Shabica & Associates, Inc.

Ms. Kathy Chernich
East Section Chief, Regulatory Branch
Chicago District
U.S. Army Corps of Engineers
231 S. LaSalle Street, Suite 1500
Chicago, IL 60604

Dear Ms. Chernich: February 24, 2022, Rev. April 11, 2022

Please find enclosed a permit application for shore protection and sand nourishment for the Elder Lane Park and Centennial Park Shoreline Stabilization Project located at 225 - 299 Sheridan Road, Winnetka, Illinois 60093. This permit application is being submitted by the Park District and Orchard 2020 (current owner of 261 Sheridan Road). The beach at Elder/Centennial is currently in an erosive state and needs updating to its infrastructure to provide a stable more sustainable shoreline amenity for the public. The project design is in-line with the Park District's recently completed *Winnetka Waterfront 2030: Lakefront Master Plan* (WW 2030).

A *Design of Shoreline Erosion Protection* report has been attached to this cover letter as the coastal design specifications component of this permit. All references and figures referred to in the cover letter and the following report can be found in the Appendix.

The proposed activity complies with the approved Illinois Coastal Management Program and will be conducted in a manner consistent with such policies.

Project Purpose Statement

The Winnetka Park District (WPD) retained Shabica & Associates (SA) to consult on improvements to the Elder/Centennial Beach in accordance with the *Winnetka Waterfront 2030: Lakefront Master Plan* (WW 2030). The WW 2030 was officially adopted in 2016 after much community engagement (beginning in 2014) in the form of public meetings, public open houses, surveys, and focus groups, as well as the formation of the Lakefront Advisory Committee (a citizens advisory committee). Community engagement has continued in an ongoing manner. *Winnetka Waterfront 2030: Lakefront Master Plan (LMP) weblink: https://www.winpark.org/park-district-info/plans-projects/waterfront-2030/*

The property owners to the north are aware of and support this project (see attached letters of support). The property owner to the south, Orchard 2020 Revocable Trust (Orchard), also owns 261 Sheridan Road, the home and lot situated between Elder Lane Park and Centennial Park. The WPD and Orchard executed a property exchange agreement in October of 2020 whereupon Orchard will grant title to the home and lot at 261 Sheridan in exchange for an equal width of property at the south end of Centennial Park. This application is jointly submitted by both the Winnetka Park District and Orchard as co-applicants, with the understanding that the permit as requested will not be released until such time as the property exchange is completed.

The project also has the support of several federal and state elected officials including United States Senators Richard J. Durbin and Tammy Duckworth, United States Representative Jan Schakowsky, Illinois Representative Robyn Gabel, and Illinois Senator Laura Fine and the Village of Winnetka (please see attached letters of support).

The beach has functioned typically between average to high water levels but the extreme increase in Lake Michigan water levels from 2013 to 2020 severely damaged the beach and Park District infrastructure. Due to shoreline damage and beach stability concerns, Elder Lane beach has been closed for two years and Centennial Beach has been intermittently closed. Both properties are prioritized by the Park District for restoration starting in the summer of 2022.

The Winnetka Park District website and discussion of the WW 2030 for Elder/Centennial Beach states that the following work will be completed for shore stabilization:

> *"**New breakwater system:** a new breakwater system will be installed to reduce wave action near the shoreline, reduce bluff erosion, and make the beach better for patrons. The new system will also hold sand more effectively, maintaining a usable beach during high and low lake levels.*
>
> https://www.winpark.org/elder-centennial-design-development/

Based on the needs and input from the community, this project will provide a higher level of shore protection for the bluff, infrastructure, and lakebed. The property currently has an eroding beach with an exposed steel seawall (that was buried for decades), a beach house that has historically been damaged by stormwaves, a failing modular concrete block pier and stormwater outfall, and boat storage racks on concrete foundations. The proposed system is designed to help improve these issues, provide greater and more stable public access to Lake Michigan waters, offer new recreational activities to beach-goers, and provide a sustainable shoreline for the community.

Project Description

This application is submitted for the removal of existing structures and for the construction of new structures.

Four steel jetties, steel sheet piles, a concrete pier, an existing stormwater discharge pipe, and a chain-link fence are being removed as part of this project.

The proposed new breakwater protected beach system is comprised of three quarrystone and steel breakwater structures and a steel and concrete pier in the center. All the lengths noted below are toe to toe.

The northernmost breakwater is a shore-connected stone and steel breakwater that projects east into the lake and then curves south. It is 265' in length as measured perpendicular to shore and includes two sections of sheetpile. The northern section of sheetpile is a 155' long curved row of capped steel tapering from 590' at the bluff toe down to 587'. Attached to the cap are 155' of steel louvers tapering from 596.7' down to 588.5'. The southern section of sheetpile is a 100' long row of capped steel tapering from 590' at the bluff toe down to 587'. This row creates the planter pocket and establishes the vehicular ramp edge. The most eastern section of the breakwater structure will be quarrystone with a 3 stone crest tapering from 587' to 586' lakeward. The existing 54" stormwater outfall will be relocated into this breakwater with two 36" steel ductile pipes that exit at the east end of the structure embedded within the armor stone.

Moving to the south after a 150' gap is a 260' long breakwater/pier with a 300' long steel and concrete pier connecting to land. The lakeward portion of the pier will be 16' wide with a crest of 585' surrounded by quarrystone with a crest at 587'. The land connecting section will be 13' wide and will taper from 587' landward to 585' where it connects to the lakeward section.

Moving south past a 180' gap, there is the southernmost shore-connected stone and steel breakwater. This breakwater projects east into the lake and then curves north, mirroring the north breakwater. It is 300' in length as measured perpendicular to shore and includes two sections of sheetpile. The southern section of sheetpile is a 185' foot long row of capped steel tapering from 591' at the bluff toe down to 587'. Attached to the cap are 185' of steel louvers tapering from 597.5' down to 588.5'. The northern section of sheet piling is a 113' long curved row of capped steel tapering from 590' at the bluff toe down to 587'. This row creates the planter pocket. The most eastern section of the breakwater structure will be quarrystone with a 3 stone crest tapering from 587' to 586' lakeward. The slopes of all quarrystone structures will be 1v:1.5h, and sandfill will be placed in accordance with IDNR regulations.

New steel sheetpiles and caps will be installed along the bluff and beach. The new vehicular access ramp apron at the beach will be formed by a steel sheetpile wall. Starting at 590' near the existing sea wall, it tapers east to 580'. South of this structure, approximately 156.25' of sheeting, set at elevation 590', will be installed along the bluff until it reaches the existing concrete stairs adjacent to the existing beach house. South and east of the beach house, three new sections of sheeting will be installed in lengths of approximately 183.9', 152' and 126.9'. These lengths of sheeting will allow for ADA ramp connections to be made to the proposed pier and center breakwater structure. All of the steel is being installed to protect these improvements from undercutting and possible future damage due to fluctuating lake levels.

The Winnetka Park District is requesting a 10-year sand nourishment permit. The Winnetka Park District would like to have the ability to mobilize up to 2,000 cubic yards of sand annually if and when necessary to help maintain a stable beach and the metastable equilibrium.

Coastal Geology

This section of coastline has historically lost sand due to lakebed downcutting especially during prolonged periods of low lake levels. Nearshore sand deposits are thin and less than one foot in some locations at this site (Figure 1, Appendix) and scientists estimate that the rate of lakebed erosion up to 6 inches per year (Nairn, 1997). The net result is similar to the effects of global warming and rising sea level on marine coasts. This includes deeper water nearshore, larger stormwaves and progressively narrower beaches as the nearshore lakebed continues to erode.

The effect of lakebed downcutting is very evident at the beach at Elder shown by the significant loss of beach recently at above average water levels. Historically this beach has held a small beach at time of high-water levels. The loss of beach from the record low 2013 water levels to an above average water level in 2016 took almost all of the sand out of the steel groin encapsulated system at Elder leaving the site without a sandy beach and damage to the existing boathouse. The effects of lakebed downcutting are evident with the large stormwaves breaking onshore as observed in the 2014 Halloween storm, the 2015 October storm, and ongoing storms events at high Lake Michigan water levels.

The Illinois Lake Michigan shoreline is considered "sediment starved" by coastal scientists. This is in contrast to East Coast and Gulf Coast open ocean shores where tens of thousands of tons of sand are found in the nearshore system that provides a primary line of defense against stormwaves. On most Great Lakes shores including southern Lake Michigan, natural sand beaches are not able to protect the lakeshore (exceptions may be during very low lake levels like 1964 or 2004-13). Large quantities of sand have been trapped or diverted offshore by municipal structures that extend 900 feet or more into the lake. Today, the main sand supply is wave erosion of the nearshore glacial clay lakebed that contains only about 10% sand (Shabica and Pranschke, 1994). The result is that groins and piers are losing their effectiveness at holding a sandy beach during average to high lake levels. To retain a sand covering of the shallow lakebed (where downcutting is most active) as well as to protect the bluff toe, SA has modified the design of this beach system to better hold sand as necessary and protect the lakebed and bluff during variable lake levels.

2013 Google Earth image at record low Lake Michigan water levels (left) compared to 2020 high water levels (right)

If beach and nearshore sand is lost, degradation of the nearshore ecosystem will result. Meadows et al., (2005) reports an increase in zebra mussels *Dreissena polymorpha*, and a decrease in native zooplankton in waters where the lakebed is eroding clay and rocks. In comparison, a nearshore area with 100% sand cover supports a species-rich community. The report concludes, "it [is] nonetheless clear that sand-based areas were characterized by sufficient shallow water fish CPUE and species richness to suggest that these are important habitats within the context of the Great Lakes Basin and not simply 'wet deserts' as they are often considered."

Coastal Climate

One of the largest factors in determining the scope of a project is analyzing current lake levels and climatic conditions. Over the past several years, larger-than-normal stormwaves have impacted the shoreline of Lake Michigan. The shoreline presented in this application has been impacted by the recent extreme increase in water level and effects of lakebed downcutting evidenced by waves eroding the sand and destroying concrete boat storage racks. These stormwaves, in combination with a severe rebound in Lake Michigan water levels, have exacerbated the nearshore erosion along the lakefront.

One thing most Great Lakes hydrologists agree upon: with global warming, lake storms will continue to get more intense and destructive.

The **Illinois State Water Survey, Prairie Research Institute** report on *Potential Impacts of Climate Change on Water Availability* (http://www.isws.illinois.edu/iswsdocs/wsp/climate_impacts_012808.pdf) states that:

> *"Scientists cannot predict future Illinois climatic conditions with confidence. The historical climate and hydrological records since the nineteenth century show that climate has changed significantly in the past and, even without human interference, could change significantly in the future."*

The Illinois State Water Survey goes on to graph future precipitation models, illustrating conditions that are wetter or drier than previous historic extremes. Either scenario is likely to cause loss of property due to stormwave erosion from either lakebed downcutting and/or larger stormwaves. Currently, Lake Michigan has risen over 6' since January of 2013 leading to a significant loss of nearshore sand. US Army Corps of Engineers forecasts predict that Lake Michigan water levels will continue to fluctuate even as water levels start to recede from the record 2020 highs.

Ongoing storms continue to damage the shoreline and beach house even as Lake Michigan water levels start to recede.

2020 photo looking north at the damaged non-motorized storage pads and gabion baskets,
existing steel groin and north shoreline structures

2021 photo looking north along the steel seawall at Centennial Park

Benefits of Sandy Beaches

The Great Lakes represent the most important natural resource in the United States. Sandy beaches play an important role in maintaining water quality and stable access. Furthermore, a sandy beach makes a better ecotone (transitional environment) for flora and fauna than seawalls and revetments. As the permit application is for the public benefit, it is crucial that the beach and boat launching facility remain available and usable for the public. Summary arguments supporting a sandy beach system include:

1) Beaches are filters for non-point source runoff.
2) Beaches reduce lakebed downcutting, a source of fine clay pollutants.
3) Beaches support endangered species such as sea rocket, marram grass, and seaside spurge.
4) Beaches make better wildlife habitat than actively eroding bluffs or seawalls.
5) Stone headlands make better fish habitat than eroding lakebed clay.

6) Beaches protect the lakebed from erosion that causes larger stormwaves to impact the shore.
7) Beaches are far more appropriate for swimmers and boaters than a coast lined with seawalls or revetments, especially in an emergency.

On urban coasts, more than 35 years of system monitoring (Shabica et al, 2011) has shown that engineered pocket beaches (aka bay-beaches or attached-breakwater beaches), pre-nourished with sand, have shown a great resilience to changing lake-levels and decreased sediment-supply. After an intense storm such as the storm on Halloween, 2014, pocket beach recovery is fast. Further, net sand loss and renourishment costs are lower than for unprotected beaches on open Great Lakes coasts. And with each beach, thousands of tons of new sand is brought in, not only to initially nourish the pocket beach but also to add 20% overfill sand to the adjacent lakeshore. Periodic sand re-nourishment has proven to be a successful management tool and provides additional sand for the entire Illinois coastal ecosystem.

Impact to Littoral Drift System

The proposed plan for this site includes construction of a breakwater-protected beach system including placement of mitigational sandfill, as required for permit. The design of the proposed system, including the mitigational sandfill, will help assure no negative impact to the littoral drift system. This region of the Lake Michigan shoreline around the project site is completely engineered. The shoreline north and south of the Elder/Centennial Beach is privately owned residential property that is protected by revetments, steel groins and breakwater protected beaches. Sand mitigation (as required by the IDNR) will be placed on the subject property and on the properties immediately to the north and south with a 20% overfill as required.

The proposed quarrystone breakwaters for the beach will extend to approximately 300' offshore. The littoral drift system is designed to remain at a dynamic equilibrium once the mitigational sand is placed (anticipated quantity plus 20% overfill). The proposed beach at Elder/Centennial is on a relatively straight section of shoreline.

IDNR regulations for structures that will retain sand require pre- and post-construction surveys, as well as surveys at the one- and five-year intervals. A more intensive monitoring plan has been developed due to the scale of the project, see Appendix. This requirement will help assure that a sand equilibrium is met and that the new project is gaining and losing sand at a similar rate to neighboring properties or mitigation may be required.

Impact on Public Uses

The breakwaters and beach will help to provide a more stable shoreline environment for boaters and swimmers with two separated usage bays and easier access to the water. Fishing will not be impacted negatively, as the underwater area of the quarrystone breakwater protection will create an improved fish habitat. Open water navigation will not be impacted, as the proposed construction extends slightly further east than the existing nearby structures. Launching of kayaks and paddleboards will be improved by the dual bay beach system. The new park borders and boundaries established by the project afford the Park District the opportunity to permit dogs on the beach during off-season months without introducing the risk of dogs straying onto adjacent private property.

Impact on Natural Resources

Quarrystone structures in the nearshore waters of Lake Michigan and sandy beaches improve native species habitat. The LandOwner Resource Centre with support from the Canadian Wildlife Service and the Ontario Ministry of Natural Resources states that, "unstable shorelines can release silt that can choke nearby aquatic habitats." Additionally, underwater structures such as artificial reefs constructed of large boulders and clean riprap material "in large water bodies, such as the Great Lakes . . . are often the best method of creating habitat." As stated above, according to Meadows, et al., 2005, "a nearshore area with 100% sand cover support[s] a species rich community." As the design does not impact the bluff and vegetation, the local terrestrial wildlife will continue to inhabit this property. In many nearshore areas in Illinois where the sand is less than 3 feet thick, lakebed erosion of glacial clay results in large suspended plumes of clay in the water during storm wave events. An eroding clay lakebed is not considered good aquatic habitat.

Type of Permit
The scope of this project requires an individual permit.

Description and Schedule of Proposed Activity
Installation of the breakwaters will start soon after the permits are issued as the beach is not currently usable for residents. The breakwaters will be built by a combination of marine and land-based access (pending lake level and conditions at the time of construction). This project is anticipated to be completed within a single year.

Type and Quantity of Fill/Measures Taken to Avoid Impact/Erosion and Sediment Control Plan
All material will be clean and from inland quarries. Approximately 21,243 tons of clean quarried stone will be placed to construct the breakwater system. Approximately 23,200 cubic yards of clean sand will be placed as sandfill in and around the system. The area of fill to be placed below the Ordinary High Water Mark (581.5 feet, IGLD 1985) is 1.0 acre.

Ongoing Maintenance
The Winnetka Park District is requesting a 10-year sand nourishment permit. As lake levels lower, sand will tend to accumulate more in the beach bays. The Winnetka Park District would like to have the ability to mobilize up to 2,000 cubic yards of sand annually if and when necessary to help maintain a stable beach and the metastable equilibrium.

Mitigation
This project covers 1.0 acre of the lakebed below the OHWM with fill. The fill does improve the quality of the lakebed and water with the quarrystone breakwaters creating habitat for fish. As this system will be monitored annually for 5 years north of and south of the proposed system, sand removed from the littoral drift system can be better quantified for replacement. Additionally, this permit calls for up to 2,000 tons of sand to be placed annually or as needed for beach nourishment. Based on this information, we offer no additional mitigation unless specified by the USACE or IDNR.

Summary
All of the above-described activities and plans will follow IPP terms and conditions. All of the proposed work adheres to the guidelines prescribed by the Illinois Environmental Protection Agency and its Anti-Degradation Assessment. U.S. Fish & Wildlife Service will be updated on all relevant correspondence.

If you have any questions, please feel free to call me at the phone number below.

Sincerely,

Jon Shabica
Vice President

C: IDNR/OWR
Illinois EPA, Bureau of Water, Permit Section
U.S. Fish & Wildlife Service
Winnetka Park District (Peterson)

Letters of authorization attached:

- John Edwardson, 301 Sheridan Road – Placement of sand and stone
- Peter Lee, 205 Sheridan Road – Placement of sand and stone

Letters of support attached:

- US Senator Richard Durbin
- US Senator Tammy Duckworth
- US Representative Jan Schakowsky
- Illinois Representative Robyn Gabel
- Illinois Senator Laura Fine
- Village of Winnetka
- Dmitry Godin, 319 Sheridan Road, Winnetka
- John Edwardson, 301 Sheridan Road, Winnetka
- Orchard 2020 Revocable Trust, 203 Sheridan Road, Winnetka
- Leo Birov, 195 Sheridan Road, Winnetka

DESIGN OF SHORELINE EROSION PROTECTION

Introduction
The following report summarizes assumptions and design criteria for a quarrystone breakwater system and sandfill, along with other recreational improvements to help retain a beach, provide lake access, and better protect the property located at 225 - 299 Sheridan Road, Winnetka. The design is based on the drawings included in this submission dated April 7, 2022.

The entire reach of shoreline within the project limits, and including areas north and south of these limits, has been modified by the construction of groins, seawalls, revetments and breakwater-protected beaches in the past. This section of coast is sand-starved due to municipal structures (littoral barriers) constructed over the past 130 years that extend east past the littoral zone and reduce sand bypass, as well as armoring of the shoreline reducing erosion of the glacial clay bluffs. According to the Illinois State Geological Survey, there is almost no sand moving along this section of coast. All structures in the area have been steadily losing their effectiveness at holding beach sand. This problem is exacerbated by lakebed erosion. In many cases where all the sand has been lost, the adjacent bluffs have begun to erode. To provide adequate protection for the upland property, solutions have typically been of two types: breakwater- or groin-anchored beaches to protect the bluffs, or a lower-cost system with a lower level of protection in the form of quarrystone revetments placed against the toe of the bluff that prevents stormwave erosion but at the expense of the beach and pedestrian access.

Project Description
The proposed design includes a two bay beach design with three breakwaters, a pier and sandfill. The project will include sandfill mitigation that fulfills the design requirements of 20-year stormwave erosion protection. The current public beach is suffering from erosion as well as is unstable for users including the summer programming for the community with the current site conditions. Additionally, with the high lake levels, there has been damage and destruction to lakefront structures in addition to stormwaves causing erosion of the bluff toe, as well as severe icing problems and impacts to the property.

AECOM has provided coastal and structural evaluations of the steel breakwater structures in the attached report. Their report demonstrates the steel portions will provide environmental benefit by managing wave attack, providing reductions in potential beach erosion, and protecting the planting pocket habitats from damage. Additionally, the report includes the structural engineering studies and results to demonstrate the structures are properly engineered and robust enough to withstand Lake Michigan wind, wave, and ice events without exceeding material limits for allowable stress or deformation.

Summary Specifications
Using the Army Corps of Engineers Shore Protection Manual (1984), performance of nearby prototypes and other sources, the following specifications were developed for this site (elevations are based on IGLD 1985):

Breakwater Specifications – for Breakwaters	
Lakeward Crest Elevation:	586 ft
Toe of Breakwater:	572 ft
Crest Width:	11 ft
Average Armor Size:	4.5 tons
"B" Stone	600 - 1200 lbs
Slope:	1:1.5
Tons/linear ft:	32 tons

Assumptions

• Design High Water (DHW):	584 ft *
• Design Water Level:	582.0 ft
• Design Low Water (DLW):	577.5 ft *
• Existing clay/dense sand & gravel elevation:	570 to 572.0 ft
• 20-yr lakebed erosion at toe of groin:	3 ft
• Design wave height:	Hs = 12.3 ft
• Nearshore Slope:	1:40 – 1:100
• Design Wave Period (T):	9.9 s **
• Depth at Structure Toe DHW (Ds):	12'
• Design Deepwater Wave (Ho):	20.0'***
• Design Wave Length (Lo):	501.8'
• Stone Porosity:	37%

* DHW includes 2 ft storm setup, DLW is equivalent to Low Water Datum
** Resio & Vincent, 1976
*** US Army Corps of Engineers 1982 Draft Reconnaissance Report

Shoreline/Bathymetry
A full bathymetric survey was performed in September 2020, updated in November 2021. Survey notes: Lake conditions at the time of survey were waves of 1 foot or less. Bathymetric survey was performed using a Trimble R10 GPS Receiver along with a Hydrolite-TM Single Beam Echosounder. Survey was performed tied to Trimble's VRS Now Network, data points were collected in NAV88 datum and converted to IGLD1985. Cross Sections were cut from a surface created from actual survey points.

Water Levels
The following table summarizes water level data representing daily highest extremes measured at Calumet Harbor, Illinois, approximately 26 miles to the south of Winnetka. Note: Low water datum LWD = 577.5 ft (IGLD 1985).

Lake Level	LWD	IGLD 1985
Record High	+5.5	583.0
Record Low	-1.4	576.1

Project Supporting Data
To help facilitate project review, Shabica & Associates offers the following supporting data based on standard coastal engineering practices:

1. **Sediment transport around structure**
The structure is designed to lie within the surf zone (zone of breaking waves), therefore allowing sediment transport around the structure. The range of breaking wave heights is from 8.3 ft based on a 6-second wave with a wave length of 184 ft (using 1/25 Lo) to 18 ft based on a 9.9-second wave with a wave length of 501.8 ft (Resio and Vincent, 1976). The commonly accepted zone of sediment transport is to 18 ft (depth of closure) in this section of Lake Michigan, which is a function of the design wave parameters. Based on this data, once the structure has been filled with sand, it will continue to bypass littoral drift sand. Survey monitoring will be conducted, as required by the IDNR, to assure that the system performs as designed.

The IDNR requires sandfill in areas where sediment will be trapped by the new system. Sand volume quantities have been calculated as shown in the permit drawings. As required by the IDNR, a 20% overfill will be added to the calculated volume. Additionally, the new pre- and post-construction monitoring will be performed and submitted to the IDNR to verify the impacts to the system.

2. **Effect on Adjacent Shorelines**
   A wave diffraction diagram (Figure 2, Appendix) has been overlain on the proposed shore protection system. Using a refracted incident wave angle of 90 degrees (USACE, Shore Protection Manual), with average and design waves, there will be a decrease in wave energy on adjacent properties. The wave diffraction pattern shows that the coefficient of diffraction (K) reduces the wave energy to a distance of about ½ the wave length downdrift and does not have an impact further downdrift. For the average 6-second wave, that distance of reduced wave energy is about 90 ft and for the design wave, the protected distance is about 250 ft. This protected area close to the structure has diminished wave energy that will in turn reduce erosion in the area.

3. **Wave Reduction in Rubble-Mound Structures**
   The Iribarren number (ξ), or surf similarity number, is used to determine the wave reflection coefficient. For rubble-mound structures, wave reflection (and wave energy) is reduced by one half or more (0.2 to 0.53) (Figure 3, Appendix). For example, a wave reflection of 0.25 means that the wave energy is reduced by 75%. The range of wave reflection for beaches peaks at about 0.44. The range for plane slopes, however, quickly rises to 0.5 and peaks at .91. This illustrates that rubble-mound structures reduce wave energy almost as well as beaches.

Lakebed Erosion

Lakebed erosion, active in water depths of 10 ft or less, is a design component of this plan. This section of the Winnetka lakeshore is considered sediment starved. Sand deposits were measured at this site (Elder Lane Beach, Winnetka) from the backshore to a depth of 6.7 m (22 ft) in 1989. In 1989, the nearshore sand deposits averaged 1.6 to 2.0 ft thick from shore to 50 ft offshore and thinned to 0 feet thickness at 100 ft, and then thickening to 4.5 ft at 250 ft offshore. At 1,000 ft offshore, no sand was present through the end of the transect. Farther offshore, the sand ranged from 1.8 to 2.9 ft thick (Shabica & Pranschke, 1994). In July of 2010, the clay depth and sand cover were resurveyed to a depth of 2m (6.3 ft). In 2010, the nearshore sand deposits were typically 1 foot thick with the exception of a sandbar that averaged 2 feet thick. The site is underlain by highly-erodable, cohesive glacial clay-till. During the period from 1989 to 2010, erosion of the clay lakebed varied from negligible to 2.3 ft. The 2.3 ft of erosion occurred in the location where there was no sand cover in 1989. See Shabica survey data and cross-section (Figures 1 a-c, Appendix) showing loss of lakebed sand from 1975 to 1989. Calculated sand deposits at this site in 1989 were 161 cubic meters per meter of lakeshore to a depth of 4 meters. According to Robert Nairn, approximately 200 m^3 of sand cover per meter of lakeshore (out to a depth of 4 m) is necessary to protect the underlying cohesive profile from lakebed erosion under most conditions. Sand and coarser sediments represent typically less than 15% of the material eroding from the lakebed and bluffs.

