/8 inch solid iron pin set at the southwest corner of Sub Lot 6 of Water's Edge Subdivision, said point also being the southeast corner of Sub Lot 5 conveyed to (NAME OF WEST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the west line of said Sub Lot 6, also being the east line of said Sub Lot 5, North 00 degrees, 07 minutes, 38 seconds East, 323.63 feet to a point on the natural shoreline of Lake Erie as determined by a field survey on (DATE) not monumented due to location on submerged lands of Lake Erie, and passing for reference a 5/8 inch solid iron pin found at 264.99 feet, also being the northwest corner of said Sub Lot 6 and the northeast corner of said Sub Lot 5, said point being the True Point of Beginning of the Lease Property described;

Thence departing the north line of said Sub Lot 6, across the open waters of Lake Erie, along the littoral partition boundary between said Sub Lot 5 and said Sub Lot 6 as determined by radial means, North 07 degrees, 57 minutes, 10 seconds East, 12.50 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence across the open waters of Lake Erie, South 68 degrees, 06 minutes, 27 seconds East, 52.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, South 77 degrees, 36 minutes, 38 seconds East, 25.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing across the open waters of Lake Erie, North 84 degrees, 22 minutes, 58 seconds East, 25.65 feet to a point not monumented due to the location on submerged lands of Lake Erie on the littoral partition boundary as determined by radial means of said Sub Lot 6 and Sub Lot 7 as conveyed to (NAME OF EAST ADJOINER) by Record Number (XXXXXXXXX);

Thence along the littoral partition boundary between said Sub Lot 6 and said Sub Lot 7 as determined by radial means, South 00 degrees, 59 minutes, 40 seconds East, 5.00 feet to a point not monumented due to location on submerged lands of Lake Erie, also being the location of said natural shoreline and the northeast corner of said Sub Lot 6;

Thence along said natural shoreline, South 75 degrees, 14 minutes, 56 seconds West, 25.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, North 84 degrees, 45 minutes, 34 seconds West, 18.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

