McKinley Beach Safety Study

Milwaukee, WI

Milwaukee County

April 21, 2022

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Dr. Stephen P. Leatherman of Coastal and Environmental Consultants is Professor and Director of the Laboratory for Coastal Research at Florida International University. For over three decades, he has reviewed, evaluated and rated beaches and coastal areas throughout the world and has worked to increase awareness about the dangers of rip currents at beaches


1937


1963


1980


1990


2010


2020

Introduction

For over a century, McKinley Beach has served Milwaukee County residents and visitors alike as an opportunity to recreate, exercise and relax in and along Lake Michigan's shoreline. In Summer of 2020, during a period of record high water levels, four fatalities occurred in the waters of McKinley Beach resulting in a closure and impetus to study the beach conditions seeking understanding and resolution.

Purpose and Scope

The purpose of this study is to identify measures necessary to improve swim safety, beach sustainability and water quality at McKinley Beach.

This study sought to answer the following questions:

- Is the beach safe to (eventually) re-open to swimmers?
- Can design mitigate the challenges faced by McKinley Beach?
- How can swim safety be improved and encouraged amongst Milwaukee County beach goers?
- How is water quality impacted at present, and under proposed modifications?
- Are high water levels, similar to those seen in 2020 likely to damage McKinley Beach or other nearby infrastructure such as Lincoln Memorial Drive?

In addressing the above questions, this study sought to answer the questions below as well:

- Do rip currents appear to be present (or possible) given current configuration?
- Has storm damage over time or major storm events contributed to the increase in adverse events?
- What maintainable, sustainable and client resilient solutions could be implemented to improve swim safety?

Recognizing the fatal events of the summer of 2020, special consideration will be taken of wind and wave conditions during and in the leadup to those events as well as to the record high and low water levels experienced. This data was utilized in selection of timing windows for field observation, dye testing and modeling scenarios.

History

One of Milwaukee's first public accesses to the shore, McKinley Beach was an unintentional product of the 1892 construction of the breakwater on the south side, which interrupted the longshore currents running north to south and allowed sand to build up and create a narrow beach. This quasi-natural configuration remained in place until the current configuration was constructed in early 1989.

Figure 1, below, shows McKinley Beach in 1937, the earliest available aerial imagery, and 1990, the first aerial imagery of the then newly designed pocket beach configuration, which remains today.

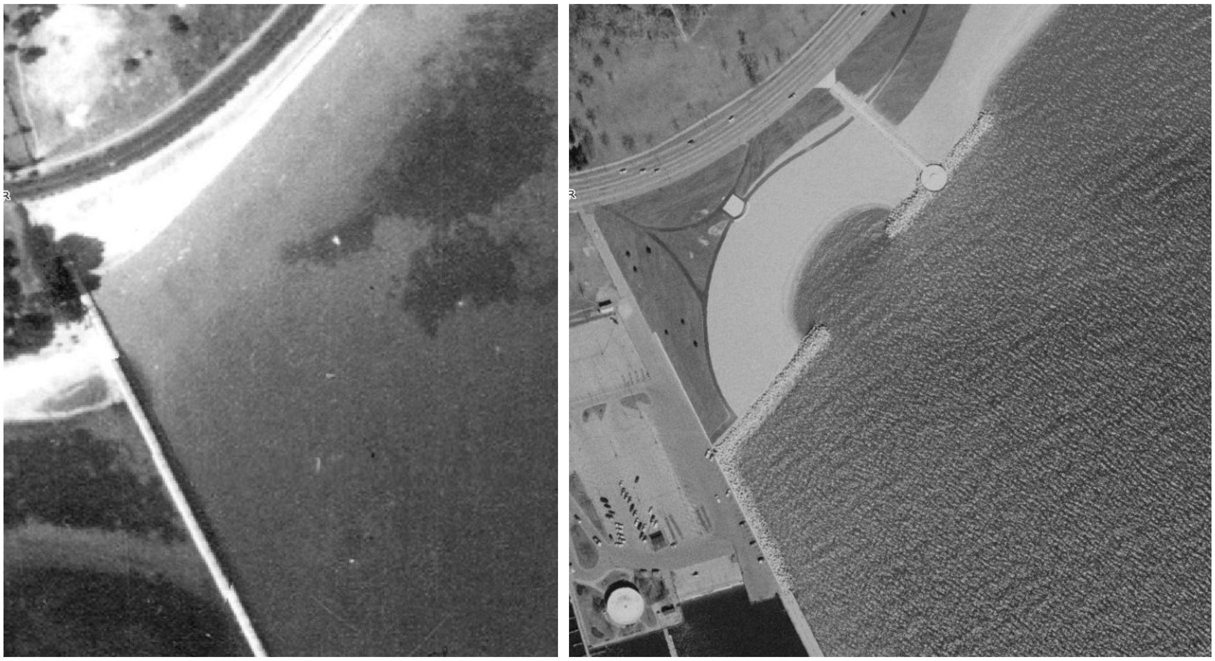

Figure 1 – McKinley Beach 1937 and 1989 (Milwaukee County Land Information Office)