Using the historic rate of lakebed downcutting of 0.15 ft/yr, an irreversible lowering of the nearshore lakebed clay of approximately 3.0 ft over a 20-year period is predicted in unprotected areas. With the breakwater and sandfill installed, the lakebed erosion will be reduced.

Stone Stability, Armorstone

The proposed quarrystone breakwater has two layers 3 – 6 ton armorstone built on a 1:1.5 slope. Overtopping of the structure is expected during storms and higher water levels. Design conditions include:

* Lakeward breakwater crest elevation 2 ft above DHW, 8.5 ft above DLW
* Depth-limited breaking waves will break on the stone revetment, stone breakwaters and sand beach
* Depth at the toe of the structure is 14 ft (572) at design high water
* Incident wave directions: NE, E and SE
* Wave period for DHW T = 9.9 seconds
* Wave period for average conditions T = 6 seconds

Quartzite, granite or Limestone armorstone is recommended as it is highly durable and is locally available in most gradations under 6 tons. Hudson's formula was used to estimate armorstone size. An armorstone of 4.3 tons is predicted for 2-layer random placement armorstone based on the design conditions. Based on experience and prototype structures, an average stone size of 4.5 tons is being specified for this project, and the armorstone gradation selected for this project is 3 – 6 tons.

PHOTO 1

2013 Google Earth image at record low Lake Michigan water levels (left) compared to 2020 high water levels (right)

PHOTO 2

Photo looking north at recent erosion and damaged storage pads (yellow arrows)

PHOTO 3
Photo looking north at the adjacent shoreline and lack of access

PHOTO 4
Shoreline looking north along the toe of the bluff at Centennial Beach

PHOTO 5
1997 Shabica aerial photograph of Elder Beach

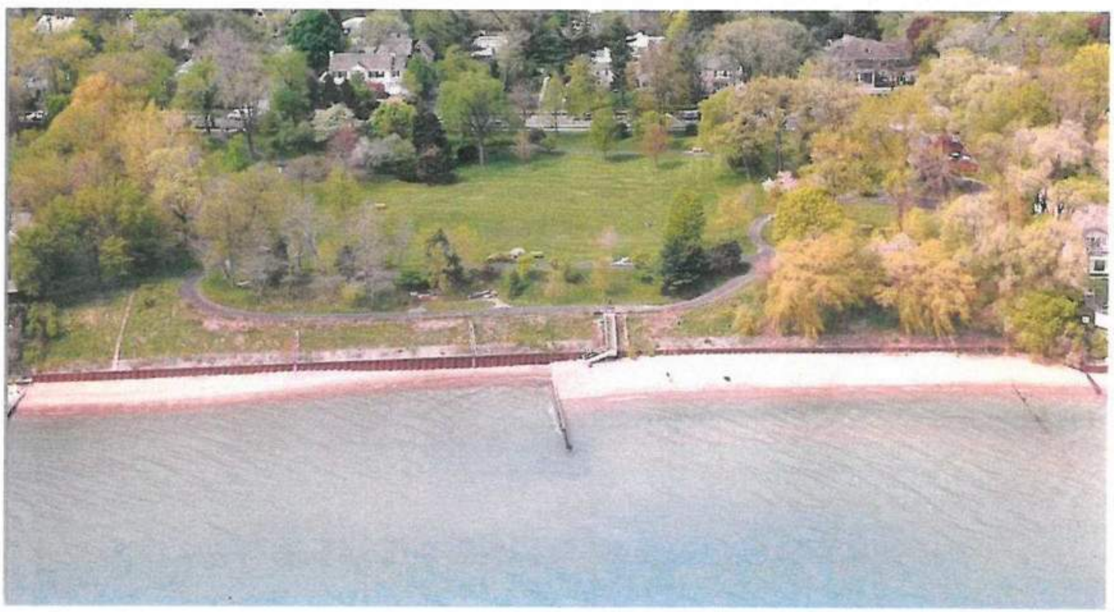

PHOTO 6
1997 Shabica aerial photograph of Centennial Beach

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Shabica, C.W., F. Pranschke, 1994, *Survey of Littoral Drift Sand Deposits Along the Illinois and Indiana Shores of Lake Michigan*, U.S. Geological Survey Symposium Volume, Journal of Great Lakes Research, vol. 20, no.1, pp 61-72.

Shabica, Charles and Assoc., 1997, *Lake Bluff Beach Monitoring and Mitigation Report 5*, US Army Corps of Engineers, Chicago District.

US Army Corps of Engineers, 1984, *Shore Protection Manual*, Coastal Engineering Research Center, Vicksburg, Mississippi.

US Army Corps of Engineers *Reconnaissance Report on Beach Erosion at Lloyd Park Beach*, 1982

FIGURE 1a

Winnetka - Elder Lane Date:06/27/89 Time:

Enter lake surface 578.90 elevation for time of survey

Enter Graph: DATA A DATA B DATA C

Enter Dist. From Shore	Enter Water Depth	Enter Sand Thickness	Top of Sand Elev. 1990	Bottom of Sand Elev. 1990	Enter Sand Thick. 1975	Top of sand 1975	Enter Hard-pan Type	Sand Volume Cu.Yd. Per ft. 1975	1990
-10.0	-1.0	2.0	579.9	577.9	10.0	587.9		1.9	0.4
0.0	0.0	1.8	578.9	577.1	10.0	587.1		6.5	1.2
25.0	0.8	1.6	578.1	576.5	10.0	586.5		9.3	1.5
50.0	1.9	1.9	577.0	575.1	10.0	585.1		13.9	2.6
100.0	3.3	0.0	575.6	575.6	10.0	585.6		18.5	0.0
150.0	5.9	0.7	573.0	572.3	10.0	582.3		27.8	1.9
250.0	6.5	4.5	572.4	567.9	10.0	577.9		64.8	29.2
500.0	9.8	2.9	569.1	566.2	7.0	573.2		64.8	26.9
750.0	13.3	1.0	565.6	564.6	5.0	569.6		46.3	9.3
1000.0	15.0	0.0	563.9	563.9	4.0	567.9		37.0	0.0
1250.0	15.9	2.6	563.0	560.4	3.0	563.4		27.8	24.1
1500.0	16.9	2.9	562.0	559.1	3.0	562.1		27.8	26.9
1750.0	20.3	1.8	558.6	556.8	2.0	558.8		18.5	16.7
2000.0			578.9	578.9		578.9		0.0	0.0
0.0			578.9	578.9		578.9		0.0	0.0
0.0			578.9	578.9		578.9		0.0	0.0
0.0									
							TOTAL	364.8 CuYd/ft 1975	140.5 CuYd/ft 1990

Note all measurements in feet

All Elevations IGLD 1955

Field Worksheet from 1991 USGS Lakefront Sand Thickness Survey at Elder Lane Beach, Winnetka (Shabica et al., 1991)

FIGURE 1b

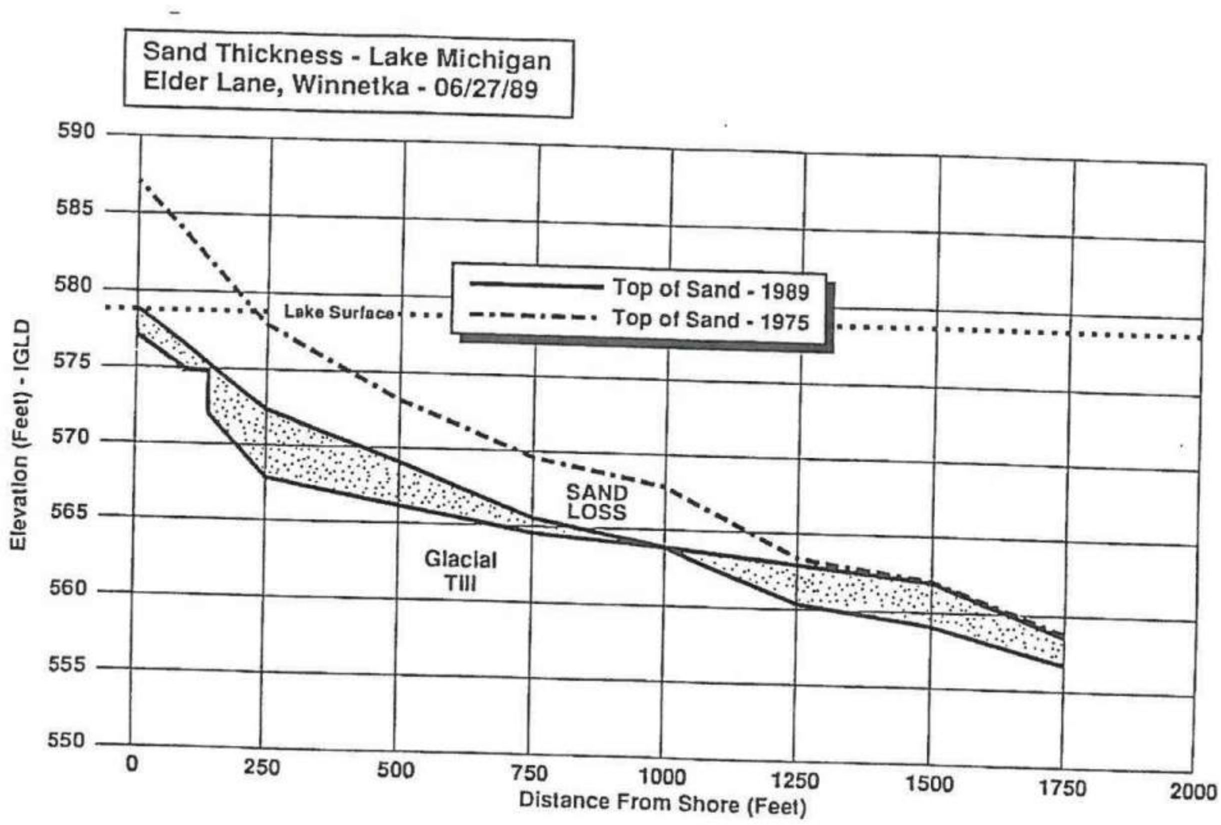

Sand Thickness - Lake Michigan
Elder Lane, Winnetka - 06/27/89
Top of Sand - 1989
Top of Sand - 1975
Lake Surface
SAND LOSS
Glacial Till
Elevation (Feet) - IGLD
590
585
580
575
570
565
560
555
550
0
250
500
750
1000
1250
1500
1750
2000
Distance From Shore (Feet)

FIGURE 1c

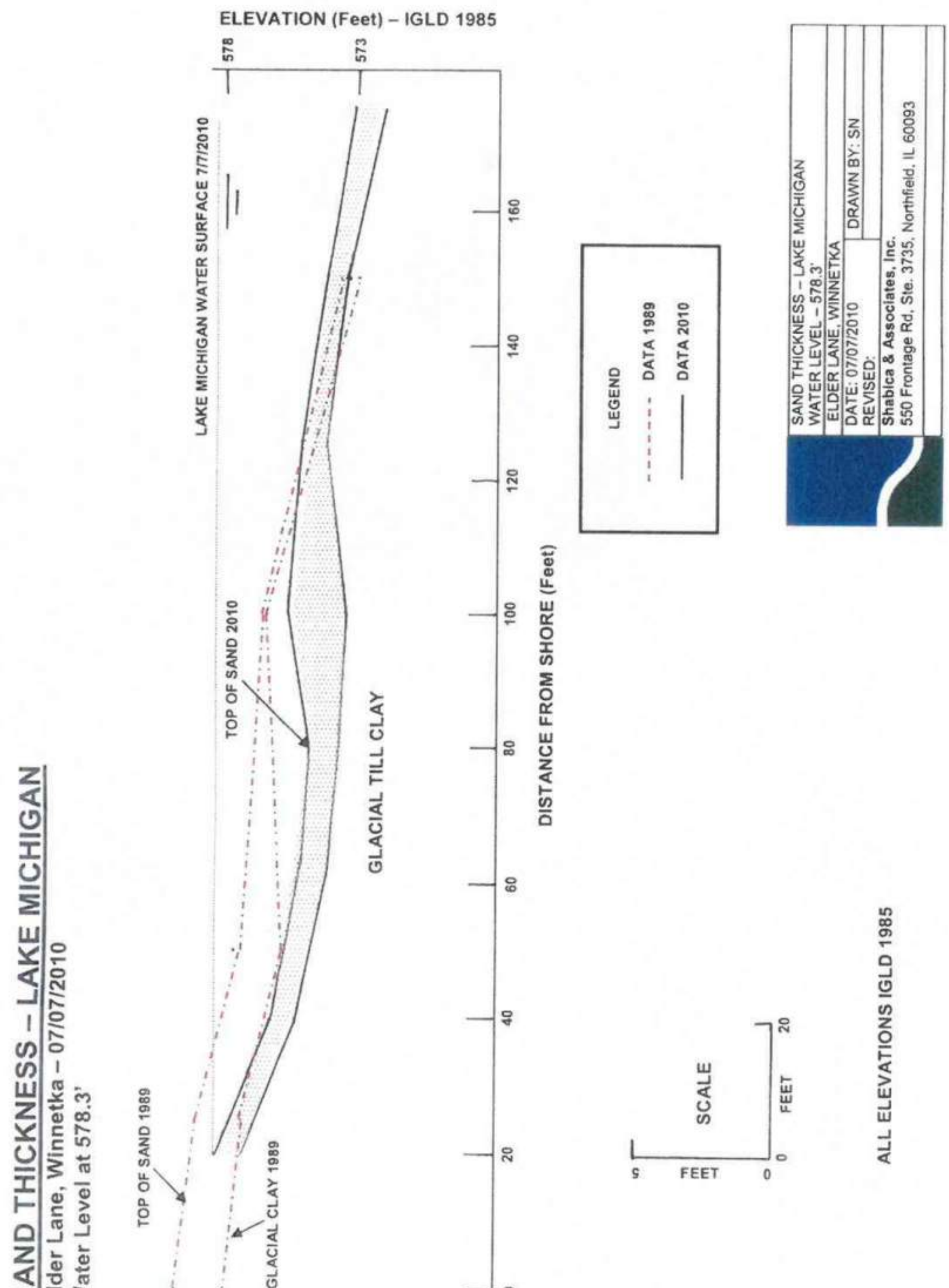
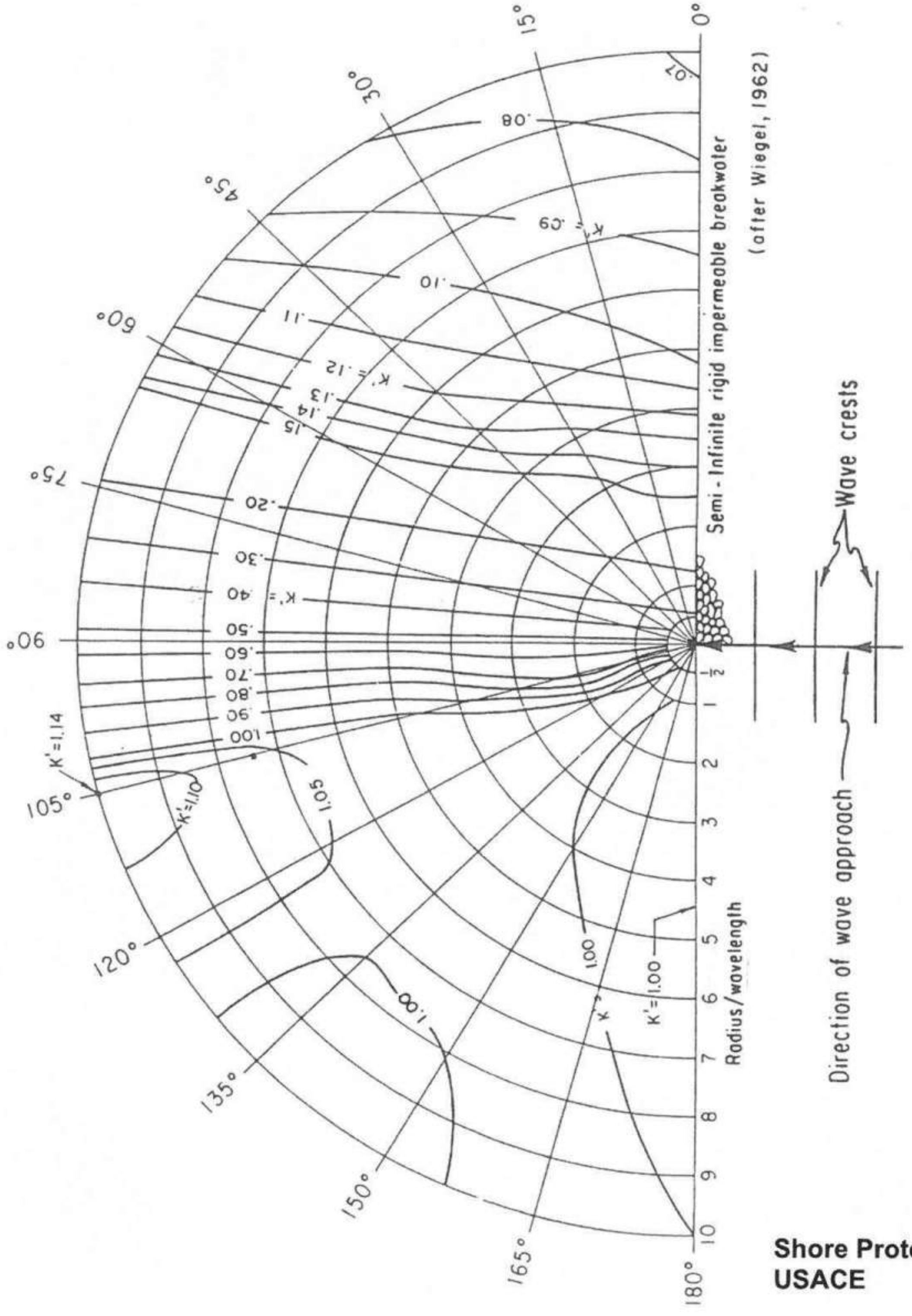

SAND THICKNESS – LAKE MICHIGAN
Elder Lane, Winnetka – 07/07/2010
Water Level at 578.3'
ELEVATION (Feet) – IGLD 1985
578
573
LAKE MICHIGAN WATER SURFACE 7/7/2010
TOP OF SAND 1989
GLACIAL CLAY 1989
TOP OF SAND 2010
GLACIAL TILL CLAY
DISTANCE FROM SHORE (Feet)
0
20
40
60
80
100
120
140
160
LEGEND
DATA 1989
DATA 2010
SCALE
FEET
0
5
0
20
ALL ELEVATIONS IGLD 1985
SAND THICKNESS – LAKE MICHIGAN
WATER LEVEL – 578.3'
ELDER LANE, WINNETKA
DATE: 07/07/2010
DRAWN BY: SN
REVISED:
Shabica & Associates, Inc.
550 Frontage Rd, Ste. 3735, Northfield, IL 60093

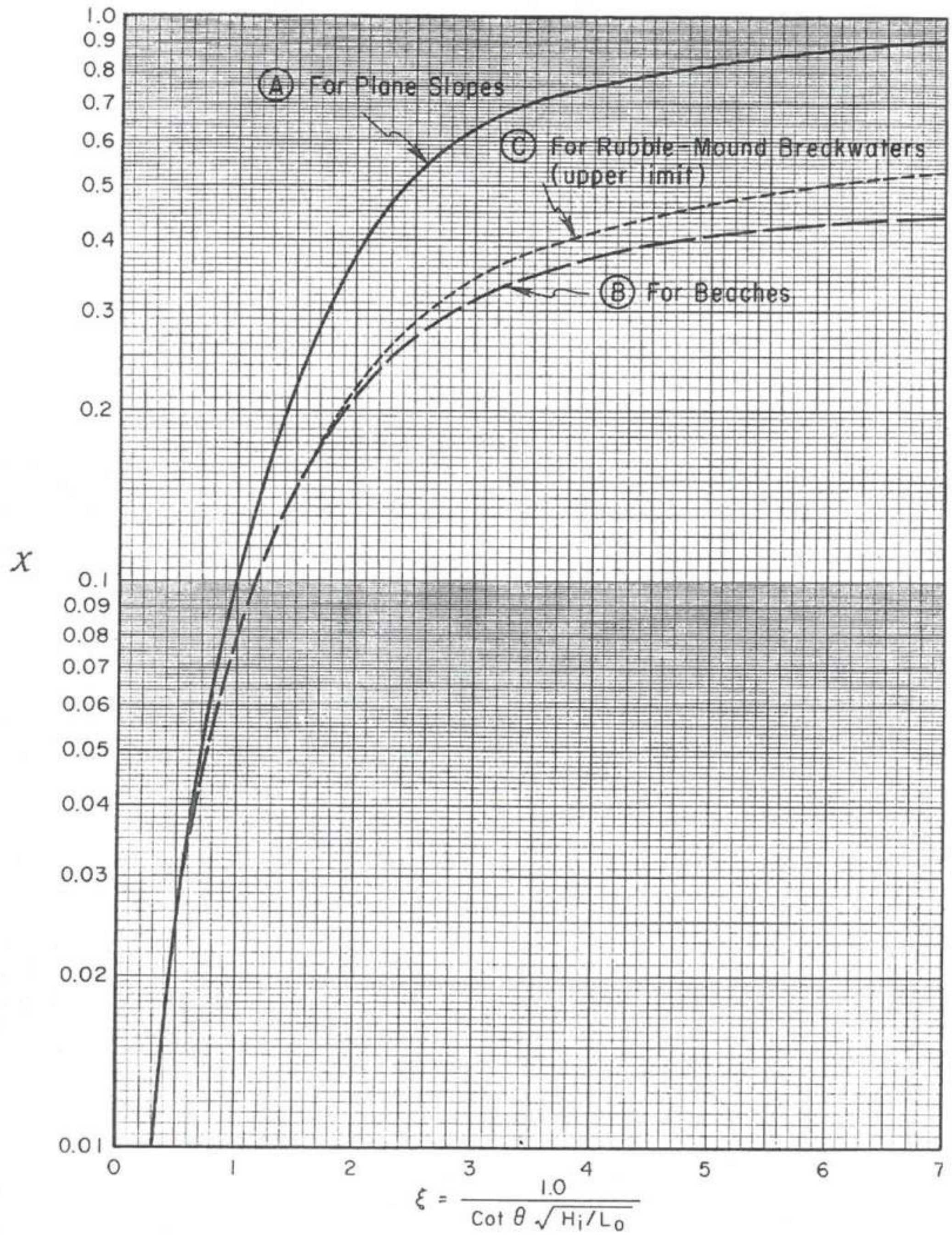
FIGURE 2



Wave diffraction diagram--90° wave angle.

Shore Protection Manual
USACE

FIGURE 3

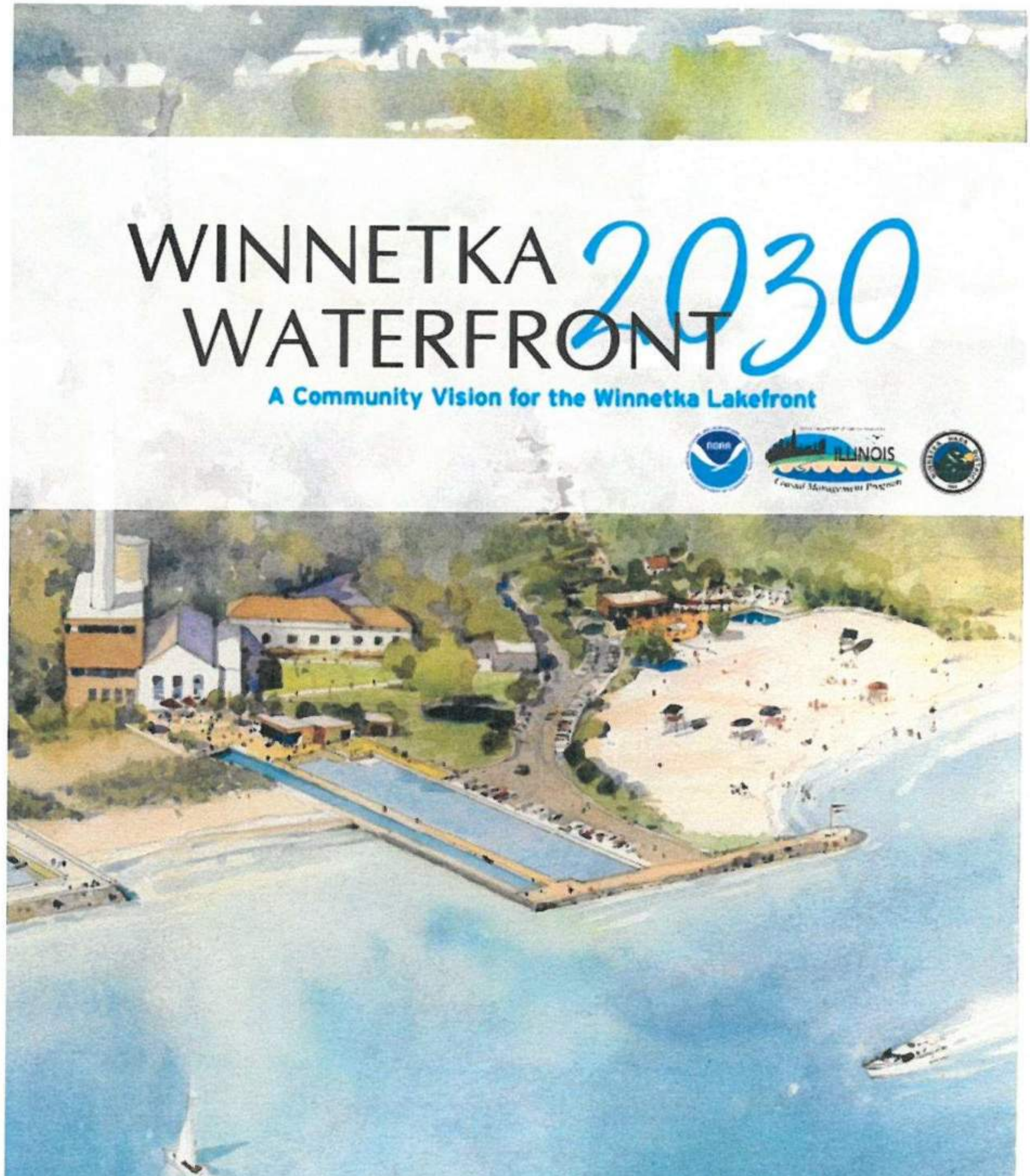


Wave reflection coefficients for slopes, beaches, and rubble-mound breakwaters as a function of the surf similarity parameter ξ .