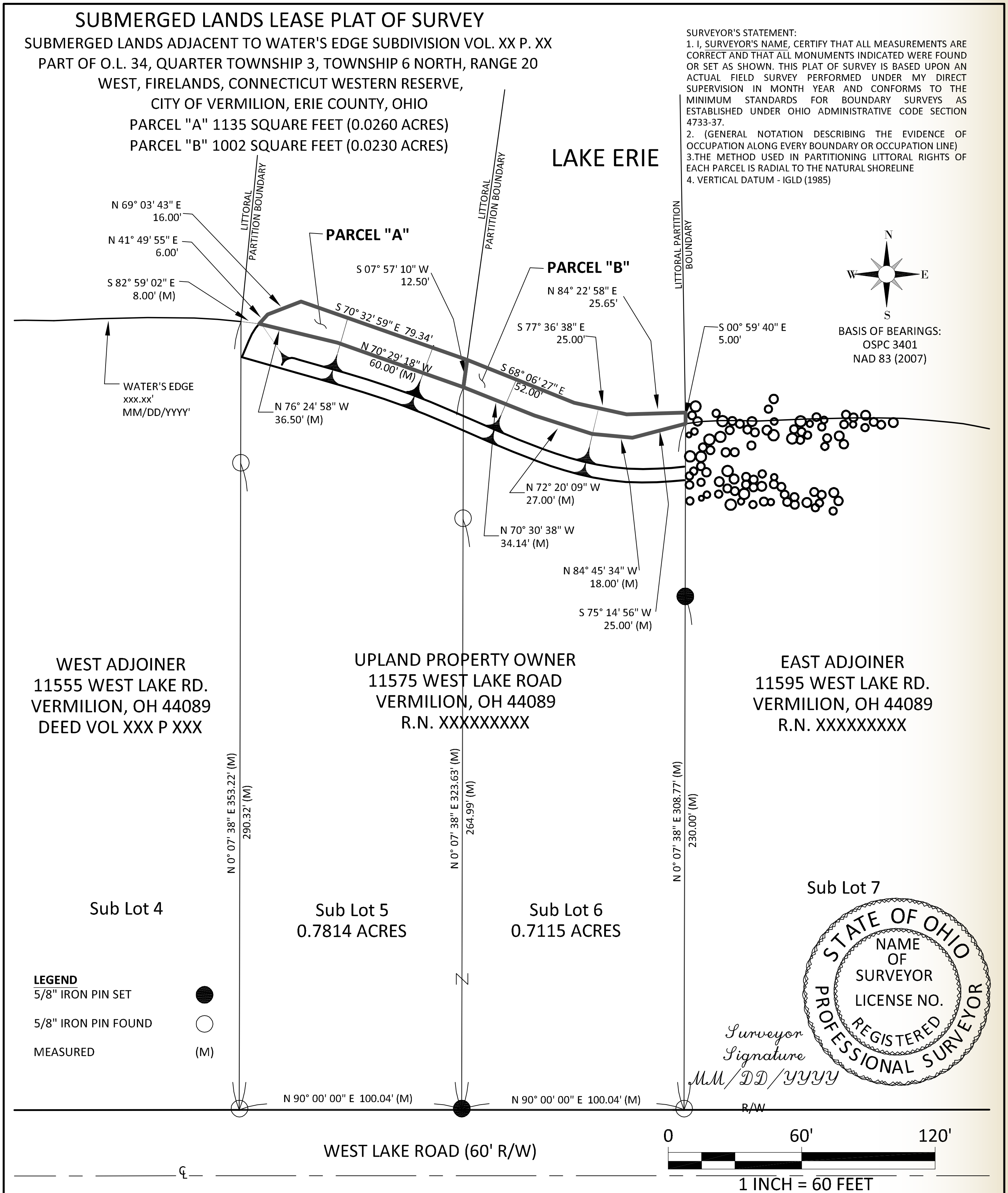
Thence continuing along said natural shoreline, North 72 degrees, 20 minutes, 09 seconds West, 27.00 feet to a point not monumented due to the location on submerged lands of Lake Erie;

Thence continuing along said natural shoreline, North 70 degrees, 30 minutes, 38 seconds West, 34.14 feet to the True Point of Beginning of the submerged parcel herein described. Said parcel contains 1002 square feet (0.0230 acres) more or less and subject to all legal highways, easements, restrictions, and covenants of records. Based on a field survey performed by (NAME OF SURVEYOR), P.S. (#XXXX State of Ohio) performed in (MONTH, YEAR).

Basis of Bearings: Determined by the Ohio State Plane Coordinate System North Zone (3401) NAD 83 (2007).

SEAL

____
(NAME OF SURVEYOR)
Registered Surveyor (#XXXX)



PROJECT: STEEL CRIB SEAWALL	TITLE: SUBMERGED LANDS PLAT	PREPARED BY: SAMPLE SURVEYING AND ENGINEERING INC. STREET ADDRESS
ADJACENT PROPERTY OWNERS: WEST ADJOINER 11555 WEST LAKE ROAD, VERMILION, OH 44089 EAST ADJOINER 11595 WEST LAKE ROAD, VERMILION, OH 44089	APPLICANT: APPLICANT 11575 WEST LAKE RD, VERMILION, OH 44089	SHEET: 1 OF 1 — DATE: 02/01/2011

Ohio Coastal Design Manual: Acknowledgements

The Ohio Coastal Design Manual is a product of the Ohio Department of Natural Resources (ODNR) Office of Coastal Management (OCM). All text, design drawings, design calculations and photographs were written and developed by OCM staff and reviewed by OCM staff and our partners. The valuable contributions of our coastal partners made this document possible.