Historic Design

The pocket beach with armored breakwaters/headlands was likely implemented in order to provide a sheltered environment for swimmers, add to available shore-adjacent land and impede sediment transport away from the shoreline. A Southeastern Wisconsin Regional Planning Commission (SEWRPC) report contemporary to the design and installation of the pocket beach at McKinley notes:

> "The headlands are usually protected with an armor stone revetment. A headland beach system may create a relatively large amount of land for recreational use."
>
> *A Lake Michigan Shoreline Erosion Management Plan for Northern Milwaukee County Wisconsin, SEWRPC, 1989 p. 173*

The report then goes on to provide a schematic design for a beach with revetment protected headlands and shows a picture of newly constructed McKinley Beach. An excerpt from *A Lake Michigan Shoreline Erosion Management Plan for Northern Milwaukee County Wisconsin* can be found in *Appendix A*.

Generally, McKinley Beach is perceived to be "family friendly" as the pocket beach seems to imply a safe and secluded swim area, perhaps inducing a false sense of security. The adjacent playground further supports the notion of child-friendliness. For this reason, the context under which McKinley Beach was constructed should be considered as conceptual solutions are developed. Milwaukee has an array of beaches, though many are more similar to Bradford Beach, exposed straight-line beaches. If McKinley was developed in order to provide a desired level of service for families and novice swimmers which could not be achieved elsewhere, beach closure should also be considered if a remedy is not found.

The plan and section views developed for the construction of McKinley Beach are shown below, with full plan sheets in *Appendix B.*