Shore Protection Manual
USACE

Additional Resources:

Winnetka Waterfront 2030 – A community vision for the Winnetka Lakefront – Excerpts Attached



Winnetka Waterfront 2030 – A community vision for the Winnetka Lakefront –

Elder Lane Park & Beach

299 Sheridan Rd

Classification:
Neighborhood Park

Size:
4.52 ac

PIN:
05-21-403-013-0000
05-21-412-014-0000

Owner:
Winnetka Park District

Zoning:
R-2

Parking:
65 spaces

Elder Lane Park is located immediately northeast of New Trier High School. Total area for the park is about 4.56 acres including about 400 feet of Lake Michigan shoreline. Elder Lane Park and Beach was assembled of land acquired from private owners and the Villag of Winnetka in April 1920 - December 1921 and February 1946.

Soils, Slopes, and Drainage

Land cover includes mostly open space with a small number of trees.

Amenities

Swim beach, a playground is located at the top of the bluff near the parking area. Elder Lane Park and Beach is a great child swimming beach given the shallow water depth almost to the end of the modular concrete pier.

Structures

Two steel groins and one concrete pier project from the beach into the lake. A beach house is located at the foot of the bluff.

Access and Circulation

The park includes approximately 65 parking spaces at the top of the bluff. At times when New Trier High School is in session, parking is available to students from 8:00AM - 5:00PM for all spaces except the 3 standard spaces and 2 handicap spaces on the east side of the lot. Beach access is available from an asphalt drive that begins at the top of the bluff and ends at a small building in the middle of the beach. The service drive leading down to beach level is approximately 10 feet wide with slopes of approximately 15 percent. This road geometry is likely to result in safety issues for cars traveling in opposite directions or when access is required for emergency vehicles. Concrete stairs provide pedestrian access from the top of the bluff to beach level.

Utilities

Survey information for this park includes limited information regarding underground utilities; however water, sanitary, and electrical utilities are available at the building at the base of the bluff.

Programs and Events

Special events hosted at Elder include Beach Clean-Up and BBQ (spring) and the Winnetka Total Fitness Challenge (summer).

550 Frontage Road • Suite 3735 • Northfield, Illinois 60093 • Tel 847.446.1436 • info@shabica.com
www.shabica.com

Structures

Beach House	C. 2002. The 900 SF stone-clad beach house is located just above the beach, and includes a multi-purpose room, two restrooms, a guardroom, a mechanical room, and a hallway with vending machines and a drinking fountain. There is indoor/outdoor lighting and an exterior shower. The beach house is constructed of concrete block load bearing walls over a slab with foundation walls and footings. The roof is standing seam metal over wood rafters.

Amenities

	Qty	Notes
Benches	9	Benches surround the playground and line a path overlooking the lake
Picnic Tables	6	Three picnic tables are located on the bluff, and three are adjacent to the beach house
Bike Racks	1	
Drinking Fountains	2	
Showers	2	One adjacent to the beach house, another on the beach in front of the beach house
Trash Receptacles		
Playground	1	A swing set and two play structures, located on the bluff
Lifeguard Chairs		
Fishing Pier	1	A concrete pier with removable railings projects out from the beach house stairs
Sand Volleyball	1	
Site Lighting	Y	

Beach Notes:	400 feet of shoreline. The beach is used for swimming and sand volleyball
Bluff Notes:	Gabion baskets, sheet piling, and a wrought iron fence protect the wildflower-planted bluff
Road & Pathway Notes:	A brick path runs from the parking lot entrance to the top of the bluff; The beach area and accessible parking space can be accessed by a service drive.
Stair Notes:	A series of concrete stairs leads down to the beach house from the paver path; Another set of stairs and a pedestrian ramp lead down to the beach from the beach house.
Special Amenities:	Elder Lane Park won an award for 2003 Outstanding Facility and Park Renovation (Division III) from the Illinois Park and Recreation Association.

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www.shabica.com

Centennial Park & Beach

225 Sheridan Rd

Classification:
Neighborhood Park

Size:
5.22 acres

PIN:
05-21-403-013-0000
05-21-412-014-0000

Owner:
Winnetka Park District

Zoning:
R-2

Parking:
11 spaces

Centennial Beach

Centennial Beach is located immediately northeast of New Trier High School and immediately south of Elder Lane Park. Total area for the park is about 5.22 acres including about 550 feet of Lake Michigan shoreline.

Soils, slopes, and drainage

Land cover includes mostly open space with a small number of trees. A buried foundation covers much of the parks open space footprint. This foundation will need to be considered if development is proposed in affected areas.

Amenities

Centennial Beach is home to Winnetka's only off-leash dog area.

Structures

Two steel groins project from the beach into the lake.

Access and Circulation

The park does not include beach access for vehicles. The park includes approximately 11 parking spaces at the top of the bluff. Concrete stairs provide pedestrian access from the top of the bluff to beach level. This park has great potential for local bike riders as it is in line with access to the Green Bay Trail.

Utilities

Survey information for this park includes limited information regarding underground utilities; however water, sanitary, and electrical utilities are available from Sheridan Road. It is also suspected that utilities were installed for a washroom near the east end of the existing parking lot.

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www.shabica.com

Structures

N/A

Amenities

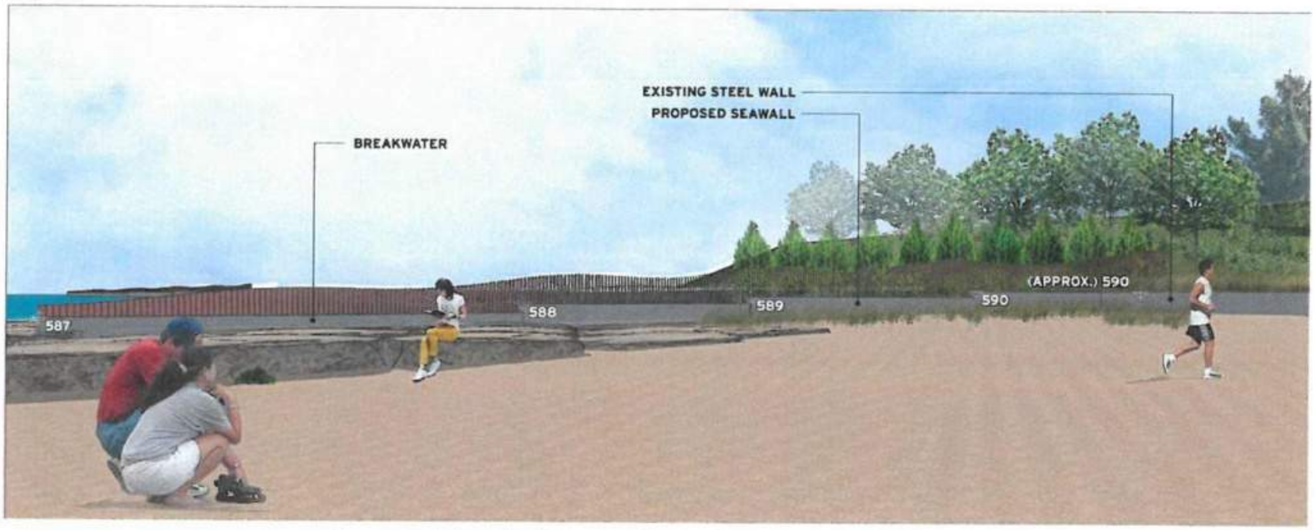
	Qty	Notes
Benches	6	
Picnic Tables		
Grills		
Bike Racks	1	
Drinking Fountains	2	Located at the southwest and north ends of the upper bluff walkway.
Showers	1	For dog-washing
Trash Receptacles		
Playground		
Lifeguard Chairs		
Fishing Pier		
Sand Volleyball		
Site Lighting		

Beach Notes:	525 feet of shoreline. Used as Winnetka's dog beach
Bluff Notes:	Sheet piling protects the bluff, which is planted with wildflowers.
Road & Pathway Notes:	A curbed asphalt parking lot with spaces for 11 vehicles and a turnaround circle is located on the northwest corner of the site; A winding concrete pathway encircles the upper bluff; Another concrete path connects upper bluff walkways to a lower bluff section.
Stair Notes:	A steel and wooden stairway provides access from the bluff down to the beach.
Special Amenities:	A card-swipe at the gate limits access to the beach for patrons who purchase a pass; A wash area for the dogs is located just west of the gate; A cluster of stepped outcropping stone and pavers known as the Babize Memorial occupies the lower bluff area.

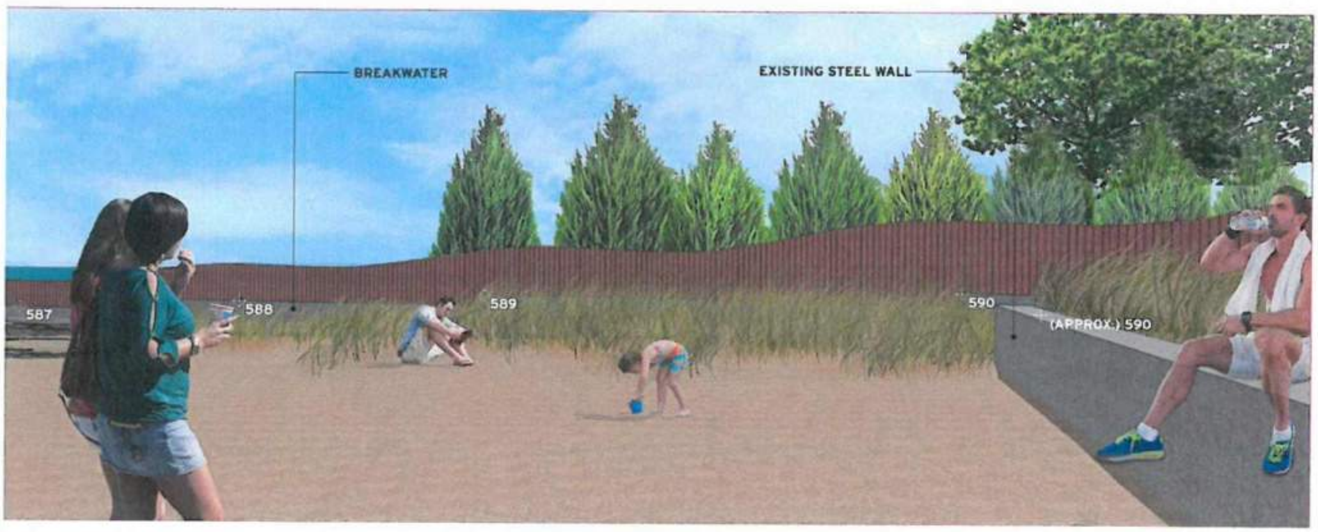
- A Rubble-mound breakwater structure
- B Stormwater management improvements
- C Secure non-motorized water craft storage
- D Existing boat house improvements
- E Boardwalk improvements
- F Dune landscape restoration
- G Bluff restoration
- H Expand surface parking
- I Nature based play area
- J Construct a new upper-level restroom building
- K Vehicular circulation improvements and retaining walls
- L Lifeguard stations
- M New sheet-pile groin
- N Renovate single-family home into new beachfront event space
- O New beach house

550 Frontage Road • Suite 3735 • Northfield, Illinois 60093 • Tel 847.446.1436 • info@shabica.com
www.shabica.com

Elder & Centennial Design Development – Renderings

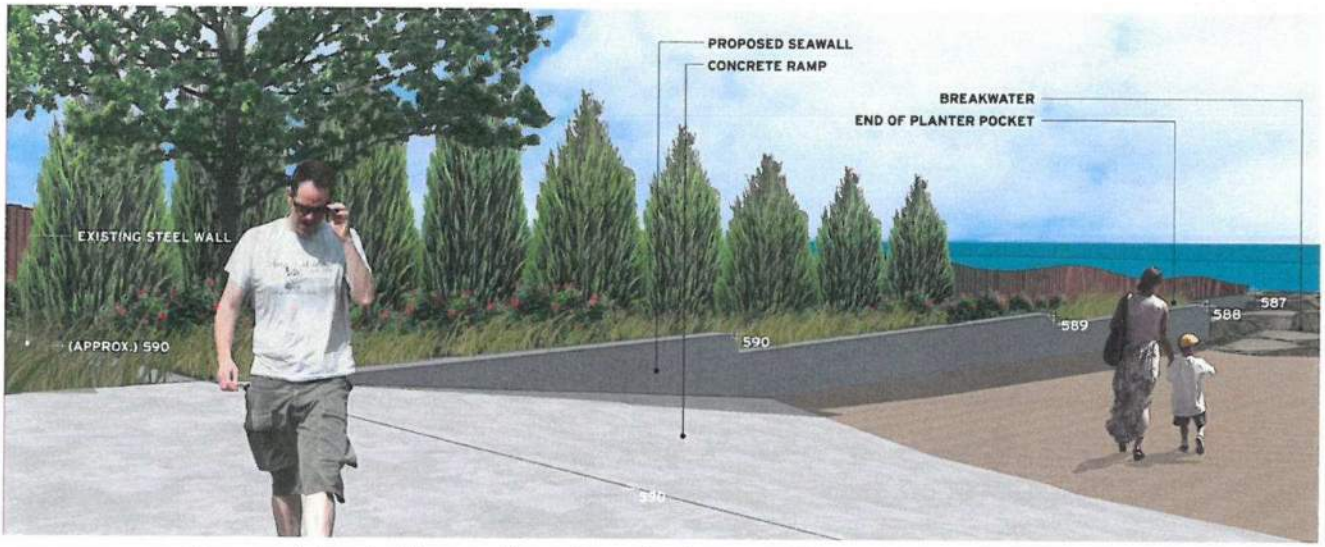


Proposed view looking southwest from Centennial Beach

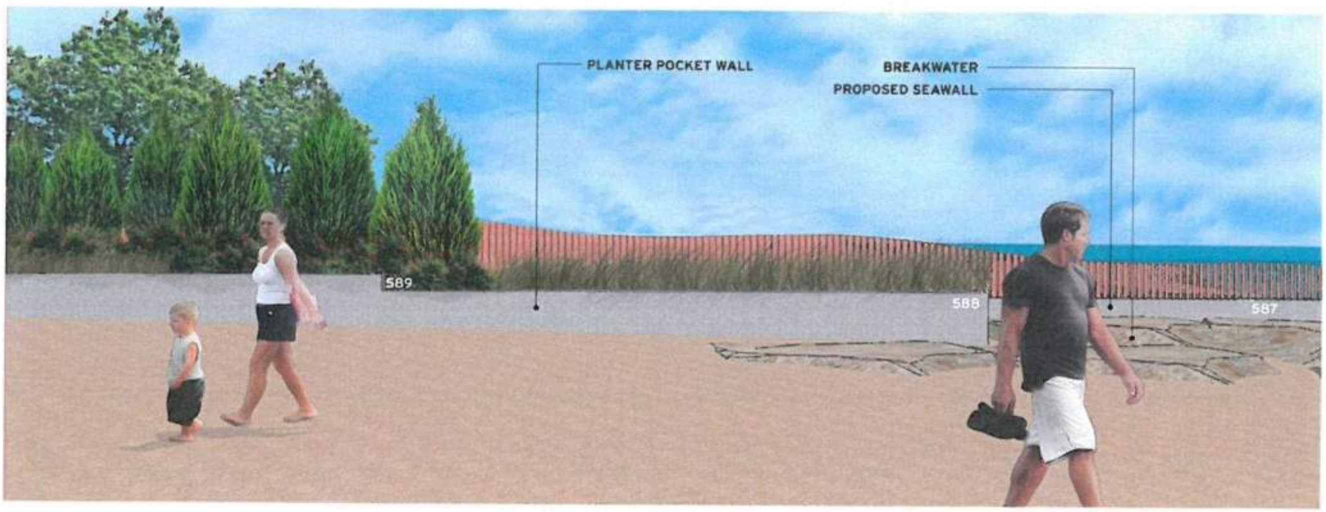


Proposed view looking south toward Elder Beach

Elder & Centennial Design Development – Renderings



Proposed view looking northeast from the bottom of the Elder Beach access ramp



Proposed view looking northwest from Elder Beach

John Edwardson
585 Bank Lane
Lake Forest, Illinois 60045

U.S. Army Corps of Engineers - Chicago District Regulatory Branch - East Section
231 South LaSalle Street, Suite 1500
Chicago, Illinois 60604

November 15, 2021

Dear Sir or Madam,

I authorize the placement of sand and stone on my property at 301 Sheridan Road as part of the Winnetka Park District lakefront project at Elder Lane Park Beach, 299 Sheridan Road, Winnetka. If additional information is required, please contact me at the address above.

Sincerely,

John Edwardson

C: Illinois Department of Natural Resources
Illinois Environmental Protection Agency
Shabica & Associates, Inc.

Orchard 2020 Revocable Trust
c/o Peter Lee, Trustee
353 N. Clark St., Floor 27
Chicago, Illinois 60654

U.S. Army Corps of Engineers - Chicago District Regulatory Branch - East Section
231 South LaSalle Street, Suite 1500
Chicago, Illinois 60604

November 15, 2021

Dear Sir or Madam,

I authorize the placement of sand and stone on the property at 209 Sheridan Road (to be known as 205 Sheridan Road) as part of the Winnetka Park District lakefront project at Centennial Park Beach, 225 Sheridan Road, Winnetka. If additional information is required, please contact me at the address above.

Sincerely,

Peter Lee, Trustee

C: Illinois Department of Natural Resources
Illinois Environmental Protection Agency
Shabica & Associates, Inc.

RICHARD J. DURBIN
ILLINOIS
DEMOCRATIC WHIP

United States Senate
WASHINGTON, DC 20510-1304

COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY
COMMITTEE ON APPROPRIATIONS
COMMITTEE ON THE JUDICIARY
COMMITTEE ON RULES AND ADMINISTRATION

October 13 2021

Colonel Paul Culberson
Commander, Chicago District
U.S. Army Corps of Engineers
231 S. LaSalle Street, Suite 1500
Chicago, Illinois, 60604

Dear Colonel Culberson:

I am writing to in support of the Winnetka Park District's proposal to create a protected beachfront area encompassing Elder and Centennial Parks. If approved, this project will fulfill a major piece of the Park District's "Winnetka Waterfront 2030" Plan and provide meaningful beachfront recreational opportunities for individuals in the community.

Extreme weather and climate change have been key factors in the high water levels along Lake Michigan, and have contributed to erosion and destruction of the shoreline. In addition to the elimination of accessible beachfront, the impact to the shoreline creates significant safety hazards.

Winnetka Park District's plan will address both the erosion of the beachfront as well as the safety risks presented by the current waterfront. My staff visited the current parks and witnessed firsthand the need to improve safety and accessibility of these beaches moving forward.

Please give full and fair consideration to Winnetka Park District's proposal. If you require additional information, please contact my State Director, Clarisol Duque, at (312) 353-4952.

Sincerely,

Dick Durbin

Richard J. Durbin
United States Senator

TAMMY DUCKWORTH
ILLINOIS

United States Senate

ARMED SERVICES
COMMERCE, SCIENCE, AND TRANSPORTATION
ENVIRONMENT AND PUBLIC WORKS
SMALL BUSINESS AND ENTREPRENEURSHIP

October 8, 2021

Colonel Paul Culberson
Commander, Chicago District
U.S. Army Corps of Engineers
231 S. LaSalle Street, Suite 1500
Chicago, Illinois, 60604

Colonel Culberson:

I write to express my support for the Winnetka Park District's Elder and Centennial Park Combined Park (the "Park") project. Understanding the importance of building sustainable beachfront infrastructure while handling Lake Michigan's high water levels and increasingly extreme weather conditions, Winnetka endeavors to prevent further erosion of their beaches and bluffs while accomplishing the long-stated goal of creating a unified park.

The Park is the culmination of the vision and strategy adopted by the Winnetka Park District in its Winnetka Waterfront 2030 Plan. It is my understanding that the Winnetka Park District's plan for this project includes combining two beach-front parks that are currently separated by a private residence into one contiguous parcel with nearly 1,000 feet of safe shoreline. Beyond generating significant new beach area, the Park plan aims to protect against further erosion of the beach, bluff and table land by including thoughtfully designed, soil protecting planting pockets and breakwaters with safety enhancements at the northern and southern boundaries of the Park. Additionally, the Park District has taken several measures to include ADA ramp access to the boardwalk and beach enabling recreational participation at the Park for individuals of all abilities.

As a U.S. Senator, I have made it a priority to support locally led projects that enhance public access to Illinois beaches, address potential safety concerns and sustainably protect against erosion. I believe the public's safe use of all parts of this park is of the utmost importance and I believe the Winnetka Park District is acting proactively to protect our residents and Park patrons.

In keeping with your existing rules and regulations, I urge you to give this proposal full and fair consideration. Should you have any questions, please contact my Chicago Director, Loren Harris, at (312) 886-3506.

Sincerely,

Tammy Duckworth

Tammy Duckworth
United States Senator

JANICE D. SCHAKOWSKY
9th District, Illinois

Committee on Energy and Commerce
Chair, Consumer Protection and Commerce
Environment and Climate Change
Oversight and Investigations

Committee on the Budget

Senior Chief Deputy Whip

Congress of the United States
House of Representatives
Washington, DC 20515-1309

2367 Rayburn House Office Building
Telephone 202-225-2111
Fax 202-226-6890
TTY 202-224-3901

5533 N. Broadway, Suite 2
Chicago, IL 60640
Telephone 773-506-7100
Fax 773-506-9202

1852 Johns Drive
Glenview, IL 60025
Telephone 847-328-3409
Fax 847-328-3425

October 8, 2021

Colonel Paul Culberson
Commander, Chicago District
U.S. Army Corps of Engineers
231 S. LaSalle Street, Suite 1500
Chicago, Illinois, 60604

RE: Letter of Support for Winnetka Park District's recent proposal for a lake front project encompassing Elder & Centennial Parks

Dear Colonel Culberson:

I am writing to share my enthusiastic support for the recent proposal submitted by the Winnetka Park District for an effort to create a protected beachfront area encompassing Elder and Centennial Parks. If approved, this project will fulfill a major piece of the Park District's "Winnetka Waterfront 2030" Plan and provide meaningful beachfront recreational opportunities for individuals in the community.

As a Member of Congress representing the 9th Congressional District for many years, I know that many of our community's proximity to Lake Michigan's shoreline is both a major benefit and a major challenge. High water levels along Lake Michigan in recent years have had a devastating impact on public spaces along its entire shoreline, and Winnetka is no exception. My staff were able to tour these parks firsthand and confirm that significant efforts are necessary to ensure safe and accessible use of these beaches moving forward.

It is my understanding that the Winnetka Park District's plan for this site encompasses the combination of these two parks in a way that ensure almost 1,000 feet of protected and safe shoreline for public use. According to Park District staff, this design will include dedicated and distinct swimming and paddleboat/kayak areas, a boardwalk, an event space, and more.

I am convinced that this proposed project will meaningfully benefit Winnetka and its residents. In keeping within your existing rules and regulations, I urge you to give this recent application full and fair consideration. If you need additional information and/or if you have questions, I encourage you to reach out to Mr. Andrew Goczkowski, the Grants Coordinator on my staff. He is available directly by telephone at 202-427-2176 or by email at Andrew.Goczkowski@mail.house.gov.

Sincerely,

Jan Schakowsky
Member of Congress

GENERAL ASSEMBLY

STATE OF ILLINOIS

United States Army Corps of Engineers
Chicago District
Regulatory Branch
231 S. LaSalle Street, Suite 1500
Chicago, IL 60604

October 7, 2021

Illinois Department of Natural Resources
OWR Lake Michigan Management Section
Michael A. Bilandic Building
160 N. LaSalle Street, Suite S-703
Chicago, Illinois 60601

Re: Letter of Support for Elder and Centennial Park Project

Dear Army Corps of Engineers and Illinois Department of Natural Resources:

Please accept this letter as evidence of our full support for the Winnetka Park District's plan to combine Elder Lane Park and Beach and Centennial Park and Beach to dramatically improve available lakefront recreation programming for Illinois residents to embrace and enjoy.

The Park District's work to create the new park is a wonderful culmination of the vision and strategy adopted by the Winnetka Park District in its Winnetka Waterfront 2030 Plan. We understand the plan is the product of numerous community engagement and planning sessions dating back to 2011 for the Park District and a Village of Winnetka strategy since the 1990s. We visited the two parks and beaches to gain significant appreciation for the design plan to combine the parks and beaches. It is a transformative plan for the benefit of the entire community and the public at large.