Contributors *(OCM Staff by Section)*

Coastal Engineering

Deborah Beck, P.E.
Engineering Section Manager, editor
deborah.beck@dnr.state.oh.us

Mark Cencer, P.E.
design drawings, text contributor
mark.cencer@dnr.state.oh.us

Jim Park, P.E.
editor, design drawings, text contributor
james.park@dnr.state.oh.us

Jason Trapp, E.I.T.
document review
jason.trapp@dnr.state.oh.us

Coastal Lands

Patrick M. Ernst, P.S.
Survey Operations Manager, text contributor, editor
patrick.ernst@dnr.state.oh.us

Jarrod Schnell, S.I.
design drawings, document review
jarrod.schnell@dnr.state.oh.us

Anthony Leimeister, S.I.
document review

Timothy Hozalski
document review
timothy.hozalski@dnr.state.oh.us

Coastal Network

Katie Cade
copy editor
katie.cade@dnr.state.oh.us

Coastal Information

Brenda Culler
layout design & editor (print & online)
brenda.culler@dnr.state.oh.us

Contributing Partners

ODNR Division of Soil and Water Resources
Justin Reinhart, P.E.

ODNR Division of Geological Survey
Mark Jones

State of Ohio Attorney General's Office
Nicole Candelora-Norman

ODNR Coastal Resources Advisory Council

Ohio Environmental Protection Agency
Joseph Loucek

Burgess and Niple, Inc.
Mike Jones, P.S.

Matrix Engineering
John Matricardi, P.E.

P.A. Rosebeck & Associates
Phil "Rusty" Rosebeck, P.S.

Learn more:

Ohio Department of Natural Resources
Office of Coastal Management
105 West Shoreline Drive
Sandusky, OH 44870
419.626.7980
coastal@dnr.state.oh.us
www.ohiodnr.com/coastal

Coastal Design Manual Online

www.ohiodnr.com/tabid/23074/default.aspx

Additional online resources:

Ohio Coastal Management Program Document:
www.ohiodnr.com/tabid/9260/default.aspx

Coastal Management Laws and Regulations page:
www.ohiodnr.com/tabid/9281/default.aspx

Coastal Permits and Leases Application:
www.ohiodnr.com/tabid/9295/default.aspx

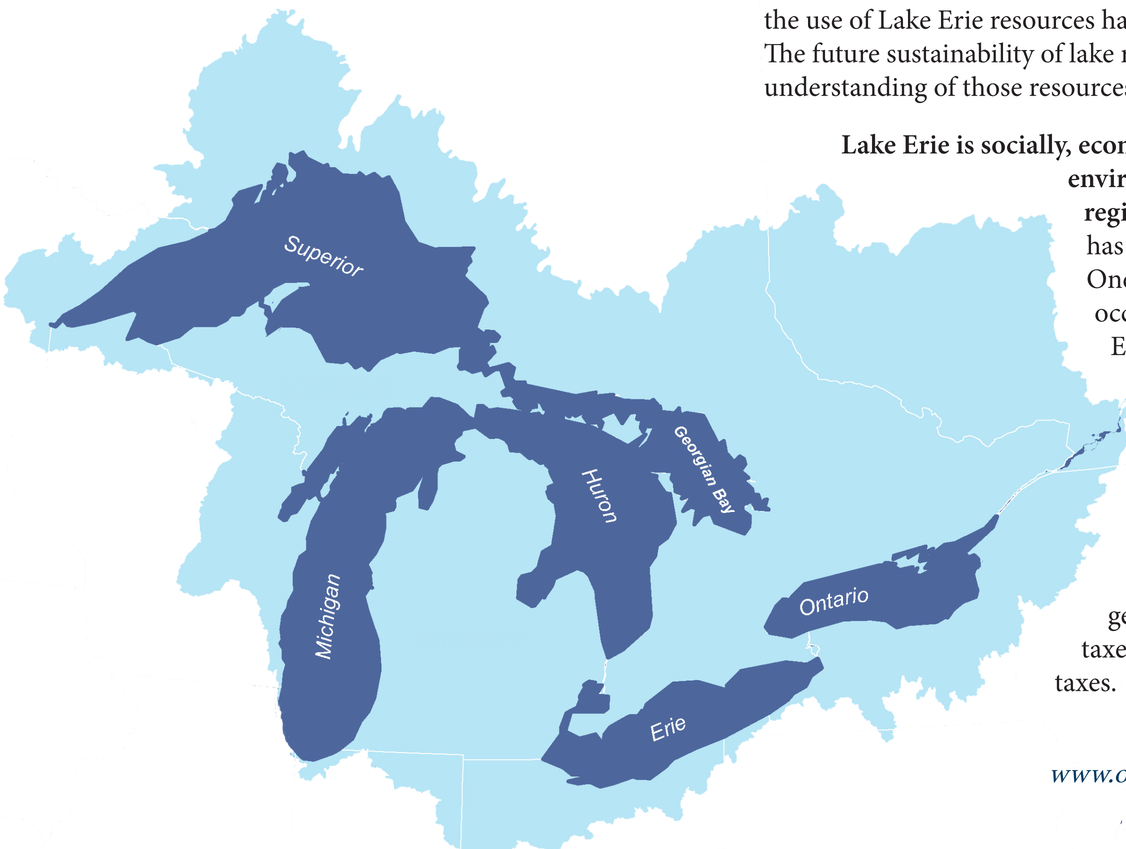
Costal Erosion Area Final 2010 CEA Maps:
www.ohiodnr.com/tabid/22349/default.aspx