During the visit to Elder Lane Beach and Centennial Beach, we witnessed how Lake Michigan's high water levels and increasingly extreme weather conditions have deteriorated the steel groins currently on the site and how the conditions have significantly eroded the shorelines and bluffs at Elder Lane Park and Beach and

Centennial Park and Beach. We also learned about how the Park District has designed a breakwater plan for the new, combined park to protect the shorelines and bluffs and provide a safe recreation environment. In our view(s), the most important component of this new park is that the plan has many thoughtful design features to prevent further erosion of the beaches and bluffs while accomplishing the long-stated goal of creating a unified park with unparalleled amenities for the community.

Importantly, this new Park as designed accomplishes the following key objectives:

- Combines two beach-front parks that are currently separated by a private residence (rendering the beach front impassable) into one contiguous parcel, with nearly 1,000 feet of safe shoreline;
- Creates distinct recreation activities including a swimming area, a non-motorized watercraft area, 800 feet of continuous boardwalk, a large "T-shaped" sunbathing pier, and a new beachfront event space; and
- Generates significant new beach area and protects against further erosion of the beach, bluff and table land by including thoughtfully designed, soil protecting planting pockets and breakwaters with safety enhancements at the northern and southern boundaries of the Park.

Individually and collectively, we fully support the way this park and beach, as designed, addresses potential safety concerns. The new park and beach are expected to attract thousands of visitors per year. The public's safe use of all parts of the park and beach is of the utmost importance, and we support the extra steps taken by the Winnetka Park District to proactively protect our citizens and patrons.

GENERAL ASSEMBLY
STATE OF ILLINOIS

Thank you for your work and please feel free to contact us if you would like to discuss any aspect of this new Park further.

Sincerely,

Robyn Gabel

Laura Fine

Robyn Gabel
State Representative
District Office Address
2100 Ridge, Suite 2600
Evanston, IL 60201

Laura Fine
State Senator
District Office Address
1812 Waukegan Road, Suite A
Glenview, IL 60025

Village of
WINNETKA, IL
Office of the Village Manager
847.716.3541

510 Green Bay Road · Winnetka, IL 60093 · 847.501.6000
contactus@villageofwinnetka.org · **villageofwinnetka.org**

October 8, 2021

United States Army Corps of Engineers
Chicago District
Regulatory Branch
231 S. LaSalle Street, Suite 1500
Chicago, IL 60604

Illinois Department of Natural Resources
OWR Lake Michigan Management Section
Michael A. Bilandic Building
160 N. LaSalle Street, Suite S-703
Chicago, Illinois 60601

Re: Letter of Support for Elder and Centennial Park Project

Dear United States Army Corps of Engineers and Illinois Department of Natural Resources:

Please accept this letter as evidence of the Village of Winnetka's full support for the Winnetka Park District's plan to combine Elder Lane Park and Beach and Centennial Park and Beach to dramatically improve available lakefront recreation programming, which Illinois residents will embrace and enjoy.

The Park District's work to create the new park is a wonderful culmination of the vision and strategy adopted by the Winnetka Park District in its Winnetka Waterfront 2030 Plan. The plan is the product of numerous community engagement and planning sessions dating back to 2011 for the Park District. The plan also has been part of the Village of Winnetka's current Comprehensive Plan. While we have visited the parks and beaches many times, we most recently visited the two parks and beaches October 5 and October 6 to, again, gain significant appreciation for the design plan to combine the parks and beaches. It is a transformative plan for the benefit of the entire community and the public at large.

We have witnessed how Lake Michigan's high water levels and increasingly extreme weather conditions have deteriorated the steel groins currently on the site and how the conditions have significantly eroded the shorelines and bluffs at Elder Lane Park and Beach and Centennial Park and Beach. The Park District has designed a breakwater plan for the new, combined park to protect the shorelines and bluffs and provide an engaging recreation environment. The most important component of this new park is that the plan has many thoughtful design features to prevent further erosion of the beaches and bluffs while accomplishing the long-stated goal of creating a unified park with unparalleled amenities for all visitors.

Importantly, this new Park as designed accomplishes the following key objectives:

- Combines two beach-front parks that are currently separated by a private residence (rendering the beach front impassable) into one contiguous parcel, with nearly 1,000 feet of shoreline;
- Creates distinct recreation activities including a swimming area, a non-motorized watercraft area, 800 feet of continuous boardwalk, a large "T-shaped" sunbathing pier, and a new beachfront event space; and
- Generates significant new beach area and protects against further erosion of the beach, bluff and tableland by including thoughtfully designed, soil protecting planting pockets and breakwaters at the northern and southern boundaries of the Park.

We fully support the Winnetka Park District's design for this park and beach. The new park and new beach are expected to attract thousands of visitors each year. The public's use of all parts of the park and beach is of the utmost importance, and we support the extra steps taken by the Winnetka Park District to provide remarkable access to Lake Michigan for our citizens and all patrons.

Thank you for your work and please feel free to contact either of us if you would like to discuss any aspect of this new park further.

Sincerely,

Christopher D. Rintz
President, Village Council
Village of Winnetka
510 Green Bay Road
Winnetka, IL 60093

Robert M. Bahan
Village Manager
Village of Winnetka
510 Green Bay Road
Winnetka, IL 60093

October 7, 2021

Mr. Soren Hall
United States Army Corps of Engineers
Chicago District, Regulatory Branch
231 South LaSalle Street, Unit 1500
Chicago, Illinois 60604

James P. Casey, Chief
Lake Michigan Management Section
Illinois Department of Natural Resources
Office of Water Resources
160 N. LaSalle Street, Suite S-703
Chicago, IL 60601

RE: Letter of Support for Elder Lane Park and Beach + Centennial Park and Beach Project

Dear United States Army Corps of Engineers and Illinois Department of Natural Resources:

Please accept this letter as evidence of my full support for the Winnetka Park District's plan to combine Elder Lane Park and Beach and Centennial Park and Beach, which will dramatically improve available lakefront recreation programming for Winnetka residents and the community at large to enjoy for decades to come.

The Park District's work to create the new park is a wonderful culmination of the vision and strategy adopted by the Winnetka Park District in its Winnetka Waterfront 2030 Plan. I understand the plan is the product of numerous community engagement and planning sessions dating back to 2011 for the Park District and a Village of Winnetka strategy since the 1990s. As a Winnetka resident and a neighbor to the north of Elder Lane Park, I often visit the two parks and beaches. I have significant appreciation for the design plan to combine the parks and beaches; it is a transformative plan for the benefit of the entire community and the public at large.

As a resident along the shoreline, I am keenly aware of Lake Michigan's high water levels and increasingly extreme weather conditions. The water levels and severe storms have deteriorated the steel groins currently on the Elder and Centennial shorelines and have significantly eroded the shorelines and bluffs at Elder and Centennial. I have come to learn about how the Park District has designed a breakwater plan for the new, combined park to protect the shorelines and bluffs and provide an engaging recreation environment.

In my opinion, the most important component of this new park is that the plan has many thoughtful design features to prevent further erosion of the beaches and bluffs while accomplishing the long-stated goal of creating a unified park with unparalleled amenities for the community.

Importantly, this new Park as designed accomplishes the following key objectives:

- Combines two beach-front parks that are currently separated by a private residence (rendering the beach front impassable) into one contiguous parcel, with nearly 1,000 feet of shoreline;
- Creates distinct recreation activities including a swimming area, a non-motorized watercraft area, 800 feet of continuous boardwalk, a large "T-shaped" sunbathing pier, and a new beachfront event space; and
- Generates significant new beach area and protects against further erosion of the beach, bluff and tableland by including thoughtfully designed, soil protecting planting pockets and breakwaters at the northern and southern boundaries of the combined property.

I fully support the Winnetka Park District's Elder and Centennial plan, as designed. The new park likely will attract thousands of visitors per year. The public's use of all parts of this park received my full support. I appreciate the extra steps taken by the Winnetka Park District to proactively provide Winnetka residents and all park patrons with remarkable access to Lake Michigan.

Thank you for your work with the Winnetka Park District.

Sincerely,

Dmitry Godin

Dmitry Godin
319 Sheridan Road
Winnetka, IL 60093

October 7, 2021

Mr. Soren Hall

United States Army Corps of Engineers

Chicago District, Regulatory Branch

231 South LaSalle Street, Unit 1500

Chicago, Illinois 60604

James P. Casey, Chief

Lake Michigan Management Section

Illinois Department of Natural Resources

Office of Water Resources

160 N. LaSalle Street, Suite S-703

Chicago, Illinois 60601

RE: Letter of Support for Elder Lane Park and Beach + Centennial Park and Beach Project

Dear United States Army Corps of Engineers and Illinois Department of Natural Resources:

Please accept this letter as evidence of my full support for the Winnetka Park District's plan dated September 9, 2021 to combine Elder Lane Park and Beach and Centennial Park and Beach, which will improve available lakefront recreation programming for Winnetka residents and the community at large to enjoy for decades to come. The Park District's work to create the new park is a wonderful culmination of the vision and strategy adopted by the Winnetka Park District in its Winnetka Waterfront 2030 Plan. I understand the plan is the product of numerous community engagement and planning sessions dating back to 2011 for the Park District and a Village of Winnetka strategy since the 1990s. As a Winnetka resident and a neighbor to the north of Elder Lane Park, I often visit the two parks and beaches. I have great appreciation for the design plan to combine the parks and beaches; it is a transformative plan for the benefit of the entire community and the public at large.

As a resident along the shoreline, I am keenly aware of Lake Michigan's high water levels and the damage resulting therefrom. The recent water levels and severe storms have deteriorated the steel groins currently on the Elder and Centennial shorelines and have significantly eroded the shorelines and bluffs at Elder and Centennial. I support the Park District's breakwater plan for the new, combined park to protect the shorelines and bluffs and, at the same time, provide a remarkable recreation environment. The most important component of this new park is that the plan has many thoughtful design features to prevent further erosion of the beaches and bluffs while accomplishing the long-stated goal of creating a unified park with unparalleled amenities for the community.

Importantly, this new Park as designed accomplishes the following key objectives:

- Combines two beach-front parks currently separated by a private residence (rendering the beach front impassable) into one contiguous parcel, with nearly 1,000 feet of shoreline;
- Creates distinct recreation activities: a swimming area, a non-motorized watercraft area, 800 feet of continuous boardwalk, a large "T-shaped" sunbathing pier, and a new beachfront event space; and
- Generates significant new beach area and protects against further erosion of the beach, bluff and tableland by including thoughtfully designed, soil protecting planting pockets and breakwaters with enhancements at the northern and southern boundaries of the Park.

I fully support the plan for Elder and Centennial, as designed. The new park likely will attract thousands of visitors per year. The public's use of all parts of this park is of the utmost importance, and I support the extra steps taken by the Winnetka Park District to proactively provide such for Winnetka residents and all park patrons.

This letter of support does not grant any easements to the Winnetka Park District.

Thank you for your work with the Winnetka Park District.

Sincerely,

301 Sheridan Road, Winnetka, IL 60093

Re: Letter of Support for Elder and Centennial Park Project 10/5/2021

Dear Winnetka Park District,

My family and I would like to express our complete support for the pending combination of Elder and Centennial Park into one large lakefront park and beach system. We are in full support of the combined park in its current design.

We are excited about the many opportunities and amenities the project offers to all Winnetka residents and their guests. We appreciate the Park District's effort to support infrastructure improvements which are required due of high lake water levels, and address erosion and bluff deterioration through the project.

Additionally, we fully encourage the Park District's addition of an accessible walking path to the beach and the new driveway allowing emergency vehicle access to the beach. Should the Park District allow any kind of usage for dogs, keeping the dogs on Park District property and beach is critical.

Thank you to the Winnetka Park District for their planning, hard work, and perseverance to bring these unbelievable new amenities to the shores of our Village.

Sincerely,

Re: Letter of Support for Elder and Centennial Park Project 10/5/2021

Dear Winnetka Park District,

My family and I would like to express our complete support for the pending combination of Elder and Centennial Park into one large lakefront park and beach system. We are in full support of the combined park in its current design.

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Additionally, we fully encourage the Park District's addition of an accessible walking path to the beach and the new driveway allowing emergency vehicle access to the beach. Should the Park District allow any kind of usage for dogs, keeping the dogs on Park District property and beach is critical.

Thank you to the Winnetka Park District for their planning, hard work, and perseverance to bring these unbelievable new amenities to the shores of our Village.

LEO BIRDU

Sincerely, 195 SHERIDAN RD

WINNETKA, IL, 60093

847-4620500

JOINT APPLICATION FORM FOR ILLINOIS

ITEMS 1 AND 2 FOR AGENCY USE

1. Application Number	2. Date Received

3. and 4. (SEE SPECIAL INSTRUCTIONS) NAME, MAILING ADDRESS AND TELEPHONE NUMBERS

3a. Applicant's Name:	3b. Co-Applicant/Property Owner Name (if needed or if different from applicant):	4. Authorized Agent (an agent is not required):
John Peterson, Executive Director	Peter Lee, Trustee	Jon Shabica
Company Name (if any): Winnetka Park District	Company Name (if any): Orchard Revocable Trust	Company Name (if any): Shabica & Associates, Inc.
Address: 540 Hibbard Road Winnetka, IL 60093	Address: 353 N. Clark Street, Floor 27 Chicago, IL 60654	Address: 550 Frontage Road, Suite 3735 Northfield, IL 60093
Email Address: JPeterson@winpark.org	Email Address: peter.lee@summittrail.com	Email Address: jon@shabica.com
Applicant's Phone Nos. w/area code	Applicant's Phone Nos. w/area code	Agent's Phone Nos. w/area code
Business: 847-501-2074	Business: 312-660-1260	Business: 847-446-1436
Residence:	Residence:	Residence:
Cell:	Cell:	Cell:
Fax:	Fax:	Fax:

STATEMENT OF AUTHORIZATION

I hereby authorize, Shabica & Associates, Inc. to act in my behalf as my agent in the processing of this application and to furnish, upon request, supplemental information in support of this permit application.

[signatures] 11.01.2021 (JP) 11/2/21 (PL)

Applicant's Signature Date

5. ADJOINING PROPERTY OWNERS (Upstream and Downstream of the water body and within Visual Reach of Project)

Name	Mailing Address	Phone No. w/area code
a. see attached list		
b.		
c.		
d.		

6. PROJECT TITLE:
Breakwater-Protected Beach System

7. PROJECT LOCATION:
299, 261 and 225 Sheridan Road, Winnetka, IL 60093

LATITUDE: 42.09959 °N	UTMs	
LONGITUDE: -87.71571 °W	Northing: 4661083.75 m	
	Easting: 16T 440816.10 m	

STREET, ROAD, OR OTHER DESCRIPTIVE LOCATION	LEGAL DESCRIPT	QUARTER	SECTION	TOWNSHIP NO.	RANGE
299, 261 and 225 Sheridan Road		SE	21	42N	13E

☐ IN OR ☐ NEAR CITY OF TOWN (check appropriate box)	WATERWAY	RIVER MILE (if applicable)
Municipality Name: Winnetka	Lake Michigan	

COUNTY	STATE	ZIP CODE
Cook	IL	60093

Revised 2010

☐ Corps of Engineers ☐ IL Dep't of Natural Resources ☐ IL Environmental Protection Agency ☐ Applicant's Copy

8. PROJECT DESCRIPTION (Include all features):

This application is submitted for the removal of existing structures and for the construction of new structures. Four steel jetties, steel sheet piles, a concrete pier, an existing stormwater discharge pipe, and a chain-link fence are being removed as part of this project. The proposed new breakwater protected beach system is comprised of three quarrystone and steel breakwater structures and a steel and concrete pier in the center. All the lengths noted below are toe to toe. The northernmost breakwater is a shore-connected stone and steel breakwater that projects east into the lake and then curves south. It is 265' in length as measured perpendicular to shore and includes two sections of sheetpile. The northern section of sheetpile is a 155' long curved row of capped steel tapering from 590' at the bluff toe down to 587'. Attached to the cap are 155' of steel louvers tapering from 596.7' down to 588.5'. The southern section of sheetpile is a 100' long row of capped steel tapering from 590' at the bluff toe down to 587'. This row creates the planter pocket and establishes the vehicular ramp edge. The most eastern section of the breakwater structure will be quarrystone with a 3 stone crest tapering from 587' to 586' lakeward. The existing 54" stormwater outfall will be relocated into this breakwater with two 36" steel ductile pipes that exit at the east end of the structure embedded within the armor stone. Moving to the south after a 150' gap is a 260' long breakwater/pier with a 300' long steel and concrete pier connecting to land. The lakeward portion of the pier will be 16' wide with a crest of 585' surrounded by quarrystone with a crest at 587'. The land connecting section will be 13' wide and will taper from 587' landward to 585' where it connects to the lakeward section. Moving south past a 180' gap, there is the southernmost shore-connected stone and steel breakwater. This breakwater projects east into the lake and then curves north, mirroring the north breakwater. It is 300' in length as measured perpendicular to shore and includes two sections of sheetpile. The southern section of sheetpile is a 185' foot long row of capped steel tapering from 591' at the bluff toe down to 587'. Attached to the cap are 185' of steel louvers tapering from 597.5' down to 588.5'. The northern section of sheet piling is a 113' long curved row of capped steel tapering from 590' at the bluff toe down to 587'. This row creates the planter pocket. The most eastern section of the breakwater structure will be quarrystone with a 3 stone crest tapering from 587' to 586' lakeward. The slopes of all quarrystone structures will be 1v:1.5h, and sandfill will be placed in accordance with IDNR regulations. New steel sheetpiles and caps will be installed along the bluff and beach. The new vehicular access ramp apron at the beach will be formed by a steel sheetpile wall. Starting at 590' near the existing sea wall, it tapers east to 580'. South of this structure, approximately 156.25' of sheeting, set at elevation 590', will be installed along the bluff until it reaches the existing concrete stairs adjacent to the existing beach house. South and east of the beach house, three new sections of sheeting will be installed in lengths of approximately 183.9', 152' and 126.9'. These lengths of sheeting will allow for ADA ramp connections to be made to the proposed pier and center breakwater structure. All of the steel is being installed to protect these improvements from undercutting and possible future damage due to fluctuating lake levels. The Winnetka Park District is requesting a 10-year sand nourishment permit. The Winnetka Park District would like to have the ability to mobilize up to 2,000 cubic yards of sand annually if and when necessary to help maintain a stable beach and the metastable equilibrium.

9. PURPOSE AND NEED OF PROJECT:

Stabilization of a public beach facility, as well as bluff toe protection, improved access, and increased public recreational activities

COMPLETE THE FOLLOWING FOUR BLOCKS IF DREDGED AND/OR FILL MATERIAL IS TO BE DISCHARGED

10. REASON(S) FOR DISCHARGE:

Stabilization of a public beach facility, as well as bluff toe protection

11. TYPE(S) OF MATERIAL BEING DISCHARGED AND THE AMOUNT OF EACH TYPE IN CUBIC YARDS FOR WATERWAYS:

TYPE: Quarried stone and sand

AMOUNT IN CUBIC YARDS:

9,276 cubic yards of stone, 23,200 cubic yards of sand

12. SURFACE AREA IN ACRES OF WETLANDS OR OTHER WATERS FILLED (See Instructions)

1.0 acre

13. DESCRIPTION OF AVOIDANCE, MINIMIZATION AND COMPENSATION (See instructions)

After working through the master plan process, the design meets the needs of the community.

14. Date activity is proposed to commence

Summer 2022

Date activity is expected to be completed

Fall 2023

15. Is any portion of the activity for which authorization is sought now complete? Yes ☐ No ☒

NOTE: If answer is "YES" give reasons in the Project Description and Remarks section. Indicate the existing work on drawings.

Month and Year the activity was completed

16. List all approvals or certification and denials received from other Federal, interstate, state, or local agencies for structures, construction, discharges or other activities described in this application.

Issuing Agency	Type of Approval	Identification No.	Date of Application	Date of Approval	Date of Denial

17. CONSENT TO ENTER PROPERTY LISTED IN PART 7 ABOVE IS HEREBY GRANTED. Yes No

18. APPLICATION VERIFICATION (SEE SPECIAL INSTRUCTIONS)

Application is hereby made for the activities described herein. I certify that I am familiar with the information contained in the application, and that to the best of my knowledge and belief, such information is true, complete, and accurate. I further certify that I possess the authority to undertake the proposed activities.

[signature] 4-11-2022

Signature of Applicant or Authorized Agent — Date

Signature of Applicant or Authorized Agent — Date

Signature of Applicant or Authorized Agent — Date

☐ Corps of Engineers ☐ IL Dep't of Natural Resources ☐ IL Environmental Protection Agency ☐ Applicant's Copy

Revised 2010

SEE INSTRUCTIONS FOR ADDRESS

Vicinity Map

Shoreline Stabilization Project

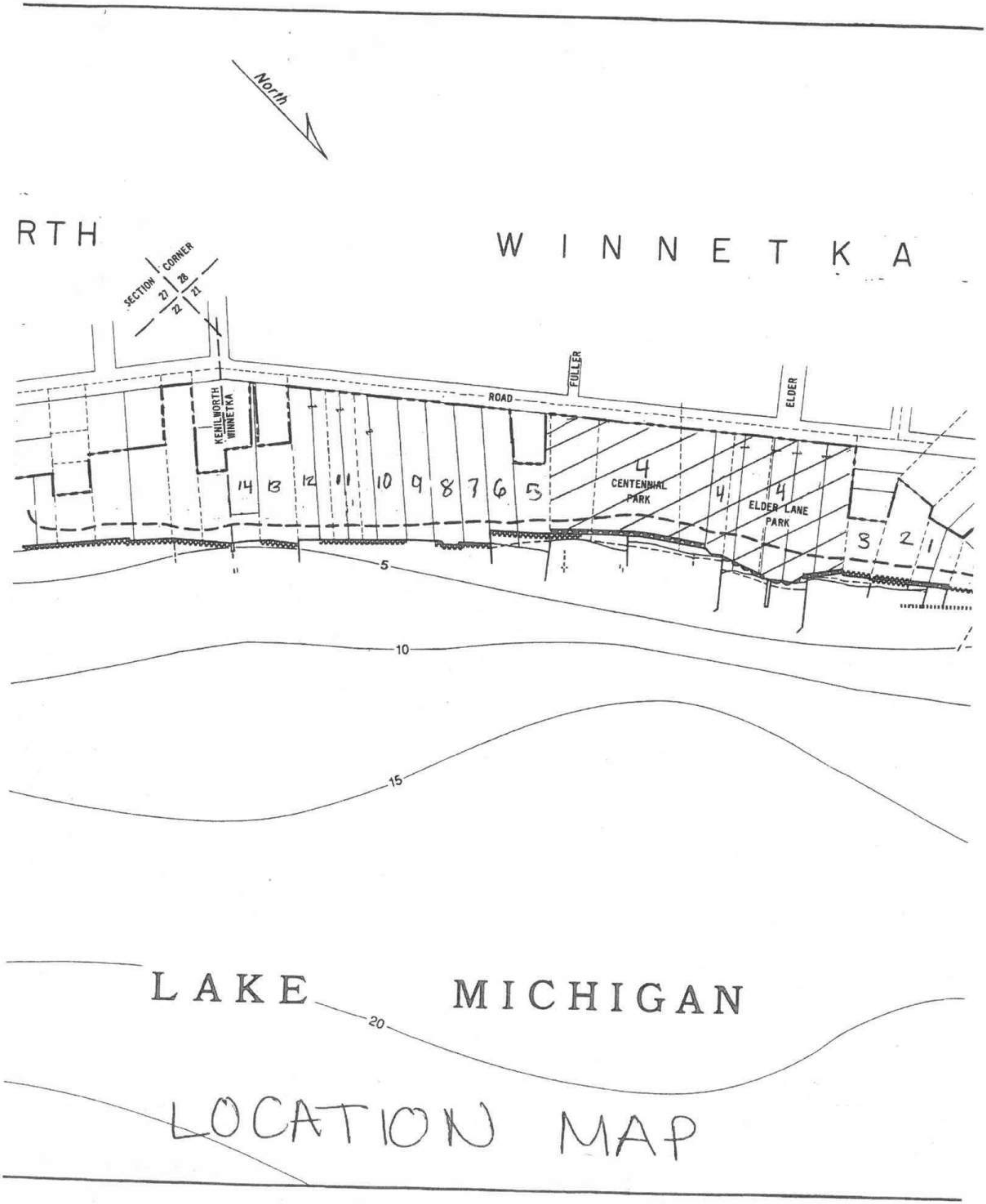
Elder Lane Park and Centennial Park
299, 261 and 225 Sheridan Road
Winnetka, IL 60093

Shabica & Associates, Inc.

Location of Project: 299, 261 and 225 Sheridan, Winnetka, IL 60093

List of property owners (from North to South):

1. Doug & Karen Kiersey, 335 Sheridan Road, Winnetka, IL 60093
2. Dmitry Godin, 319 Sheridan Road, Winnetka, IL 60093
3. John A. Edwardson, 301 Sheridan Road, Winnetka, IL 60093
   (mailing: 585 Bank Lane, Lake Forest IL 60045)
4. Subject Properties: Elder Lane Park, 299 Sheridan Road, Winnetka, IL 60093
   (mailing: Winnetka Park District, 540 Hibbard Road, Winnetka, IL 60093)
   Orchard 2020 Revocable Trust, 261 Sheridan Road, Winnetka, IL 60093
   (mailing: 353 N. Clark Street, Floor 27, Chicago, IL 60654)
   Centennial Park, 225 Sheridan Road, Winnetka, IL 60093
   (mailing: Winnetka Park District, 540 Hibbard Road, Winnetka, IL 60093)
5. Orchard 2020 Revocable Trust, 209 Sheridan Road (to be known as 205 Sheridan Road), Winnetka, IL 60093
   (mailing: 353 N. Clark Street, Floor 27, Chicago, IL 60654)
6. Walton 2019 Revocable Trust, 203 Sheridan Road (to be known as 205 Sheridan Road), Winnetka, IL 60093
   (mailing: 353 N. Clark Street, Floor 27, Chicago, IL 60654)
7. Leo Birov, 195 Sheridan Road, Winnetka, IL 60093
   (mailing: 1741 Harding Road, Northfield, IL 60093)
8. Nancy Santi, 191 Sheridan Road, Winnetka, IL 60093
9. Joint Management LLC, 181 Sheridan Road, Winnetka, IL 60093
   (mailing: 309 W. Chicago Avenue, #1R, Chicago, IL 60654)
10. Robert & Carol Rasmus, 175 Sheridan Road, Winnetka, IL 60093
11. Richard Tinberg, 159 Sheridan Road, Winnetka, IL 60093
12. Jason Hanold, 151 Sheridan Road, Winnetka, IL 60093
    (mailing: 207 Cumberland Avenue, Kenilworth, IL 60043)
13. John McDonagh III, 141 Sheridan Road, Winnetka, IL 60093
    (mailing: 700 Harvard Street, Wilmette, IL 60091)
14. Mike Bonds, 139 Sheridan Road, Winnetka, IL 60093
    (mailing: 137 Sheridan Road, Winnetka, IL 60093)



LOCATION MAP

Elder/Centennial Beach Monitoring **February 24, 2022**

As the performance of shore protection structures cannot be predicted with absolute certainty, the shore protection system for Elder/Centennial Beach, Winnetka will be inspected as described in the 5-Year Monitoring Plan.

Objective: Document amount of sand that accumulates or is lost from the littoral system after construction of the proposed project. Based on 30+ years experience monitoring similar projects, for example Sunrise Beach, Lake Bluff and Forest Park Beach, Lake Forest, we recommend the following:

Survey: Pre and Post construction (as-built) and 4 more annual surveys.

Method: Bathymetry using Trimble R10 GPS Receiver with Hydrolite-TM Single Beam Echosounder. Survey tied to Trimble VRS Now Network. Data points are collected in NAVD88 Datum, converted to IGLD88. Lakebed elevation changes will be shown at 1 foot intervals along shore perpendicular transects spaced 50 feet apart at project site and 100 feet apart downdrift.

Location: 500 feet updrift (north) of Elder Lane Park, 950 feet through both beaches and 700 feet downdrift (south) of Centennial Park. Bathymetric surveys to extend from bluff toe (or seawall or revetment) to 600 feet offshore. See attached map.

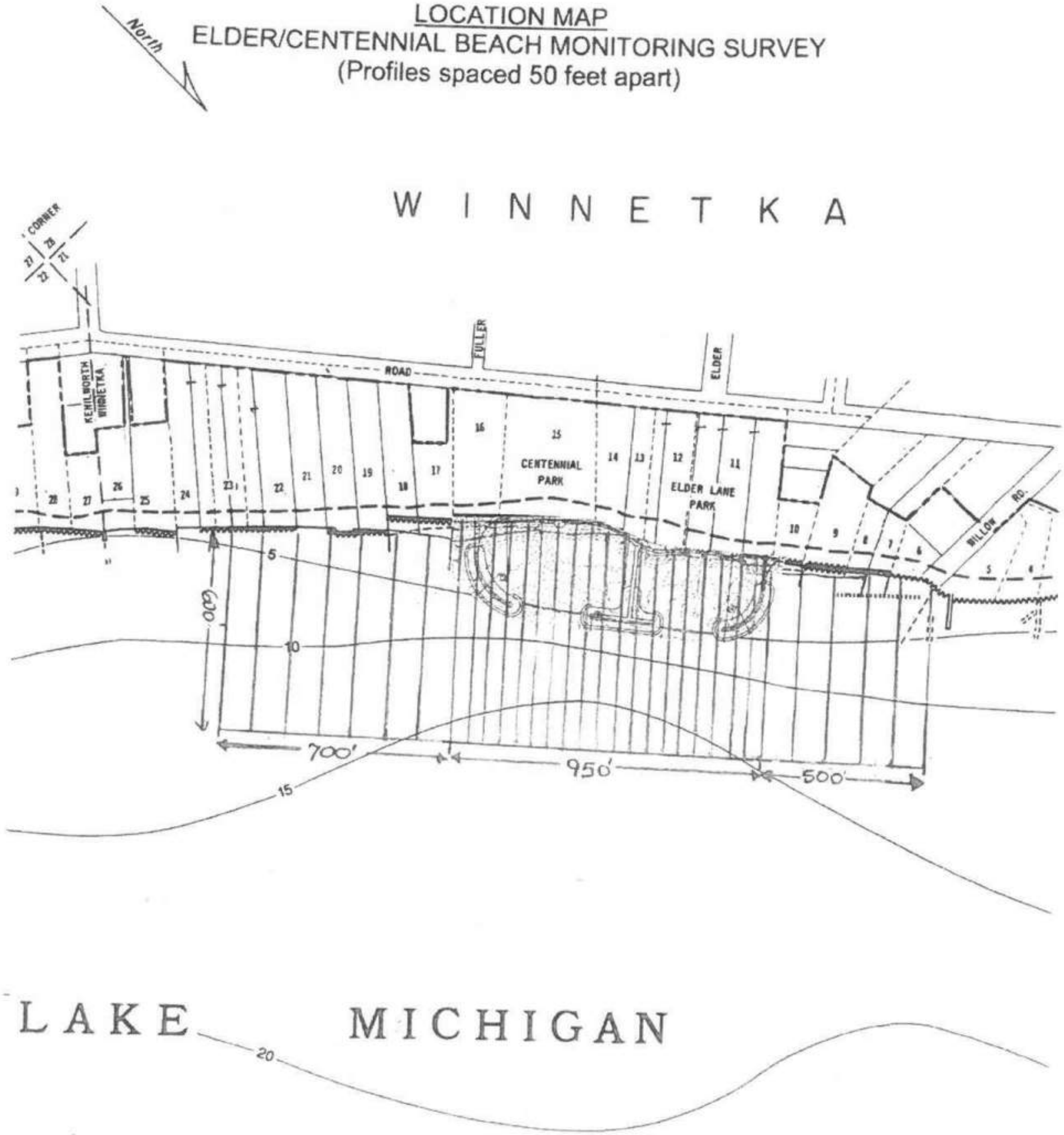
Sand Loss/Gain: Calculate annual sand volume change within the beach system as well as updrift and downdrift properties. Show areas of sand gain and loss. Any dredged material removed after the most recent survey will be included in the sand calculations for the following year.

Additionally:

1. Surveys will be performed by a licensed surveyor with experience working in coastal environments
2. Surveys will be performed on the water when wave conditions are less than one foot
3. The location of the Ordinary High Water Mark (581.5 IGLD-85) will be clearly marked along the entire monitoring area
4. Survey notes will include: water level and weather/wave conditions at the time of the data collection
5. Records of major storm events occurring each year will be included

550 Frontage Road • Suite 3735 • Northfield, Illinois 60093 • Tel 847.446.1436 • info@shabica.com
www.shabica.com

LOCATION MAP
ELDER/CENTENNIAL BEACH MONITORING SURVEY
(Profiles spaced 50 feet apart)



550 Frontage Road • Suite 3735 • Northfield, Illinois 60093 • Tel 847.446.1436 • info@shabica.com
www.shabica.com

Table of Contents

AECOM Technical Services, Inc.
303 E. Wacker DRive, Suite 1400 Chicago, Ill.
60601-5276

Executive Summary

Subject: Elder/Centennial Park Shoreline Improvements
Planting Pocket Habitat, Beach Sand Nourishment Protection, & Breakwater Structure Design

The Winnetka Park District (WPD) plans to improve and conjoin Elder and Centennial Park and the adjacent beach areas into one combined park. The project will resolve access, erosion and structural damages in the beach areas that have occurred over time and will provide a significant upgrade to the community park system in Winnetka.

Other portions of the permit application for this project will outline the existing deficiencies at the project site and describe portions of the stone and steel breakwaters proposed for the project. This report and supporting calculations focus largely on the steel portions of the proposed breakwaters. It will demonstrate the included steel wave baffle structures will provide protection for the beach and planting pocket areas; will reduce the potential for beach erosion during storm events; and show that the steel portions of the breakwater system are appropriately structurally engineered and robust enough to withstand Lake Michigan wind, wave, and ice events without exceeding material limits for allowable stress or deformation.

- The project will include an expansion of beach size and character by replacing the existing Lake Michigan coastal structures. Details are provided in the permit application.
- The steel portions of the breakwater structure ("baffle structure") will be comprised of both steel sheet piles ("piles"), steel caps ("caps") and panelized vertical steel plate wave louvers ("louvers") designed to manage wave attack and minimize overtopping damage.
- The louvers will increase the stability of the beach and sand retention by reducing wave transmission and turbulence. The additional amount of retained sand on the lakebed will increase habitat.
- The planting pocket zones, which are shielded by the landward 100' of louvers, will experience a reduced amount of stress and damage because the louvers will reduce wave overtopping and runup in these areas. Sand entrained waves will strike the baffle structures and reduce impact potential by reducing wave overtopping flows and also by reflecting some of these flows back to the lake.
- The baffle structures will provide additional protection within the beach cell areas that are protected by the breakwaters. The louvers alone will reduce breakwater wave overtopping potential by approximately 9% at the north breakwater and by approximately 4% at the south breakwater, when compared to the armor stone breakwater areas that don't include these structures. The reduced flows through the louvers will reduce the amount of wave energy that reaches shore, thus helping retain sand within the beach cells and reducing the amount of stress at the planting areas.
- These baffle structures are to be constructed as part of and on the crest of the breakwaters and provide the amount of overtopping reduction indicated above without increasing the footprint of the breakwater structures on the lake bottom. The composite design provides for wave overtopping control in a compact fashion that minimizes the lake bottom fill when compared to an armor stone breakwater constructed at higher elevations.
- The baffle structures have been designed to withstand wave attack from a 200-year recurrence interval wave storm. Several combinations of lake level and wave height recurrence intervals were considered in the design. The baffle structures are comprised of a steel sheet pile wall and vertical steel plate louvers mounted on top of the steel sheet pile cap. They are designed to withstand the

wave loads that the structure will be exposed to. The louvers will be structurally connected to the steel sheet pile and designed to withstand loads imparted by wave storms. The base of the structure will be a wide flange steel sheet pile wall driven into the ground and buttressed on both sides by the armor stone breakwater.

Project Understanding

The Winnetka Park District (WPD) plans to improve Elder and Centennial Beaches as shown on the following rendering:

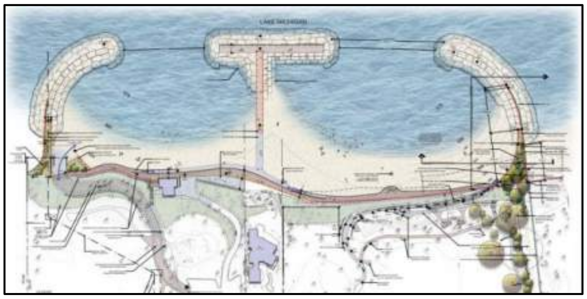


Figure 1. Proposed Beach Plan

Steel Baffle structures are proposed to be placed as a vertical extension of the armor stone breakwaters at the west end of the North and South breakwater structures. These baffle structures will provide a vertical extension of the breakwater crest to provide protection against wave overtopping that would otherwise cause beach erosion and damage to proposed planted habitat. The wave baffle concept includes the following features:

- A steel sheet pile wall base and attached vertical steel plate wave louvers that extend the vertical height of the breakwater to reduce wave overtopping potential. This concept allows for added wave protection without a large increase in the footprint of the armor stone breakwater on the lakebed.
- The reduction in wave overtopping and transmission will reduce potential for beach erosion. It will also reduce the potential for wave overtopping and transmission that would otherwise approach the proposed planting beds along the shoreline at the west end of the breakwater structures.
- The louvers are angled at 40 degrees with a 4" spacing providing views to the lake from shore while also reducing wave overtopping and transmission.

This report summarizes the following engineering studies performed for the baffle structures:

- Wave transformation analysis from deep water proceeding to the design site quantifies wave characteristics and attack stress that approach and impact the baffle structures.
- Structural analysis guides the baffle structure design.
- Breakwater system overtopping analysis for the design storm events provides information needed to design the baffle structures. The design seeks to reduce wave overtopping and runup in areas where waves would cause beach erosion and approach the planted habitat areas.

The baffle structures are designed to reduce beach erosion and to protect proposed plant habitat.

Wave Transformation Analysis

Wave transformation analysis includes an evaluation of the design wave condition at the project site. This analysis is completed in steps as follows:

- The analysis begins with a determination of offshore deep water wave storm conditions. The Corps of Engineers Wave Information Study Site No. 94027 provides deep-water wave information offshore from the project site. The deep-water location provides sufficient depth that the wave character is not significantly influenced by the lakebed. This information includes a wave height data base for the period of record from 1960 to 2014. Wave height recurrence intervals are determined for several directions of attack to the design site. Wave frequency analysis is performed for the historic wave record to evaluate wave height recurrence intervals from a variety of directions.

For this project, the directions of interest are from the North-Northeast, East, and Southeast. Waves from the NNE are likely to provide the greatest amount of stress for the North Breakwater and from the Southeast are likely to provide the greatest stress on the south breakwater. Waves from the East will travel directly towards shore approximately perpendicular to the beach. While we don't anticipate that this third wave case will control the design, it is included in the analysis to be sure.

The analysis evaluates wave attack from three directions. Waves from the NNE (Class 3) are the largest waves. We also analyze waves approaching from the East (Class 2) and waves approaching from the SE (Class1). Class 1 and Class 3 waves will refract to shore and approach the design site at an angle. Class 2 waves approach shore with only minor refraction and generally travel in a westerly direction. The controlling case for the North breakwater will be the Class 3 wave and for the South breakwater will be the Class 1 wave. The wave transformation analysis provides the wave characteristics approaching the breakwater structures including the angle of attack, wave height, wavelength, wave period and other factors that influence the wave stress that reaches the proposed breakwater structures.

The analysis considers a 200-year wind wave storm. Wave storm recurrence intervals consider the combined probability of lake levels and wave heights. The analysis considers two different combinations of these factors: a) a storm with a 20-year lake level and a10-year wave height, and b) a storm with a 10-year lake level and a 20-year wave height. Both events produce a 200-year wave event. Both are evaluated to assess which produces the worst-case condition in terms of wave stress on the breakwater baffle structures. The wave transformation analysis considers the following wave influences:

- Wave refraction causes the waves to turn from their deep-water direction of travel towards shore. This phenomenon is due to the influence of the gradually shallower lakebed and increased bottom friction on the side of the wave that is closest to shore. This analysis provides an indication of the angle at which the wave will approach the breakwater. Waves that approach the breakwater perpendicular to the structure cause a greater stress compared to waves that hit the breakwater at an angle.
- As a wave approaches shore, the water depth is gradually reduced. This causes the wave to break and reform at smaller wave heights. This process occurs gradually as the wave approaches shore. A surf zone analysis was completed to evaluate the transformation of the wave as it progresses through the surf zone to the design site. The analysis provides an estimate of the wave height and other characteristics that influence the forces imparted to the breakwater and baffle structures. The location of baffle structures included in the breakwater crest varies for the north and south breakwater structures. the inside surfaces of the breakwater structures that are within the overall proposed beach cell receive less wave stress than the outside faces of the north and south breakwaters. This is because the central breakwater and the water gaps on each side will cause wave diffraction as waves expand into the beach area west of the gap. The baffle structure design focuses on the north side of the north breakwater, and the south side of the south breakwater. These locations are where the wave attack stresses are the greatest and where structural intervention can have the most significant influence on wave energy reduction within the beach cell.
- Results of the wave transformation analysis provide design boundary conditions for the breakwater and baffle structures. This includes the height of the wave that attacks or breaks on the breakwaters and other wave characteristics that are needed for design such as wave period, lake level and breakwater structure geometry. Structural analysis is then performed to design baffle structures that can manage the wave attack. Wave overtopping analysis for the storm events is also performed to help understand the potential for beach erosion and to design baffle structures to protect the beach and proposed plant habitat to be created adjacent to the west ends of the structures.

A wave transformation analysis that transforms the wave from deep water to the breakwater locations is provided in Appendix A. This analysis provides the wave height approaching the north and south breakwaters and the angle of attack to the structures. Results indicate that the 200-year Class 3 storm produces the critical design case. The incident wave height is 6.6 feet as it approaches this structure. The waves approach the north breakwater at an acute angle of approximately 10 degrees relative to the east-west orientation of the breakwater at the location of the baffle structures.

The South Breakwater 200-year storm Class 1 wave approaching from the south has a height of 4.9 feet as it reaches the structure. This wave approaches the breakwater at an acute angle of approximately 17 degrees relative to the orientation of the breakwater which is east west at the location of the baffle structures.

The wave information developed in this analysis provides boundary condition input for further analysis of the baffle structures.

Wave Stress Evaluation

Wave stress analysis provides estimated wave attack forces that interact with the breakwater steel baffle structures. The analysis is based on the lakebed and wave conditions that are constant for much of the baffle structure length. Two methods are used to estimate the wave loads at the baffle structures. The first method estimates the wave stress that is approaching the breakwaters. This method provides a general sense of the approach loads before they hit the structure. The second method estimates wave loads that interact with the baffle wall structures.

Wave Load Estimates Approaching the Structure

The Class 1 wave approaching from the southeast at the South Breakwater is estimated to have a design height of 4.9 feet. The Class 3 wave approaching the North Breakwater is estimated to be 6.6 feet. These waves are taken from the Wave Transformation Analysis discussed earlier in this report.

This method estimates wave loads approaching the breakwater, but assumes the wave is hitting a solid vertical wall. This method is not intended as a determination of wave forces on an armor stone breakwater; however, it provides a good reference point for the designer to compare to the wave loads estimated by the second method that we utilized. The wave loads from this method are higher than method 2 because much of the approach energy is spent on the rubble mound breakwater.

This first approach uses the Goda method ("Random Seas and Design of Maritime Structures, 3rd Edition, Yashimi Goda, 2010). It provides an estimate of the wave stress before the wave interacts with the breakwater. This analysis provides wave pressure at various elevations at the breakwater. The greatest stress occurs at the normal water line and gradually dissipates with height.

This method is not an ideal representation of the stress because it doesn't consider the influence of waves breaking on the breakwater stone and then converting to an overtopping flow on the stone crest. However, it provides a good sense of the pressures approaching the structure. This analysis is provided in Appendix B. The wave stresses are summarized on the third page of the analysis:

- P1 = the wave force at the Lake elevation
- P2 = the load at the bottom of the lake
- P3 = not applicable to this breakwater configuration.
- n* is the height at which zero wave pressure occurs. The pressure reduction from P1 to n* is linear.

Wave Load Estimates at the Baffle Structure

This method of wave load estimation is based on the Jensen and Bradbury (CEM Equation VI-5-186) method. This method is based on physical model studies in a laboratory for stone breakwaters that have a wall structure on top. The breakwater/baffle structure combination fits reasonably well with this method. The method considers the incident wave height, distance between the design water level and the breakwater crest, the significant design wave height attacking the breakwater, deep-water wavelength, the height of the baffle wall structure on top of the breakwater, computation of the wave steepness parameter, and two parameters that were developed from model study tests performed by the authors.

This method estimates a total force on the baffle wall for each longitudinal foot of wall. The computations for this analysis are provided in Appendix C. The analysis results indicate that the total force per foot of baffle wall, which includes the top of the sheet pile wall that sticks up one foot above the breakwater stone, and the height of the baffle wall; is 3,578 pounds per lineal foot of the 4.6-foot baffle wall. This load is apportioned with 778 pounds to the 1' high sheet pile wall at the base of the baffle wall.

The 2,800-pound remainder of the load is taken on by the baffle wall that is connected to the steel sheet pile wall at its base. This load is reduced to an extent since the baffle plates are angled, and the load is a glancing blow. In addition, water that passes through the angled baffle wall louvers reduces pressure somewhat.

The breakwater louvers are an extension of the armor stone breakwater height designed to reduce wave overtopping and transmission. These structures provide a reduction in wave overtopping and transmission. This provides erosion protection for the beach sand due to the elimination of a significant portion of the wave energy that would otherwise enter the harbor. The baffle wall structure also absorbs some of the wave stress that would otherwise have access to the planted habitat zones on the west ends of the breakwater structures.

The baffle structure louvers are spaced at 4" and angled at 40 degrees. The waves that strike the louvers are broken up and the wave load is imparted to the louver surfaces. This has the effect of spreading the load out over a surface area that is larger than the the linear length of the baffle wall alignment.

Wave Overtopping and Transmission Analysis

An analysis of wave overtopping and transmission at the baffle wall locations, performed with and without the baffle structure in place, provides an estimate of the amount of wave overtopping stress that is avoided. The steel sheet pile, which comprises the lowest 1 foot of the baffle structure intercepts and reflects a portion of the overtopping flow back out to the lake. The baffle structure louvers above the level of the steel sheet pile further reduce the overtopping. The baffles restrict and deflect the flow through the louvers and deflect the flows onto the armor stone crest of the breakwater.

The method used to estimate wave overtopping at the baffle structure is the Eurotop *Manual on Wave Overtopping of Sea Defenses and Related Structures* (2018). We first estimate the breakwater overtopping flows without the wave baffle structure. We then estimate the overtopping flow reduction factor for the steel baffle structure based on a literature review of wave energy reduction through perforated structures, and analysis of the impacts of flow influences of angled plates.

Table 1 provides overtopping flow reductions for the north and south breakwater structures with the baffle structures in place. The baffle breakwater structures are located adjacent and to the east of the habitat planting zones and will will help protect these areas from erosion. The baffled breakwater structures also reduce the erosion potential for the beach nourishment sand and associated habitat. The baffle structures add height to the breakwater without any increase in the footprint of the armor stone breakwater that supports this structure. This feature reduces the lakebed impact. The breakwater armor stones also provide fish habitat.

Table 1. Wave Overtopping Flow Reductions at Baffle Structures

Breakwater	Event Recurrence	2% Wave Runup (ft)	SSP Wall Flow Reduction	Baffle Wall Flow
South	200 Year	5.8	96%	4%
North	200 Year	8.0	90.9%	9.1%

The total flow reduction at the North Breakwater is estimated to be 82%, and at the South Breakwater 92%. Several field studies and wave tank studies have documented wave transmission reduction due to wave screens, perforated breakwaters, or curtainwall pile breakwaters. Rageh et. al showed that reductions of 40% to 50% occur in breakwaters using slotted wave screens (2013). Fugazza and Natale showed a similar trend of 45% to 75% reductions based on single chamber perforated breakwaters (1992).

These examples account for reduction of energy based on perforated devices near the water surface. The proposed design has the louvers located 5' above normal water. The lower 1 foot of the structure is a solid steel sheet pile wall which will reflect all water that approaches it back out to the lake. The baffle structure louvers will be hit by water that overtops the breakwater at an oblique angle. This will cause wave reflections within the 4-inch spaces between adjacent louver structures. The turbulent flow in the louver space will cause confused flow conditions that reduce wave transmission. The flows passing through will then spend energy on the sizeable breakwater stone crest before falling back into the water on the lee side of the structure.

Based on the impulse momentum equation and assuming continuity of flow, the angles of the louvers and the angles of waves is estimated to result in a significant reduction in flowrate that would pass through the louvers. The flows coming through the baffle structure are expected to run on the armor stone breakwater crest and slope back into the water. It will no longer be in a wave form and will flow back into the lake with much of the energy being spent on the louvers and breakwater rocks.

The breakwater baffle structure will manage wave attack and reduce wave erosion potential in the vicinity of the proposed plant habitat zones at the west ends of the north and south breakwaters.

In addition, the breakwater baffle structures that are proposed adjacent to the habitat planting areas - north of the north breakwater and south of the south breakwater will provide protection from wave action on the steel sheet pile walls and adjacent beach areas. Wave energy can converge in the corner areas formed where the breakwaters meet the beach.

Breakwater Baffle Structure Design

AECOM performed preliminary structural analyses and design of the breakwater structure baffle wall structure. The wave load calculations indicate that the controlling wave case for the North breakwater baffle wall is a Class 3, 20-year wave attack with a 10-year lake level. The South breakwater baffle wall controlling wave case would be a Class 1, 20-year wave attack with a 10-year lake level. The Class 3 wave load is greater than Class 1 wave load. Both walls are designed using the larger Class 3 wave to provide a consistent structure for both baffle walls.

The baffle walls will be prefabricated in panels. Each panel will consist of several baffle louvers and are comprised of the following: 8-inch-wide x 3.6 ft high x 5/8-inch-thick steel plates welded to a 12-inch-wide x 6-ft long (+/-) x 1-inch thick steel baseplate. The north breakwater baffle wall design is as follows:

- The largest controlling wave loads occur at the eastern 40 feet of the baffle wall. The wave loads developed for this area are also used for the baffle wall areas located closer to shore where the wave heights and loads are less due to more shallow water depths. The western portions of the baffle wall are in shallow water. The waves will converge somewhat in the corner formed by the lake edge and the planter walls. This convergence will provide some splash and spray and the baffle structure will provide protection from this. The baffle wall structural design for this area will be the same as for the eastern end of the baffle wall. Though the louver lengths are longer.

- The top of the baffle wall at the eastern 40 feet of North breakwater and 55 feet at the South breakwater is at a maximum elevation of 590.60', and gradually reduces in height going east.

- The bottom of the baseplate at the steel sheet pile cap is at Elevation 587.00' in the deep-water locations, and gradually rises approaching shore. The wave loads on the baffle walls are reduced as the wall approaches shore. The lake depth becomes gradually shallower, and the wave loads gradually reduced.