Lake Erie Shore Erosion Management Program:
www.ohiodnr.com/tabid/20501/default.aspx

The Ohio Coastal Atlas & GIS including 240-page printed Ohio Coastal Atlas Second Edition, the Interactive Atlas, Use Case Map Viewers, the coastal map library and additional resources:
www.ohiodnr.com/tabid/23320/default.aspx

Ohio Coastal Management Program Grants:*www.ohiodnr.com/tabid/9346/default.aspx*

Ohio's Lake Erie Public Access Guide:
www.ohiodnr.com/tabid/21033/default.aspx



Lake Erie: Our Shared Resource

Lake Erie, one of the five Great Lakes is a body of freshwater with many features. Lake Erie is the shallowest, southernmost, warmest and most biologically diverse of the five Great Lakes.

Natural forces formed and continue to shape Lake Erie and its watershed. The lake's shore continues to change due to wind, wave action and human development.

Lake Erie has a significant influence on regional climate by absorbing, storing and moving heat and water. Lake Erie modifies the local weather and climate because water temperatures change more slowly than land temperatures. Changes in Lake Erie's water circulation, water temperatures and ice cover can produce changes in local weather patterns.

Water makes Earth habitable; fresh water sustains life. Smallest by volume at 127.7 trillion gallons, Erie is the fourth largest Great Lake in total surface area (9,910 sq. mi.) and is the source of daily drinking water for more than 3 million Ohioans.

Lake Erie supports a broad diversity of life and ecosystems. The lake frequently produces more fish for human consumption than the other four Great Lakes combined.

Lake Erie and humans in its watershed are interconnected. Ohio's Lake Erie Watershed covers 11,649 square miles and drains portions of 35 counties. The eight counties along Ohio's 312-mile shore are home to 2.55 million people.

Much remains to be learned about Lake Erie. Over time, the use of Lake Erie resources has changed significantly. The future sustainability of lake resources depends on our understanding of those resources.

Lake Erie is socially, economically and environmentally significant to the region and nation. Ohio's coast has 164 public access locations. One-third of Ohio's boating occurs on Lake Erie. Ohio's Lake Erie ports handle commodities including steel, iron ore, coal, salt and grain. More than 119,000 northern Ohio jobs are directly linked to Lake Erie-region visitors who spend more than $10.7 billion annually generating $430 million in state taxes and $320 million in local taxes.

Learn more:
www.ohiodnr.com/LakeErieLiteracy

Ohio Department of Natural Resources

Office of Coastal Management

www.ohiodnr.com/coastal 419.626.7980