- The louver plates will be spaced at 4 inches as measured in the direction perpendicular to the plane of the louver plate. The baseplates will be bolted to a steel cap (16-in channel) at the top of the steel sheet pile (SSP). The steel cap would be welded to the SSP wall. This wall will be embedded into the ground and will be buttressed on both sides by the breakwater.

- Two rows of bolts (5/8-inch diameter, A325) would connect the louver panels to the steel cap of the SSP wall. The bolts would be spaced at 12 inches (+/-) in the long direction of the cap and at 8 inches in the transverse direction of the cap.

- Structural calculations and design schematics showing details of a typical louver panel is provided in Appendix E.

The steel louvers are oriented with a 40-degree angle rotated clockwise to the northeast. The incident design wave would approach the breakwater at a skew of 14 to 17 degrees to the orientation of the breakwater – a glancing attack. The skew angle between the incident wave and the orientation of the baffle wall louvers is therefore estimated to be an angle of 54 degrees relative to the approaching wave, and a line that is perpendicular to the plane of the louver.

The component of the design wave force acting in the direction perpendicular to the plane of the louver is estimated to be reduced by 40% to account for the skewed wave strike on the face of the louvers. The resulting pressure was used to determine the moment and shear stresses in the louver plates. We followed AISC Specification Standards to design the louver plate, welded connection to the baseplate and bolted connection to the steel cap of the SSP wall.

AECOM evaluated other load cases. The wind load case was considered insignificant. The ice load case was analyzed following recommendations and guidelines presented in the USACOE (EM-2-1612). It was assumed that a 12-inch-thick by 18-ft long ice sheet is floating by waves and hitting the baffle wall at mid-height in combination with the wave pressure. This load would be infrequent since the baffle structure base elevation is 5 feet above flood stage. Results of these analyses indicate the louver panels will experience stresses below their allowable limits during Lake Michigan wind, wave and ice force events, and are therefore structurally adequate for use as proposed.

Appendix A

Wave Transformation Model

Introduction and Purpose: Perform coastal engineering calculations to transform deepwater waves in Lake Michigan to the nearshore environment. Estimate Incident wave conditions. Estimate the required armor stone sizes to resist wave forces. The shoreline and breakwater locations are illustrated on the design drawings. Use the 10-year lake level and the 20-year deepwater wave as the preliminary design condition. This combination will produce a combined event recurrence interval in excess of a 100 year event. Then perform a check for the 20-yr lake level and a 10-yr wave.

I. Deepwater Wave and Water Level Conditions, and Basic Shoreline Characteristics at Project Site

Deepwater Waves:

Figure 1 illustrates the shoreline orientation for the site relative to the regional shoreline orientation for the nearest available wave information station. This station is designated as WIS Station No. 94027. The project site is located at 42.1 deg N, 87.72 deg W. WIS Station No. 94027 is located at 42.2 deg N, 87.72 deg W. Wave station information from the year 1960 through 2014 is downloaded in ONELINES Data Format. The largest 500 waves for each class was analyzed using the CEDAS - ACES program developed by the U.S. Army Engineer Waterways Experiment Station, Bicksburg, Mississippi to produce the following Extremal Significant Wave Heights. A Weibull distribution shape parameter k = 1.0 best represents the Class 1 WIS data; k = 1.4 best represents Classes 2 and 3 WIS data.

Deepwater Waves for the 20-year event:

$H_{oClass3} := \mathbf{17.72}$ $\quad H_{oClass2} := \mathbf{13.62}$ $\quad H_{oClass1} := \mathbf{7.63}$

Deepwater Waves for the 10-year event:

$H_{oClass3\_10} := \mathbf{16.83}$ $\quad H_{oClass2\_10} := \mathbf{12.5}$ $\quad H_{oClass1\_10} := \mathbf{7.19}$

Design Basis Lake Michigan Water Level :

A Lake Michigan Level and Wave Climate Evaluation completed by AECOM in 2010 provides updated water level frequency curves for Calumet Harbor. "Chicago Lake Michigan Level and Wave Climate Evaluation, September 15, 2009." This study includes a 93 year Lake Michigan water level record. The results for Calumet Harbor are then transferred to the Winnetka design site using a proration of the Corps 2009 Lake Level Study (1993) for levels between Calumet and Milwaukee. The Extreme High Water Level Summary in IGLD 85 is shown in the below table.

	10 year	20 year
Class 1	581.8	582.3
Class 2	582.3	582.8
Class 3	582.5	583.0

In the AECOM analysis, the mean lake level for each return period is added to a storm surge to produce a total combined water level for each return period. The evaluation also took into account the effects of wave setup directionality and lag time between time of peak wave heights and wind setup. Each high water level analysis is broken up into Sectors that roughly correspond to the various classes included in this analysis.

Lake levels for this design are based on an interpretation of the Lake Michigan Level and Wave Climate Evaluation (AECOM, 2010) for Calumet Harbor. The levels at the project site will be lower than those are Calumet Harbor for Class 3 wave attack due to the reduced lake fetch to the site that produces a lesser wave lake level setup. Therefore, the AECOM (2010) analysis needs to be adjusted. This analysis corrects for this by prorating the relative difference in lake levels from the Calumet Harbor and Milwaukee gages. The annual design water levels for each gage site in IGLD 85 is reproduced in the below table from the Design Water Level Determination on the Great Lakes (US Army Corps of Engineers, 1993).

	10 year	20 year	30 year
Calumet Harbor	582.9	583.3	583.6
Milwaukee	582.2	582.5	582.8
Difference	0.7	0.8	0.8

Since the project site in Winnetka is between Milwaukee and Calumet Harbor, the AECOM (2010) lake levels will be adjusted accordingly. The distance between Calumet Harbor and Milwaukee is 90 miles and the distance between Calumet Harbor and Winnetka is approximately 31 miles. The design lake level will be adjusted by 34% of the difference between the design water levels from the above table, or 0.24 and 0.27' will be subtracted from each of the 10 year and 20 year AECOM (2010) lake level frequency values to adjust them for the project site. This adjustment is shown in the below table.

	10 year	20 year
Class 1	581.56	582.03
Class 2	582.06	582.53
Class 3	582.26	582.73

Design Water Levels for the 20-year event:

$dwl_3 := \mathbf{582.73}$ $dwl_2 := \mathbf{582.53}$ $dwl_1 := \mathbf{582.03}$

Design Water Levels for the 10-year event:

$dwl_{3\_10} := \mathbf{582.26}$ $dwl_{2\_10} := \mathbf{582.06}$ $dwl_{1\_10} := \mathbf{581.56}$

Wave Period for Deep Water Waves:

Wave periods for class 1, class 2, and class 3 waves were obtained from the 1976 "Design Wave Information for the Great Lakes, Report 3, Lake Michigan" by Resio and Vincent. Grid Point number 33 at the Winnetka, Illinois grid location 42.26, 87.73 is closest to the project site. Table E3 provides significant wave periods orgnized by both wave height and angle class. The angle classes roughly correspond to the classes used for the significant wave heights.

In 2009, DHI completed a report titled "Long Term Wind-Wave Hindcase and Wave Transformation Modeling" updating the significant wave period analysis for Calument Harbor. The DHI Report analyzes the wave period for different wave heights and the results for the 10 and 20 year frequencies are very similar to the wave periods available in Table E3 (Resio and Vincent, 1976). Because the deepwater waves for this project location are significantly different from the wave heights reported at Calumet Harbor, the wave periods are obtained from Table E3 (Resio and Vincent, 1976) and not from the DHI report.

As a final check on the reliability of using Table E3 (Resio and Vincent, 1976), the wave periods were compared to the 1979 to 2014 Percent Occurance of Height and Period by Direction tables for the WIS station closest to this project. The WIS data confirms a 9-9.9 second wave period for the class 3 10 and 20 year wave heights, 8-8.9 second wave period for class 2 10 and 20 year wave heights, and 6-6.9 second wave period for class 1 10 and 20 year wave heights.

Wave Periods for the 20-year event:

$t_3 := 9.9$ $t_2 := 8.4$ $t_1 := 7.0$

Wave Periods for the 10-year event:

$t_{3\_10} := 9.6$ $t_{2\_10} := 8.1$ $t_{1\_10} := 6.7$

II. Proposed Structure Incident Wave Condition and Forces Analysis

A. Main Breakwater Incident Wave Conditions

Main Breakwater Incident Wave Condition Analysis:

1. Lake Bottom Condition

The lake bottom elevation is taken from the lake side toe of the proposed structure at a distance approximately equal to five times the wave height at the point of attack. Assuming the wave height is approximately 8 feet, the lake bottom elevation at 40 feet from the north breakwater baffle alignment is 575.5 NAVD 88 or approximately 575.0 IGLD 85 based on a bathymetric survey completed by Terra in December of 2020. At the end of the wave condition analysis, a check will be made to confirm that the wave height does not require a second iteration with a refined lake bottom elevation.

The AECOM survey limits extend to approximately 250 feet offshore. The lake bed slope is approximately 1:30. Beyond 130 feet offshore, the lake bed slope flattens to approximately 1:70.

Estimate lake bed depth from design lake level for the 20-year event:

$dwl_3 = 582.73$ $\quad bed_{3\_20} := 575.0$ $\quad h_{3\_20} := dwl_3 - bed_{3\_20}$ $\quad h_{3\_20} = 7.73$

$dwl_2 = 582.53$ $\quad bed_{2\_20} := 575.0$ $\quad h_{2\_20} := dwl_2 - bed_{2\_20}$ $\quad h_{2\_20} = 7.53$

$dwl_1 = 582.03$ $\quad bed_{1\_20} := 575.0$ $\quad h_{1\_20} := dwl_1 - bed_{1\_20}$ $\quad h_{1\_20} = 7.03$

Estimate lake bed depth from design lake level for the 10-year event:

$dwl_{3\_10} = 582.26$ $\quad bed_{3\_10} := 575.0$ $\quad h_{3\_10} := dwl_{3\_10} - bed_{3\_10}$ $\quad h_{3\_10} = 7.26$

$dwl_{2\_10} = 582.06$ $\quad bed_{2\_10} := 575.0$ $\quad h_{2\_10} := dwl_{2\_10} - bed_{2\_10}$ $\quad h_{2\_10} = 7.06$

$dwl_{1\_10} = 581.56$ $\quad bed_{1\_10} := 575.0$ $\quad h_{1\_10} := dwl_{1\_10} - bed_{1\_10}$ $\quad h_{1\_10} = 6.56$

2. Estimate the near-breakwater Wave Height after Refraction **10-Year Lake & 20-Year Wave**

Use Class 3, 20-Year Deepwater Wave Height = H_o

$H_{oClass3} = 17.72$ $\quad t_3 = 9.9$ sec

$L_o := 1.56 \cdot t_3^2 \cdot 3.281$ $\quad L_o = 501.65$ $\quad \frac{h_{3\_10}}{L_o} = 0.014$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (Fig. 3.6):

$Kr_{20} := .78$ $\quad \alpha_o := 60$ deg

$H_{oClass3'} := Kr_{20} \cdot H_{oClass3}$

$H_{oClass3'} = 13.822$

Use Class 2, 20-Year Deepwater Wave Height = H_o

$H_{oClass2} = 13.62$ $t_2 = 8.4$ sec

$L_o := 1.56 \cdot t_2^{\,2} \cdot 3.281$ $L_o = 361.151$ $\frac{h_{2\_10}}{L_o} = 0.02$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (Fig. 3.6):

$Kr_{20} := .93$ $\alpha_o := 60$ deg

$H_{oClass2'} := Kr_{20} \cdot H_{oClass2}$

$H_{oClass2'} = 12.667$

Use Class 1, 20-Year Deepwater Wave Height = H_o

$H_{oClass1} = 7.63$ $t_1 = 7$ sec

$L_o := 1.56 \cdot t_1^{\,2} \cdot 3.281$ $L_o = 250.8$ $\frac{h_{1\_10}}{L_o} = 0.026$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (Fig. 3.6):

$Kr_{20} := .79$ $\alpha_o := 60$ deg

$H_{oClass1'} := Kr_{20} \cdot H_{oClass1}$

$H_{oClass1'} = 6.028$

3. Estimate the near-breakwater class 3 Wave Angle after Refraction

The refracted wave approaching the structures is at an angle of α_p degrees from normal.

$\alpha_o = 60$ deg $\frac{h_{3\_10}}{L_o} = 0.029$

$\alpha_p := 10\text{deg}$ Fig. 3.7 (Goda)

4. Estimate the near-breakwater class 1 Wave Angle after Refraction

The refracted wave approaching the structures is at an angle of α_p degrees from normal.

$\alpha_o = 60$ deg $\frac{h_{1\_10}}{L_o} = 0.026$

$\alpha_p := 17deg$ Fig. 3.7 (Goda)

5. Estimate the Incident Wave Height in the Surf Zone East of the Structure

Use Goda to estimate the incident wave height in the surf zone for Class 3.

$\frac{H_{oClass3'}}{L_o} = 0.055$ $\frac{h_{3\_10}}{H_{oClass3'}} = 0.525$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .49$

For slope = 1:100, surf zone factorc(SZF): $SZF_{100} := .45$

Interpolate for slope:

$s := 50$ $SZF := SZF_{100} - (100 - s)\frac{(SZF_{100} - SZF_{30})}{100 - 30}$

$SZF = 0.479$

Estimate significant wave for wave transformation:

$H_{sig3} := (SZF)\cdot(H_{oClass3'})$ $H_{sig3} = 6.615$

Estimate maximum wave height:

$H_{max} := 0.58\cdot H_{oClass3'}$ $H_{max} = 8.017$

Use Goda to estimate the incident wave height in the surf zone for Class 2.

$\frac{H_{oClass2'}}{L_o} = 0.051$ $\frac{h_{2\_10}}{H_{oClass2'}} = 0.557$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .5$

For slope = 1:100, surf zone factor (SZF): $SZF_{100} := .44$

Interpolate for slope:

$s := 50$ $SZF := SZF_{100} - (100 - s)\frac{(SZF_{100} - SZF_{30})}{100 - 30}$

$SZF = 0.483$

Estimate significant wave for wave transformation:

$H_{sig2} := (SZF) \cdot (H_{oClass2'})$ $\qquad H_{sig2} = 6.116$

Estimate maximum wave height:

$H_{max} := 0.63 \cdot H_{oClass2'}$ $\qquad H_{max} = 7.98$

Use Goda to estimate the incident wave height in the surf zone for Class 1.

$\frac{H_{oClass1'}}{L_o} = 0.024$ $\qquad \frac{h_{1\_10}}{H_{oClass1'}} = 1.088$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .8$

For slope = 1:100, surf zone factorc(SZF): $SZF_{100} := .7$

Interpolate for slope:

$s := 50$ $\qquad SZF := SZF_{100} - (100 - s)\frac{(SZF_{100} - SZF_{30})}{100 - 30}$

$SZF = 0.771$

Estimate significant wave for wave transformation:

$H_{sig1} := (SZF) \cdot (H_{oClass1'})$ $\qquad H_{sig1} = 4.65$

Estimate maximum wave height:

$H_{max} := .91 \cdot H_{oClass1'}$ $\qquad H_{max} = 5.485$

The incident wave height in the surf zone for Class 3, Class 2 and Class 1 is 6.6 , 6.1 and 4.7 respectively. Therefore, Class 3 controls.

6. Estimate the near-breakwater Wave Height after Refraction for **20 year Lake level/ 10 yr wave**:

Use Class 3, 10-Year Deepwater Wave Height = H_o

$H_{oClass3\_10} = 16.83$ $\qquad t_{3\_10} = 9.6$

$L_{o\_10} := 1.56 \cdot t_{3\_10}^{2} \cdot 3.281$ $L_{o\_10} = 471.708$ $\frac{h_{3\_20}}{L_o} = 0.031$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (figure 3.6):

$Kr_{10} := .79$ $\alpha_o := 60$ deg

$H_{oClass3\_10'} := Kr_{10} \cdot H_{oClass3\_10}$

$H_{oClass3\_10'} = 13.296$

Use Class 2, 10-Year Deepwater Wave Height = H_o

$H_{oClass2\_10} = 12.5$ $t_{2\_10} = 8.1$

$L_{o\_10} := 1.56 \cdot t_{2\_10}^{2} \cdot 3.281$ $L_{o\_10} = 335.816$ $\frac{h_{2\_20}}{L_o} = 0.03$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (figure 3.6):

$Kr_{10} := .94$ $\alpha_o := 30$ deg

$H_{oClass2\_10'} := Kr_{10} \cdot H_{oClass2\_10}$

$H_{oClass2\_10'} = 11.75$

Use Class 1, 10-Year Deepwater Wave Height = H_o

$H_{oClass1\_10} = 7.19$ $t_{1\_10} = 6.7$

$L_{o\_10} := 1.56 \cdot t_{1\_10}^{2} \cdot 3.281$ $L_{o\_10} = 229.763$ $\frac{h_{1\_20}}{L_o} = 0.028$

Offshore bottom contours are nearly parallel to shore; therefore, use Goda (figure 3.6):

$Kr_{10} := .8$ $\alpha_o := 60$ deg

$H_{oClass1\_10'} := Kr_{10} \cdot H_{oClass1\_10}$

$H_{oClass1\_10'} = 5.752$

7. Estimate the near-breakwater class 3 Wave Angle after Refraction (use Goda - figure 3.7)

The refracted wave approaching the structures is at an angle of α_p degrees from normal.

$\alpha_o = 60$ deg $\frac{h_{3\_20}}{L_o} = 0.031$

$\alpha_p := 9\text{deg}$ Fig. 3.7 (Goda)

8. Estimate the near-breakwater class 1 Wave Angle after Refraction (use Goda - figure 3.7)

The refracted wave approaching the structures is at an angle of α_p degrees from normal.

$\alpha_o = 60$ deg $\qquad \dfrac{h_{1\_20}}{L_o} = 0.028$

$\alpha_p := 9\text{deg}$ Fig. 3.7 (Goda)

9. Estimate the Incident Wave Height in the Surf Zone.

Use Goda to estimate the incident wave height in the surf zone for Class 3.

$\dfrac{H_{oClass3\_10'}}{L_{o\_10}} = 0.058 \qquad \dfrac{h_{3\_20}}{H_{oClass3\_10'}} = 0.581$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .5$

For slope = 1:100, surf zone factorc(SZF): $SZF_{100} := .46$

Interpolate for slope:

$s := 50 \qquad SZF := SZF_{100} - (100 - s)\dfrac{(SZF_{100} - SZF_{30})}{100 - 30}$

$SZF = 0.489$

Estimate significant wave for wave transformation and armor stone sizing purposes:

$H_{sig3\_10} := (SZF)\cdot(H_{oClass3\_10'}) \qquad H_{sig3\_10} = 6.496$

Estimate maximum wave height:

$H_{max} := 0.59\cdot H_{oClass3\_10'} \qquad H_{max} = 7.844$

Use Goda to estimate the incident wave height in the surf zone for Class 2.

$\dfrac{H_{oClass2\_10'}}{L_{o\_10}} = 0.051 \qquad \dfrac{h_{2\_20}}{H_{oClass2\_10'}} = 0.641$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .57$

For slope = 1:100, surf zone factor (SZF): $SZF_{100} := .51$

Interpolate for slope:

$s := 45$ $$SZF := SZF_{100} - (100 - s)\frac{(SZF_{100} - SZF_{30})}{100 - 30}$$

$SZF = 0.557$

Estimate significant wave for wave transformation and armor stone sizing purposes:

$H_{sig2\_10} := (SZF)\cdot(H_{oClass2\_10'})$ $H_{sig2\_10} = 6.546$

Estimate maximum wave height:

$H_{max} := 0.70\cdot H_{oClass2\_10'}$ $H_{max} = 8.225$

Use Goda to estimate the incident wave height in the surf zone for Class 1.

$\frac{H_{oClass1\_10'}}{L_{o\_10}} = 0.025$ $\frac{h_{1\_20}}{H_{oClass1\_10'}} = 1.222$

Use Goda Figures 3.31 and 3.32 to estimate surf zone reduction factors $H_{1/3}/H_{0'}$ using a near shore bottom slope of 1:50:

For slope = 1:30, surf zone factor (SZF): $SZF_{30} := .9$

For slope = 1:100, surf zone factor (SZF): $SZF_{100} := .75$

Interpolate for slope:

$s := 50$ $$SZF := SZF_{100} - (100 - s)\frac{(SZF_{100} - SZF_{30})}{100 - 30}$$

$SZF = 0.857$

Estimate significant wave for wave transformation:

$H_{sig1\_10} := (SZF)\cdot(H_{oClass1\_10'})$ $H_{sig1\_10} = 4.93$

Estimate maximum wave height:

$H_{max} := 1.0\cdot H_{oClass1\_10'}$ $H_{max} = 5.752$

The incident wave height in the surf zone for Class 3, Class 2, and Class 1 is 6.5 , 6.5, and 4.9 respectively. Therefore, Class 3 controls.

Appendix B

Wave Transformation – Approach Wave Loads

Incident Wave in the Surf Zone Based on AECOM Wave Heights

Shoreline Designation	Water Level (ft - LWD)	*Average Lakebed (ft - LWD)	Depth at Structure h (ft)	**Intermed. Wave Ho	h/H_o	Wave Period (sec)	Wavelength Lo	Refraction Angle α	h/L_o	Refraction Coefficient K_r (Goda Fig 3.6)	Approach Angle after Refr (α_p)	H_o'	h/H_o'	H_o'/L_o	Goda Fig. 3.32	**Nonbrk. $H_{1/3}$ (ft)	Break Loc. 5*($H_{1/3}$) [H	Lake Bottom (Near Flat)	H.max Depth @ 5*($H_{1/3}$) hb (ft)	hb/Lo	hb/Ho`	Ho`/Lo	Hmax at Hmax/Ho' Goda Fig 3.32	Hmax @ h_b
North Breakwater																								
I. 200 year event: 20 year wave \ 10 year level																								
Class 3	582.26	575.0	7.3	17.72	0.41	9.9	501.7	60.0	0.014	0.780	**10.0**	**13.8**	0.53	0.028	0.480	**6.6**	33.2	Flat	6.6	0.01	0.48	0.028	0.580	8.0
Class 2	582.06	575.0	7.1	13.62	0.52	8.4	361.2	0.0	0.020	0.930	**0.0**	**12.7**	0.56	0.035	0.480	**6.1**	30.4	20 to 1	7.1	0.02	0.56	0.035	0.630	8.0
Class 1	581.56	575.0	6.6	7.63	0.86	7	250.8	60.0	0.026	0.790	**17.0**	**6.0**	1.09	0.024	0.780	**4.7**	23.5	50 to 1	5.2	0.02	0.86	0.024	0.910	5.5
II. 200 year event: 10 year wave \ 20 year level																								
Class 3	582.73	575.0	7.7	16.83	0.46	9.6	471.7	60.0	0.016	0.790	**13.5**	**13.3**	0.58	0.028	0.49	**6.5**	32.6	Flat	6.5	0.01	0.49	0.028	0.59	7.8
Class 2	582.53	575.0	7.5	12.5	0.60	8.1	335.8	0.0	0.022	0.940	**0.0**	**11.8**	0.64	0.035	0.55	**6.5**	32.3	20 to 1	7.5	0.02	0.64	0.035	0.70	8.2
Class 1	582.03	575.0	7.0	7.19	0.98	6.7	229.8	60.0	0.031	0.800	**18.0**	**5.8**	1.22	0.025	0.85	**4.9**	24.4	50 to 1	5.4	0.02	0.94	0.025	1.00	5.8
	***Lake Bottom Slope is approx. 30:1 approching shore																							
	**Equivalent intermediate wave beyond Surf Zone.																							
	*To Lake Bottom.																							

Note: The louvers are designed for the Significant Wave Height for a 200 year wind wave storm. The Max wave height case applies to critical infrastructure such as seawalls with pedestrian access and strucures with nearby building structures - this wave represents a 1/250 wave height and doesn't apply to the louvers which are not major structures.

I. Summary of Maximum Wave In Designated Zones.

Wave Designation	Water Level (ft - LWD)	Average Lakebed (ft - LWD)	Depth at Structure h (ft)	**Incident Wave Ho''	H''$_{1/3}$ (ft)		5*H'' $_{1/3}$ (ft)	hb* (ft)	Wave Period (sec)	Wavelength Lo	hb/Lo		Incident Ho'' (ft)				Incident Ho'' (ft)	
I. 200 year event: 20 year wave \ 10 year level																		
Class 3	582.26	575	7.26	6.6	6.6		33.2	6.6	9.9	501.7	0.0132		6.6				6.6	
Class 2	582.06	575	7.06	6.1	6.1		30.4	7.1	8.4	361.2	0.0196		6.1				6.1	
Class 1	581.56	575	6.56	4.7	4.7		23.5	5.2	7	250.8	0.0207		4.7				4.7	
II. 200 year event: 10 Year wave \ 20 year level																		
Class 3	582.73	575	7.73	6.5	6.5		32.6	6.5	9.6	471.7	0.0138		6.5				6.5	
Class 2	582.53	575	7.53	6.5	6.5		32.3	7.5	8.1	335.8	0.0222		6.5				6.5	
Class 1	582.03	575	7.03	4.9	4.9		24.4	5.4	6.7	229.8	0.0235		4.9				4.9	

* Assume harbor bottom slope of near flat

**Use Highest Incident Wave Condition for Angle Class 2 for Wave Crest Pressure Computation.

II. Wave Crest Pressure Estimation

Wave Designation	Hmax at hb (ft)	Tp (sec)	alpha (deg)	h (ft)	h/Lo	Toe Berm Top Elev. LWD	Toe Berm thickness (ft)	d (ft)	hb (ft)	n* (ft)	alpha1 Fig 4.5	alpha2	alpha2	1/cosh Fig 4.6	alpha3	Wave Crest Pressures P1 (psf)	Wave Crest Pressures P2 (psf)	Wave Crest Pressures P3 (psf)
I. 200 year event: 20 year wave \ 10 year level																		
Class 3	6.6	9.9	10.0	7.3	0.014	0	0.0	7.3	6.6	9.9	1.048	-0.02625	2.19	0.950	0.95	420.1	399.1	399.1
Class 2	6.1	8.4	0.0	7.1	0.020	0	0.0	7.1	7.1	9.1	1.020	0.00070	2.32	0.932	0.93	387.2	360.9	360.9
Class 1	4.7	7.0	17.0	6.6	0.026	0	0.0	6.6	5.2	6.9	0.980	-0.04471	2.79	0.912	0.91	269.5	245.8	245.8
I. 200 year event: 10 year wave \ 20 year level						0												
Class 3	6.5	9.6	18.0	7.7	0.016	0	0.0	7.7	6.5	9.5	1.034	-0.04416	2.37	0.947	0.95	394.2	373.3	373.3
Class 2	6.5	8.1	0.0	7.5	0.022	0	0.0	7.5	7.5	9.7	1.010	-0.00222	2.33	0.930	0.93	1347.0	1252.7	1252.7
Class 1	4.9	6.7	9.0	7.0	0.031	0	0.0	7.0	5.4	7.3	0.980	-0.04909	2.88	0.900	0.90	1147.7	1033.0	1033.0

Station	Hmax at hb (ft)	h (ft)	P1 (psf)	P2 (psf)	P3 (psf)
I. 200 year event: 20 year wave \ 10 year level					
Class 3	6.6	7.3	420.1	399.1	399.1
Class 2	6.1	7.1	387.2	360.9	360.9
Class 1	6.5	7.7	269.5	245.8	245.8
I. 200 year event: 10 year wave \ 20 year level					
Class 3	6.5	7.3	394.2	373.3	373.3
Class 2	6.5	7.1	1347.0	1252.7	1252.7
Class 1	4.9	6.6	1147.7	1033.0	1033.0

Appendix C

Baffle Wall Wave Loads

North Breakwater

Class	Modeling Scenario	SWL (ft)	Breakwater Crest Elev (ft)	Depth at Breakwater Toe (ft)	Hb (ft)	L0 (ft)	Maximum Louvre Height (ft)	A_c (ft)	A_c (m)
CLASS 3	with Louver, 10 year	582.26	586	7.26	6.6	390	4.6	3.74	1.14
CLASS 3	With Louver,20 year	582.73	586	7.73	6.5	414	4.6	3.27	1.00

South Breakwater

Class	Modeling Scenario	SWL (ft)	Breakwater Crest Elev (ft)	Depth at Breakwater Toe (ft)	Hb (ft)	L0 (ft)	Maximum Louvre Height (ft)	A_c (ft)	A_c (m)
CLASS 1	with Louver, 10 year	581.56	586	6.56	4.7	190	4.6	4.44	1.35
CLASS 1	With Louver,20 year	582.03	586	7.03	4.9	207	4.6	3.97	1.21

NOTES/ASSUMPTIONS

Maximum louvre height along each breakwater was used

CEM Part VI - Wave Overtopping Force on Wall -- North Breakwater

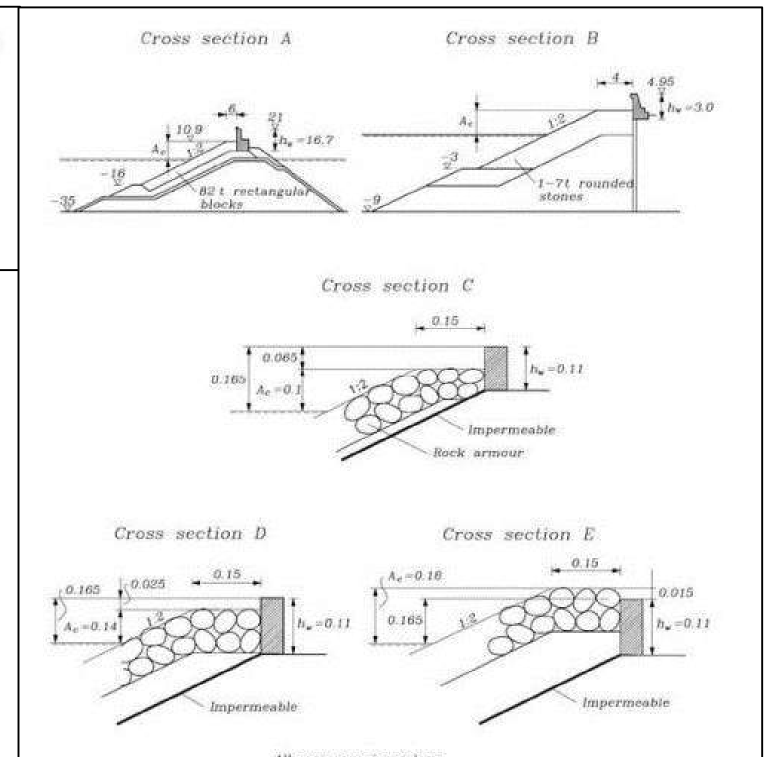
Page VI-V-176 in CEM Part VI

Force Calculations: Method 1, Jensen and Bradbury (Equation VI-5-186)

Step	Variable	Symbol					Class 3 10-Year	Class 3 20-Year	Notes
1	Mass Density of Water (slugs/ft3 or kg/m3)	r_w					*1.9*	*1.9*	Fresh water
2	Vertical Distance Between SWL and Berm Crest	A_c					*3.74*	*3.27*	
3	Gravitational Acceleration (ft/s2 or m/s2)	g					*32.174*	*32.174*	Maximum SWL along wall
4	Significant Wave Height in front of Breakwater (ft or m)	H_s					*6.6*	*6.5*	
5	Deepwater Wave Length Corresponding to Peak Wave Period (ft or m)	L_0					*390*	*414*	
6	Crown Wall Height (ft or m)	h_w					*4.60*	*4.60*	ASCE 7-22 Equation 5.4-5, Assumes Breaking Waves
7	Wave Steepness	H_s/L_0					0.02	0.02	
8	α	-					*-0.02*	*-0.02*	From CEM Table VI-5-60
9	β	-					*0.03*	*0.03*	From CEM Table VI-5-60
10	Hs/Ac	-					*1.76*	*1.99*	Calculated
11	**Force on Unit Length of Wall (lb/ft or N/m)**	$\mathbf{F_{h,0.1\%}}$					***3,148.53***	***4,005.16***	**Calculated**

$$\frac{F_{h,0.1\%}}{\rho_w\, g\, h_w\, L_{op}} = \alpha + \beta \frac{H_s}{A_C} \qquad \text{(VI-5-186)}$$

where
- $F_{h,0.1\%}$ Horizontal wave force per running meter of the wall corresponding to 0.1% exceedence probability
- ρ_w Mass density of water
- h_w Crown wall height
- L_{op} Deepwater wavelength corresponding to peak wave period
- H_s Significant wave height in front of breakwater
- A_c Vertical distance between MWL and the crest of the armor berm
- α, β Fitted coefficient, see table



Cross section	Parameter ranges in tests A_c (m)	$s_{op} = \frac{H_s}{L_{op}}$	$\frac{H_s}{A_c}$	0.1% exceedence values of coefficients in Eq (VI-5-186) α	β	Coefficient of variation	Reference
A	5.6 - 10.6	0.016 - 0.036	0.76 - 2.5	−0.026	0.051	0.21	Jensen (1984)
B	1.5 - 3.0	0.05 - 0.011	0.82 - 2.4	−0.016	0.025	0.46	
C	0.10	0.023 - 0.07	0.9 - 2.1	−0.038	0.043	0.19	Bradbury, et al. (1988)
D	0.14	0.04 - 0.05	1.43	-0.025	0.028		—
E	0.18	0.04 - 0.05	1.11	-0.088	0.011		—

CEM Part VI - Wave Overtopping Force on Wall -- South Breakwater

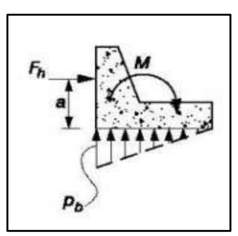
Page VI-V-176 in CEM Part VI

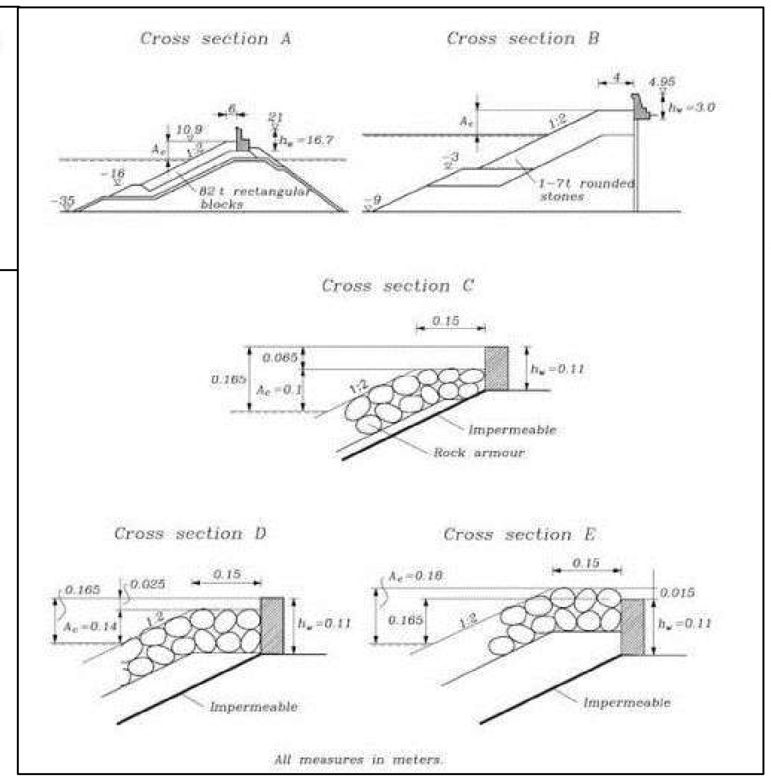
Force Calculations: Method 1, Jensen and Bradbury (Equation VI-5-186)

Step	Variable	Symbol	Class 1 10-Year	Class 1 20-Year					Notes
1	Mass Density of Water (slugs/ft3 or kg/m3)	r_w	*1.9*	*1.9*					Fresh water
2	Vertical Distance Between SWL and Berm Crest	A_c	*4.44*	*3.97*					
3	Gravitational Acceleration (ft/s2 or m/s2)	g	*32.174*	*32.174*					Maximum SWL along wall
4	Significant Wave Height in front of Breakwater (ft or m)	H_s	*4.7*	*4.9*					
5	Deepwater Wave Length Corresponding to Peak Wave Period (ft or m)	L_0	*190*	*207*					
6	Crown Wall Height (ft or m)	h_w	*4.60*	*4.60*					ASCE 7-22 Equation 5.4-5, Assumes Breaking Waves
7	Wave Steepness	H_s/L_0	*0.02*	*0.02*					
8	α	-	*-0.02*	*-0.02*					From CEM Table VI-5-60
9	β	-	*0.03*	*0.03*					From CEM Table VI-5-60
10	Hs/Ac	-	*1.06*	*1.23*					Calculated
11	**Force on Unit Length of Wall (lb/ft or N/m)**	$\mathbf{F_{h,0.1\%}}$	***570.76***	***884.53***					**Calculated**

$$\frac{F_{h,0.1\%}}{\rho_w\, g\, h_w\, L_{op}} = \alpha + \beta \frac{H_s}{A_C} \qquad \text{(VI–5–186)}$$

where
- $F_{h,0.1\%}$ Horizontal wave force per running meter of the wall corresponding to 0.1% exceedence probability
- ρ_w Mass density of water
- h_w Crown wall height
- L_{op} Deepwater wavelength corresponding to peak wave period
- H_s Significant wave height in front of breakwater
- A_c Vertical distance between MWL and the crest of the armor berm
- α, β Fitted coefficient, see table





Cross section	Parameter ranges in tests A_c (m)	$s_{op} = \frac{H_s}{L_{op}}$	$\frac{H_s}{A_c}$	0.1% exceedence values of coefficients in Eq (VI-5-186) α	β	Coefficient of variation	Reference
A	5.6 - 10.6	0.016 - 0.036	0.76 - 2.5	−0.026	0.051	0.21	Jensen (1984)
B	1.5 - 3.0	0.05 - 0.011	0.82 - 2.4	−0.016	0.025	0.46	
C	0.10	0.023 - 0.07	0.9 - 2.1	−0.038	0.043	0.19	Bradbury, et al. (1988)
D	0.14	0.04 - 0.05	1.43	-0.025	0.028		—
E	0.18	0.04 - 0.05	1.11	-0.088	0.011		—

Appendix D

Breakwater Overtopping Wave Analysis

Baffle Wall Wave Overtopping Flow Potential Summary

	Without SSP		Input Conditions												Eurotop Runup (Eqn 6.2)											Overtopping (Eqn 6.6)					
	Modeling Scenario without SSP	Event	Toe Elevation (ft)	LE (ft)	Toe Depth (ft)	Wave Period (sec)	Cot Structure Slope	Hmo (ft)	Hb	Crest Elev (ft)	Crest above toe (ft)	Gc (ft)	Rc(ft)	β (deg)	L0 (ft)	Iribarren Number, ξ_{0m}	γ_f rough	γ_f surging	$\gamma\beta$	Perm	R2% (ft)	R2% max (ft)	R2% max check	Final R2% (ft)	Max Runup (ft)	γ_f mod	q (cfs/ft)	Cr (max)	Adjusted q (cfs/ft)	Length of Baffle Struct. (ft)	Armor Stone BW Overflow Rate (cfs)*
CLASS 1	South Breakwater	200 YR - 20 YR Wave, 10 YR WL	575	581.6	6.56	7	1.5	4.7	4.7	586	11	5.5	4.4	80	207.365	4.428	0.55	0.6942	0.5	No	9.936	5.692	Good	5.692	7.343	0.55	0.00357	0.52893	0.00189	50	0.094
CLASS 1	South Breakwater	200 YR - 10 YR Wave, 20 YR WL	575	582	7.03	6.7	1.5	4.9	4.9	586	11	5.5	4	80	189.972	4.151	0.55	0.6790	0.5	No	9.710	5.763	Good	5.763	7.435	0.55	0.01455	0.56821	0.00827	50	0.413
CLASS 3	North Breakwater	200 YR - 20 YR Wave, 10 YR WL	575	582.3	7.26	9.9	1.5	6.6	5.66	586	11	5.5	3.7	80	414.773	5.706	0.55	0.7643	0.5	No	15.425	7.746	Good	7.746	9.992	0.6135	0.13849	0.71287	0.09873	40	3.949
CLASS 3	North Breakwater	201 YR - 20 YR Wave, 10 YR WL	575	582.7	7.73	9.6	1.5	6.5	6.03	586	11	5.5	3.3	80	390.016	5.362	0.55	0.7455	0.5	No	15.434	7.996	Good	7.996	10.315	0.5826	0.30524	0.77889	0.23775	40	9.510

	With SSP		Input Conditions												Eurotop Runup (Eqn 6.2)											Overtopping (Eqn 6.6)						
	Modeling Scenario with SSP	Event	Toe Elevation (ft)	LE (ft)	Toe Depth (ft)	Wave Period (sec)	Cot Structure Slope	Hmo (ft)	Hb	Crest Elev (ft)	Crest above toe (ft)	Gc (ft)	Rc (ft)	β (deg)	L0 (ft)	Iribarren Number, ξ_{0m}	γ_f rough	γ_f surging	$\gamma\beta$	Perm?	R2% (ft)	R2% max (ft)	R2% max check	Final R2% (ft)	Max Runup (ft)	γ_f mod	q (cfs/ft)	Cr (max)	Adjusted q (cfs/ft)	Length of Baffle Struct. (ft)	BW Flow with 1' SSP Added to crest elev - Flowrate (cfs)*	Reduced q Due to Baffle Louver Structure (cfs)
CLASS 1	South Breakwater	200 YR - 20 YR Wave, 10 YR WL	575	581.6	6.56	7	1.5	4.7	4.7	587	12	5.5	5.4	80	207.365	4.428	0.55	0.6942	0.5	No	9.936	5.692	Good	5.692	7.343	0.55	0.0004	0.5289	0.00020	50	0.0100	0.007
CLASS 1	South Breakwater	200 YR - 10 YR Wave, 20 YR WL	575	582	7.03	6.7	1.5	4.9	4.9	587	12	5.5	5	80	189.972	4.151	0.55	0.6790	0.5	No	9.710	5.763	Good	5.763	7.435	0.55	0.0018	0.5682	0.00105	50	0.0525	0.037
CLASS 3	North Breakwater	200 YR - 20 YR Wave, 10 YR WL	575	582.3	7.26	9.9	1.5	6.6	5.66	587	12	5.5	4.7	80	414.773	5.706	0.55	0.7643	0.5	No	15.425	7.746	Good	7.746	9.992	0.6135	0.0322	0.7129	0.02294	40	0.9177	0.642
CLASS 3	North Breakwater	200 YR - 10 YR Wave, 20 YR WL	575	582.7	7.73	9.6	1.5	6.5	6.03	587	12	5.5	4.3	80	390.016	5.362	0.55	0.7455	0.5	No	15.434	7.996	Good	7.996	10.315	0.5826	0.0761	0.7789	0.05930	40	2.3720	1.660

Design and assessment approach

$$\frac{R_{u2\%}}{H_{m0}} = 1.75 \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \xi_{m-1,0}$$

with a maximum of $\frac{R_{u2\%}}{H_{m0}} = 1.07 \cdot \gamma_{f\,surging} \cdot \gamma_\beta \left(4.0 - \frac{1.5}{\sqrt{\gamma_b \cdot \xi_{m-1,0}}}\right)$ (6.2)

From $\xi_{m-1,0} = 1.8$ the roughness factor $\gamma_{f\,surging}$ increases linearly up to 1 for $\xi_{m-1,0} = 10$:
$\gamma_{f\,surging} = \gamma_f + (\xi_{m-1,0} - 1.8)*(1 - \gamma_f)/8.2$
With a maximum $R_{u2\%}/H_{m0} = 3.21$ for structures with an impermeable core and 2.14 for a permeable core.

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right]$$ for steep slopes 1:2 to 1:4/3 (6.6)

$C_r = 3.06 \exp(-1.5 G_c/H_{m0})$ with maximum $C_r = 1$ (6.8)

$\gamma_\beta = 1 - 0.0063|\beta|$ for $0° \le |\beta| \le 80°$
for $|\beta| > 80°$ the result $\beta = 80°$ can be applied (6.9)

Assumptions

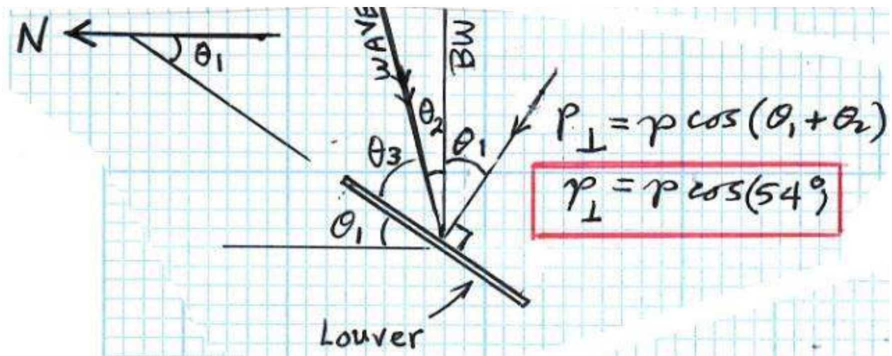
1. Waves are hitting at the toe of the breakwater at elev 575
2. Waves from north CLASS 3 (NNE)
3. Waves from south CLASS 1 (SSE)
4. Crest width Gc is half of width of breakwater assuming that is where Louvers are
5. crest height excludes louvre
6. Toe Elevation = Toe of the breakwater = 575

Note: Runup height on crest per FEMA Guidelines = 1.1' to 2.7'

Appendix E

Baffle Wall Structural Analysis

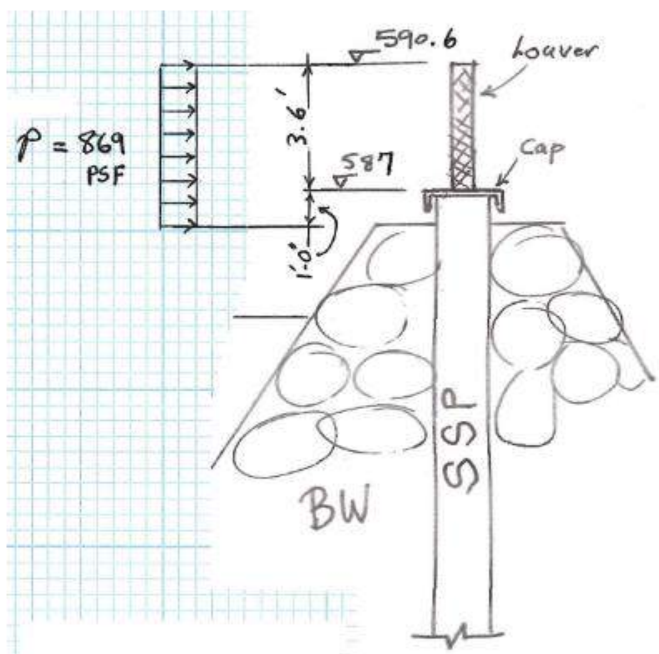
Waveload Analysis (see page 2R-7R):

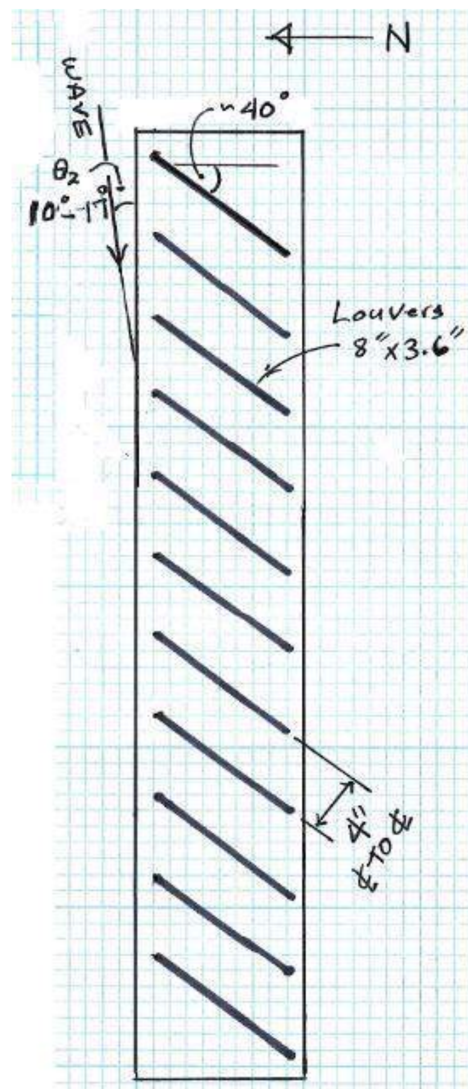


θ_2 =	14 °
θ_1 =	40 °
$\theta_3 = 90 - (\theta_2 + \theta_3)$ =	36 °

Wave pressure, p = 869 psf 20-yr, Class 3 (North B. W.)

Refer to page 8R - 12R for assumptions and louver wall design.





AECOM Calculations Cover Page, Preliminary

AECOM

Client Name		**Project Number**			
Project Name	Centennial Beach Breakwater and Lourvre Design				
Created by	Jeremy Mull, P.E.	**Date**	7-Feb-22	**Page**	1
Checked by	Bill Weaver, P.E.	**Date**	7-Feb-22	**of**	4

Subject

This workbook includes calcualtions of wave loading from coastal storm waves on the louvres, which will be installed along the top of the North and South Breakwater. The calculations follow the procedure outlined it the U.S. Army Corps of Engineerings (USACE) Coastal Engineering Manual (CEM) for waves that break on top of a rubble mound (like a breakwater) and the then overtopping bore impacts a seawall. Wave loading calculations are based on limited wave tank data and should be interpreted with caution.

Description

Version Updates:

Instructions:

1) Each sheet contains general inputs that are needed to complete the calculations, these cells are highlighted yellow.
2) Calculations are performed in cells that are not highlighted.

Purpose of Each Spreadsheet:

Wave Inputs
Summary of the wave inputs used in the wave loading calculations for each breakwater.

North Breakwater
Wave loading calcuations for the North Breakwater.

South Breakwater

North Breakwater

Class	Modeling Scenario	SWL (ft)	Breakwater Crest Elev (ft)	Depth at Breakwater Toe (ft)	Hb (ft)	L0 (ft)	Max Louvre Height (ft)	A_c (ft)	A_c (m)
CLASS 3	with Louver, 10 year	582.26	586	7.26	5.6628	390	4.6	3.74	1.14
CLASS 3	With Louver,20 year	582.73	586	7.73	6.0294	414	4.6	3.27	1.00

South Breakwater

Class	Modeling Scenario	SWL (ft)	Breakwater Crest Elev (ft)	Depth at Breakwater T	Hb (ft)	L0 (ft)	Maximum Lo	A_c (ft)	A_c (m)
CLASS 1	with Louver, 10 year	581.56	586	6.56	5.1168	190	4.6	4.44	1.35
CLASS 1	With Louver,20 year	582.03	586	7.03	5.4834	207	4.6	3.97	1.21

Bill's Earlier Version

North Breakwater

Class	Modeling Scenario	SWL (ft)	Breakwater Crest Elev (ft)	Depth at Breakwater T	Hb (ft)	L0 (ft)	Maximum Lo	A_c (ft)	A_c (m)
CLASS 3	with Louver, 10 year	582.26	586	7.26	6.6	390	4.6	3.74	1.14
CLASS 3	With Louver,20 year	582.73	586	7.73	6.5	414	4.6	3.27	1.00

NOTES/ASSUMPTIONS

Maximum louvre height along each breakwater was used

Although the Ac, wave steepness, and freeboard fall within range of the wave tank experiments, only a few ranges were tested

This analysis assumed depth limited breaking waves as no other information was provided

CEM Part VI - Wave Overtopping Force on Wall (North Wall)

Page VI-V-176 in CEM Part VI

Force Calculations: Method 1, Jensen and Bradbury (Equation VI-5-186)

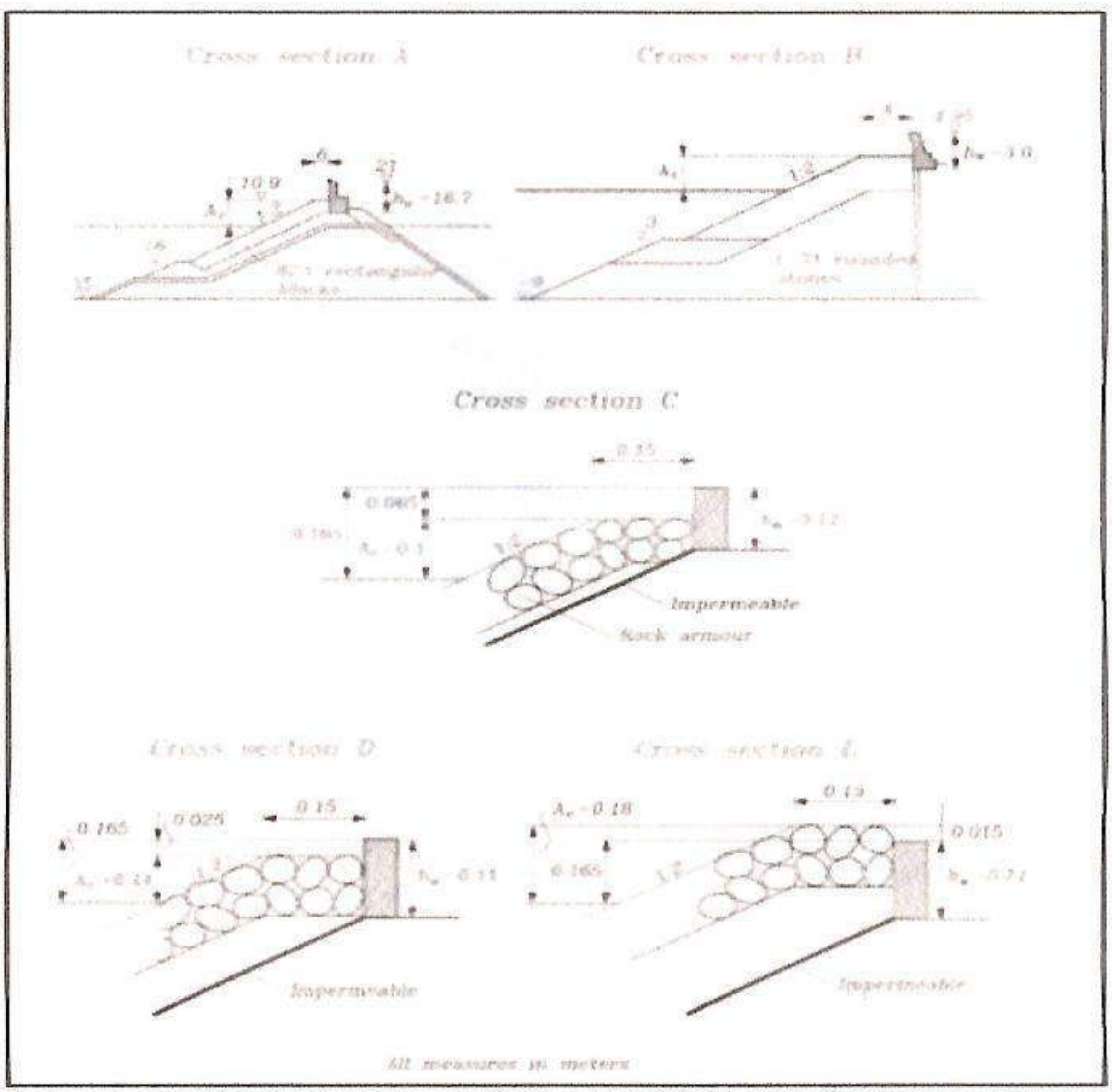
Step	Variable	Symbol	Class 3 10-Year	Class 3 20-Year
1	Mass Density of Water (slugs/ft³ or kg/m³)	ρ_w	1.9	1.9
2	Vertical Distance Between SWL and Berm Crest (ft or m)	A_c	3.74	3.27
3	Gravitational Acceleration (ft/s² or m/s²)	g	32.174	32.174
4	Significant Wave Height at Breakwater Toe (ft or m)	H_s	5.7	6.0
5	Deepwater Wave Length at Peak Wave Period (ft or m)	L_0	390	414
6	Crown Wall Height (ft or m)	h_w	4.60	4.60 *
7	Wave Steepness	H_s/L_0	0.01	0.01
8	α	-	-0.016	-0.016
9	β	-	0.025	0.025
10	Hs/Ac	-	1.51	1.84
11	**Force on Unit Length of Wall (lb/ft or N/m)**	$F_{h,0.1\%}$	**2,447.03**	**3,577.49** *

$$\frac{F_{h,0.1\%}}{\rho_w\, g\, h_w\, L_{op}} = \alpha + \beta \frac{H_s}{A_C} \qquad \text{(VI-5-186)}$$

where
- $F_{h,0.1\%}$ Horizontal wave force per running meter of the wall corresponding to 0.1% exceedence probability
- ρ_w Mass density of water
- h_w Crown wall height
- L_{op} Deepwater wavelength corresponding to peak wave period
- H_s Significant wave height in front of breakwater
- A_c Vertical distance between MWL and the crest of the armor berm
- α, β Fitted coefficient, see table

Cross section	Parameter ranges in tests			0.1% exceedence values of coefficients in Eq (VI-5-186)		Coefficient of variation	Reference
	A_c (m)	$s_{op} = \frac{H_s}{L_{op}}$	$\frac{H_s}{A_c}$	α	β		
A	5.6 - 10.6	0.016 - 0.036	0.76 - 2.5	−0.026	0.051	0.21	Jensen (1984)
B	1.5 - 3.0	0.005 - 0.011	0.82 - 2.4	−0.016	0.025	0.46	
C	0.10	0.023 - 0.07	0.9 - 2.1	−0.038	0.043	0.19	Bradbury, et al. (1988)
D	0.14	0.04 - 0.05	1.43	-0.025	0.028		
E	0.18	0.04 - 0.05	1.11	-0.088	0.011		

Notes
Fresh water
Maximum SWL along wall
ASCE 7-22 Equation 5.4-5, Assumes Breaking Waves
From CEM Table VI-5-60
From CEM Table VI-5-60
Calculated
Calculated



CEM Part VI - Wave Overtopping Force on Wall (South Wall)

Page VI-V-176 in CEM Part VI

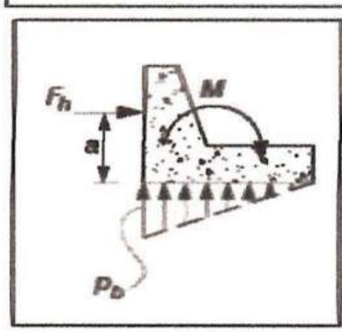
Force Calculations: Method 1, Jensen and Bradbury (Equation VI-5-186

Step	Variable	Symbol	Class 1 10-Year	Class 1 20-Year
1	Mass Density of Water (slugs/ft³ or kg/m³)	ρ_w	1.9	1.9
2	Vertical Distance Between SWL and Berm Crest (ft or m)	A_c	4.44	3.97
3	Gravitational Acceleration (ft/s² or m/s²)	g	32.174	32.174
4	Significant Wave Height at Breakwater Toe (ft or m)	H_s	4.7	4.9
5	Deepwater Wave Length at Peak Wave Period (ft or m)	L_0	190	207
6	Crown Wall Height (ft or m)	h_w	4.60	4.60 *
7	Wave Steepness	H_s/L_0	0.02	0.02
8	α	-	-0.016	-0.016
9	β	-	0.025	0.025
10	Hs/Ac	-	1.06	1.23
11	**Force on Unit Length of Wall (lb/ft or N/m)**	$F_{h,0.1\%}$	**570.76**	**884.53** *

$$\frac{F_{h,0.1\%}}{\rho_w\, g\, h_w\, L_{op}} = \alpha + \beta \frac{H_s}{A_C} \qquad \text{(VI-5-186)}$$

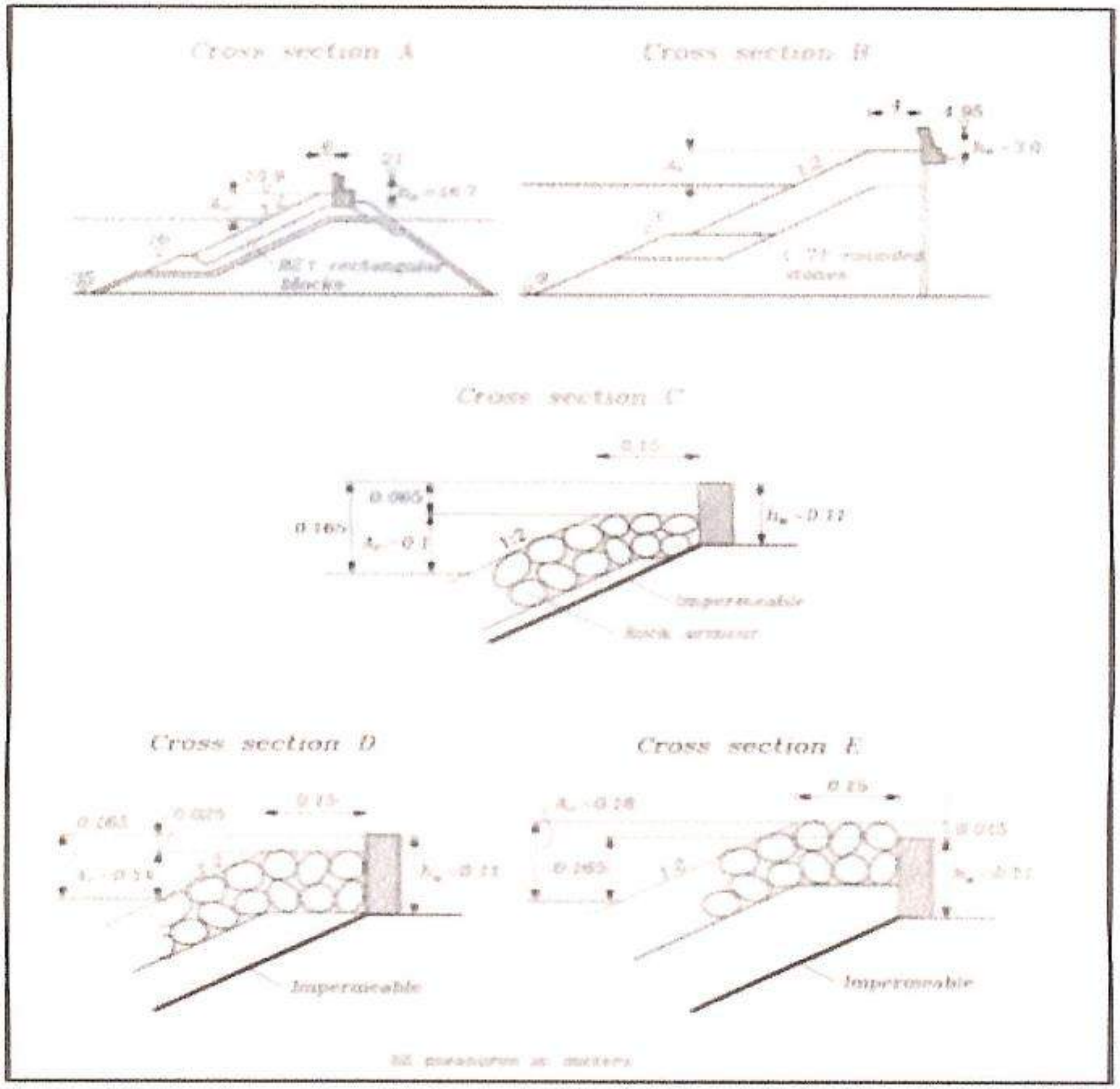
where

$F_{h,0.1\%}$	Horizontal wave force per running meter of the wall corresponding to 0.1% exceedence probability
ρ_w	Mass density of water
h_w	Crown wall height
L_{op}	Deepwater wavelength corresponding to peak wave period
H_s	Significant wave height in front of breakwater
A_c	Vertical distance between MWL and the crest of the armor berm
α, β	Fitted coefficient, see table



Cross section	Parameter ranges in tests A_c (m)	$s_{op} = \frac{H_s}{L_{op}}$	$\frac{H_s}{A_c}$	0.1% exceedence values of coefficients in Eq (VI-5-186) α	β	Coefficient of variation	Reference
A	5.6 - 10.6	0.016 - 0.036	0.76 - 2.5	-0.026	0.051	0.21	Jensen (1984)
B	1.5 - 3.0	0.05 - 0.011	0.82 - 2.4	0.016	0.025	0.46	
C	0.10	0.023 - 0.07	0.9 - 2.1	-0.038	0.043	0.19	Bradbury, et al. (1988)
D	0.14	0.04 - 0.05	1.43	-0.025	0.028		
E	0.18	0.04 - 0.05	1.11	-0.088	0.011		

Notes
Fresh water
Maximum SWL along wall
ASCE 7-22 Equation 5.4-5, Assumes Breaking Waves
From CEM Table VI-5-60
From CEM Table VI-5-60
Calculated
Calculated



Assumptions:

- The north breakwater is to be designed as "Class 3", for a 20-year wave attack and wves making 14 degrees with breakwater, as shown on page 1R. This governs the G347 design of louvers.
- The south breakwater is to be designed as "Class 1" for a 20-year wave and for waves making similar angle but opposite direction. This does not govern design of the louvers.
- Per analysis on page 4R, the force applied to a 4.6' wall = 3,578 lb/ft above crest of north breakwater:

  p = 3,578/4.6 = 778 psf

  This pressure has a component perpendicular to the louver surface:

  $p_{\perp}$ = 778*cos(54°) = 457 psf (see page 1R, to be used for design of louvers)
- Louver wall is 3.6' high above SSP wall, which extends 1' above crest of breakwater.
- The calculated force of 3,578 lb/ft of wall length will be resisted by the total wall height of 4.6' (1' SSP wall extension above breakwater + 3.6' louvers).
- Louver panels will consist of 8" wide x 3.6' long steel plates welded to 1" thick x 12" wdie base plates, which will be bolted to a steel cap (channel) at top of SSP wall.
- The spacing of the louver plates is 4" on center. The analysis and design will ignore the louver spacing, which allows for some wave water to flow through and result in pressure reduction (conservative).
- Ignore the bottom foot of the wall because it is a solid SSP and very capable of resisting the wave forces.
- Wind pressure is estimated to be ~ 30 psf << wave pressure 457 psf. Therefore, the wind pressure load case does not govern.

Louver Wall Design:

Try 3/8" thick louvers x 8" wide, fixed at bottom (welded to base plate, which will be bolted to SSP cap).

Use 1" vertical strip of louver wall to calculate flexural and shear stresses per AISC Standard Specifications (14th Ed.).

Sx = $(3/8)^2$*1/6 = 0.0234 in^3

Mmax = 3.17*$(43.2)^2$/2 = 2958 in-lb/in

Vmax = 3.17*43.2 = 137 lb/in

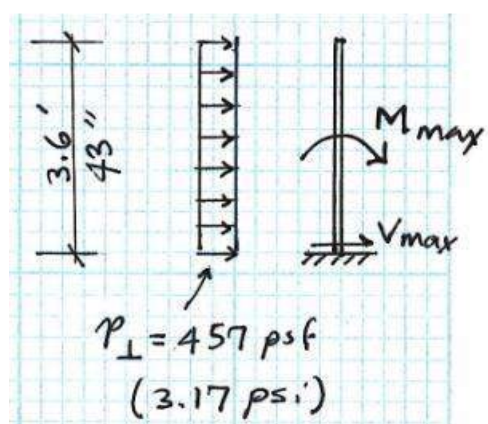
Try A36 steel (Fy = 36 ksi):

Fb = Mmax/Sx = 126.2 ksi

\>>

Fb = 36/Ω = 21.6 ksi NOT GOOD

Ω = 1.67



Re-analysis Louvers with Revised Assumptions:

- Assume louver plates are 5/8" thick, Grade 50 steel.
- Reduce wave pressures by 40% due to refraction of wave because of the nature of the multiple plate (louver wall) as it compares to smooth flat plate, per Bill Weaver's wave analysis.

$Sx = (5/8)^2*1/6 =$ 0.065 in^3

Mmax = 0.6*2,958 = 1775 in-lb/in

Fb = (2,958*0.6)/(1,000*0.065)

Fb = 27.3 ksi

<

Fb = 50/Ω = 30 ksi OKAY

Ω = 1.67

$Fv = (137*0.6)/(0.625*10^3)$

Fv = 0.13 ksi

<<

Fv = (0.6*50)/1.5

Fv = 20 ksi OKAY

Use 5/8" louver plates, Grade 50 steel, 8" wide x 3.6' high.

Design Louver Panel and Connections:

Weld:

Try 3/8" fillet weld to base plate:

e = 0.625" + 2*(0.375/2)

e = 1 in

C = T = Mmax/1" = (2,958*0.6)/(1,000*1)

C = T = 1.8 k/in

Allowable weld strength,

$Rn/\Omega = F_{n,BM}*A_{BM}/\Omega$ (based on base material)

Nominal strength of base material, $F_{n,BM}$ = 36 ksi

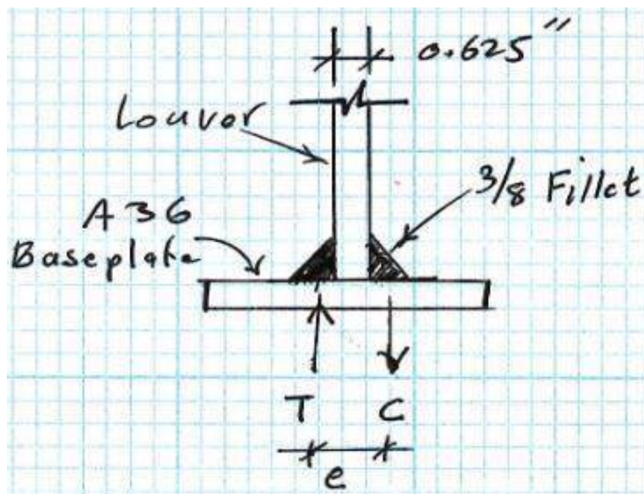
Effective area of base material, A_{BM} = 0.375"*1"

Ω = 2

Rn/Ω = 6.8 k/in

>

C = T = 1.8 k/in OKAY



Allowable weld strength,

$Rn/\Omega = F_{n,w}*A_w/\Omega$ (based on weld strength; AISC J2-3)

Nominal strength of weld, $F_{n,w}$ = 70 ksi

Effective area of weld, A_w = 0.375"*cos(45°)/2 (fillet angle)

Ω = 2

Rn/Ω = 10.1 k/in

>

C = T = 1.8 k/in OKAY

Note weld size is a bit overside to account for long-term fatigue and possible corrosion with time.

Ice Loading:

Reference: US Corp. of Engineers (USACE) EM 1110-2-1612, "Engineering and Design - Ice Engineering"

Per Section 2-3, ice breakthrough load (allowable P), floating ice sheet:

P = $A*h^2$
A = 1/16 for most practiced purposes
P = ice load in tons
h = thickness of ice sheet

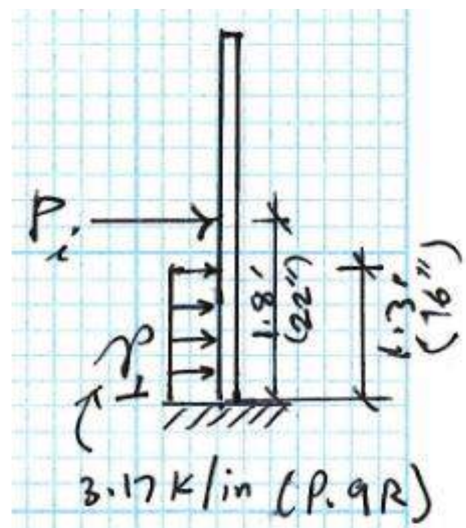
Assume a 12" thick ice sheet is floating by waves attacking the louver wall at mid height:

$P = (1/16)*(12)^2 =$ 9 tons
P = 18 kips

Characteristic length, Lc, of a floating ice sheet can be assumed to be 15 to 20 times thickness of ice for freshwater (Section 2-3C):

Lc = 18 ft (average value)
or
Ice force, Pi = (18 kips)/18')cos(54°)*(1000/12 in/ft)
Pi = 49 k/in

Mmax = $(3.17*(16^2/2)*1.0) + (49*22)$
Mmax = 1483 in-lb/in
Fb = (1483/1000)/0.065
Fb = 22.8 ksi
<
Fb = 30 ksi OKAY

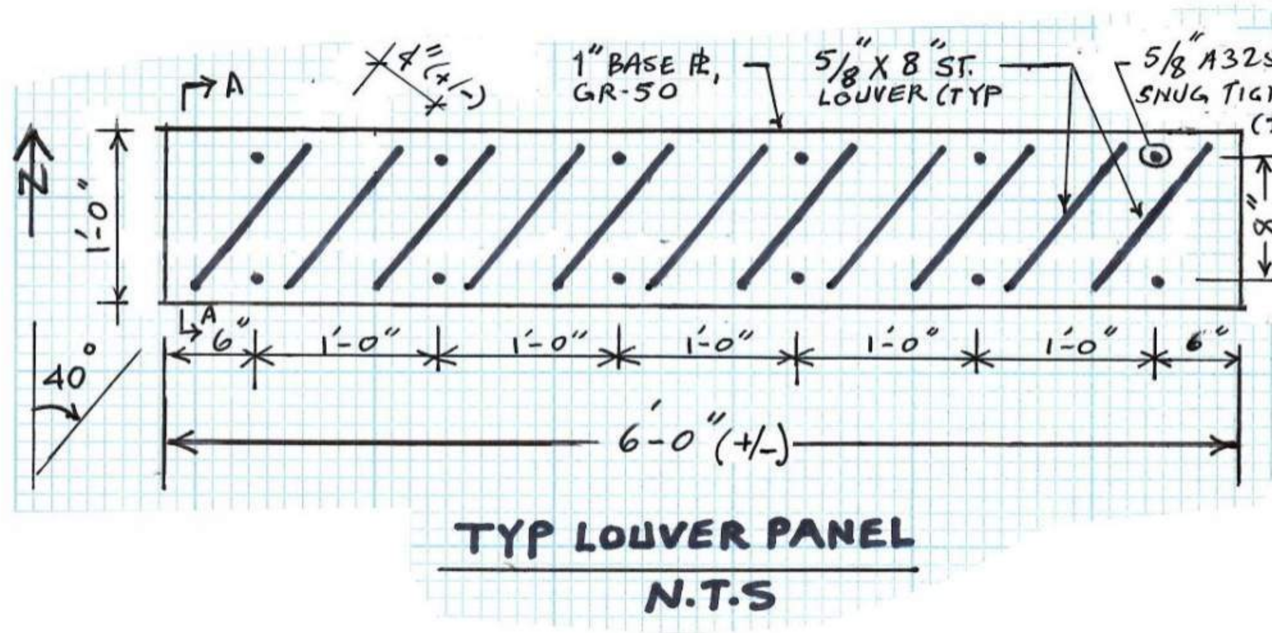


Notes:

1) Shear stress is okay by inspection.
2) No reduction was considered due to wave refraction/deflection, since water was assume dto be confined by the ice sheet, conservative.

Bolts for Base Plate to SSP Cap:

Assume 12" wide base plate bolted to SSP on both sides of louver plate.

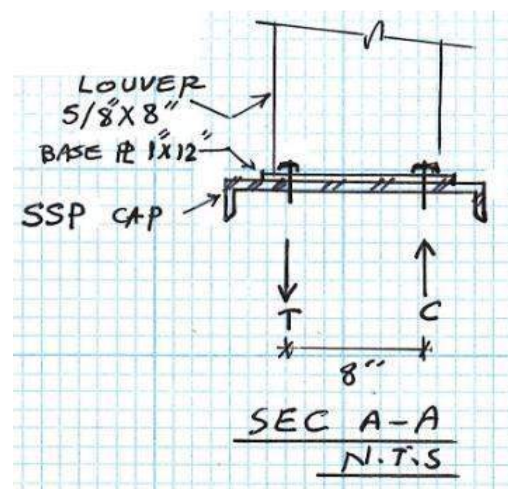


Mmax = 1775 in-lb/in (page 9R)

Bolt spacing, s = 12 in

C = T = (1775/1000)*(8"/8")*2 louvers/ft

C = T = 3.6 k/bolt



Per Table J3.1 (AISC, 14th Ed.), A325 bolts are in Group A.

Allowable tension, rn/Ω = 13.8 kips for 5/8" dia. A325
(Table 7-2, AISC, 14th Ed.)
>
C = T = 3.6 k/bolt OKAY

Use 5/8" dia. A325 snug tight @ 12" spacing, per layout shown above, H.D., galvanized.

Note bolts are a bit oversized to allow for future corrosion, cross-sectional area loss, and fatigue stresses.