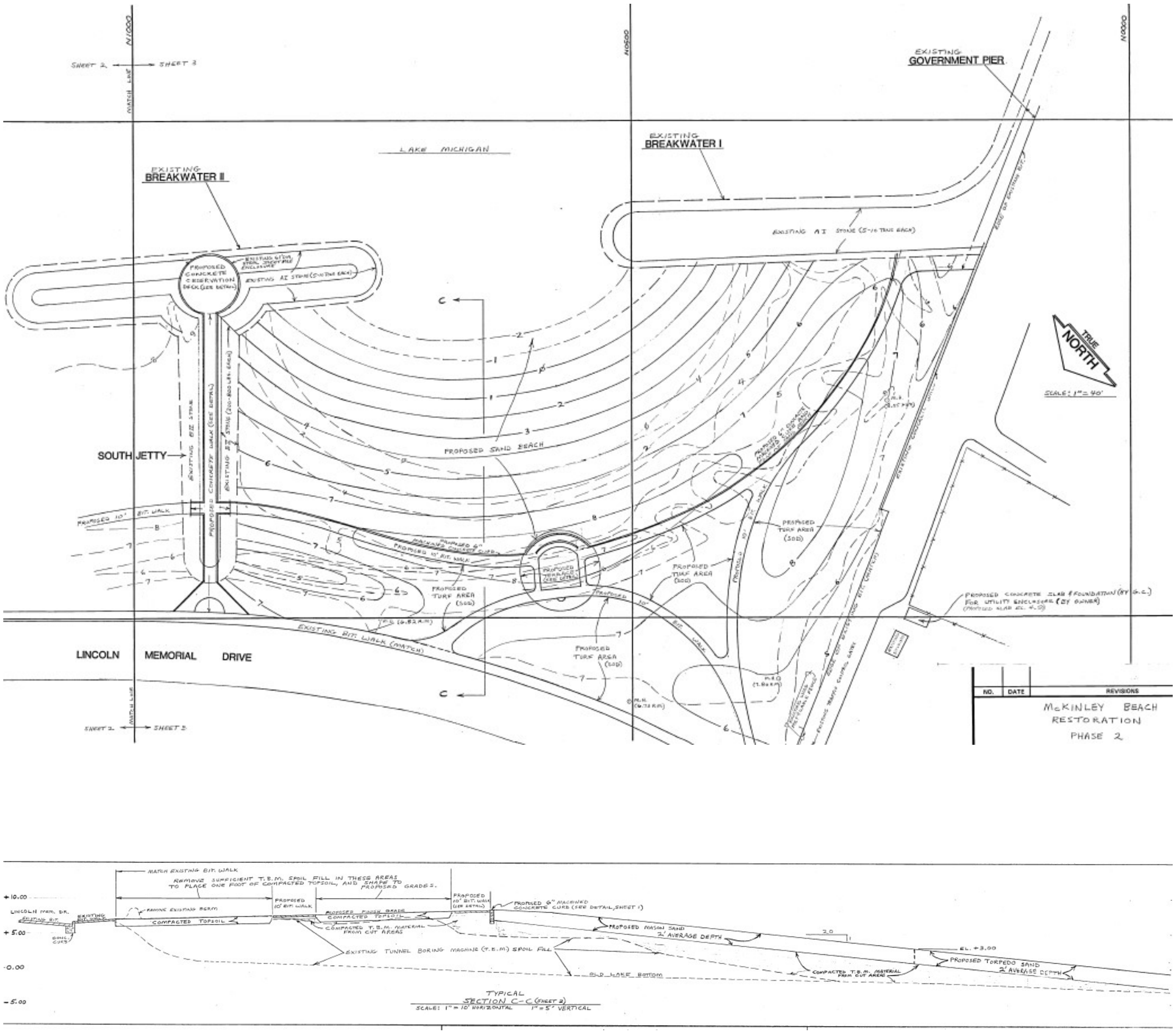

Figure 2 – McKinley Beach Construction Documents, Plan and Section View

The beach was designed to have a steady 1V:20H (5%) grade with an average depth application of 2' of sand. Mason Sand was used from the top of the beach to an elevation of approximately 583.87' and Torpedo Sand was utilized from that point out into the lake. Sand gradation plays a role in beach sustainability and developed slope as a function of wave action over time. Coarser, larger sand particles render beaches with steeper gradation while finer sand particles render more gently sloping beaches. This can be seen when considering the foreshore[1] of the Pebble Beach immediately north of McKinley versus McKinley itself. The Pebble Beach consists of large pebbles with many angular faces and is quite steep at the waters edge.

Through wind, wave and hydrodynamic modeling (an emerging science at the time of McKinley Beach construction), there have been many lessons learned, implications identified and expectations revised. We

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[1] The foreshore is the part of the beach which is wet due to wave run-up under normal conditions.

now know, for example, that pocket beaches are subject to not only cross-shore[2] transport processes which are modulated by wave energy, but also longshore[3] energy transport which may cause rotation within the protected area of the beach. Both of these can contribute to a reduction in beach sustainability. Additionally, the enclosed area can exacerbate the effects of a seiche[4] which can accompany sudden changes in atmospheric pressure or wind.

Elements external to the beach such as adjacent infrastructure may also play a role in creating unsafe conditions or increasing the occurrence of rip currents[5]. The existing beach is located where the existing marina breakwater and the natural shoreline come together at an obtuse angle. This configuration subjects the beach area to waves from at least two different directions, potentially simultaneously; waves come in from the southeast and, occasionally from the south-southwest as they reflect off of the Government Pier wall. This was observed during field observations in December 2021 as part of this study.

Historic Waves & Water Levels

Likely constructed due to rising lake levels, the pocket beach has experienced record high and record low water levels. As low water levels cause wind and wave action to interact with the lakebed of the beach differently than high water levels, it is possible this sequence of water level variation, having altered the bathymetry has resulted some of the beach instability at McKinley Beach and uptick in adverse events.

Plans for McKinley beach are dated March 1989 at which point the water monthly mean lake-wide average water level was 578.48’. Water levels had risen to an all-time high of 582.35’ in October 1986. The top ten water levels are shown in Figure 3 below.

Top Ten Mean Monthly Water Levels Since 1918

Year	Month	Water Level
1986	October	582.35'
2020	July	582.22'
2020	June	582.19'
2020	August	582.09'
1986	July	581.99'
1986	August	581.99'
1986	September	581.96'
1986	November	581.96'
2020	May	581.96'
2019	July	581.92'

Figure 3 – Lake Michigan – Huron Top Ten Monthly Mean Water Levels from 1918 to 2020 (USACE)

At time of writing, Lake Michigan currently sits at 579.49’ or 24” above the IGDL (International Great Lakes Datum) of 577.50’ and 7” above the long term average of 578.88’ for monthly mean water level between 1918 and 2020. Different technical advisory organizations have opposing forecasts for what will occur in the near and far term with regard to Lake Michigan – Huron Water levels.

Lake Michigan-Huron Water levels since 1918 can be seen in Figure 4 Below

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[2] Cross-shore currents are (nearly) perpendicular to the shore

[3] Longshore currents are (nearly) parallel to the shore, and generally run north to south along Lake Michigan’s western shoreline

4 Seiche is a standing wave which oscillates vertically, typically caused by sudden changes in atmospheric or wind conditions.

5 Rip currents are strong narrow bands of current which move away from shore

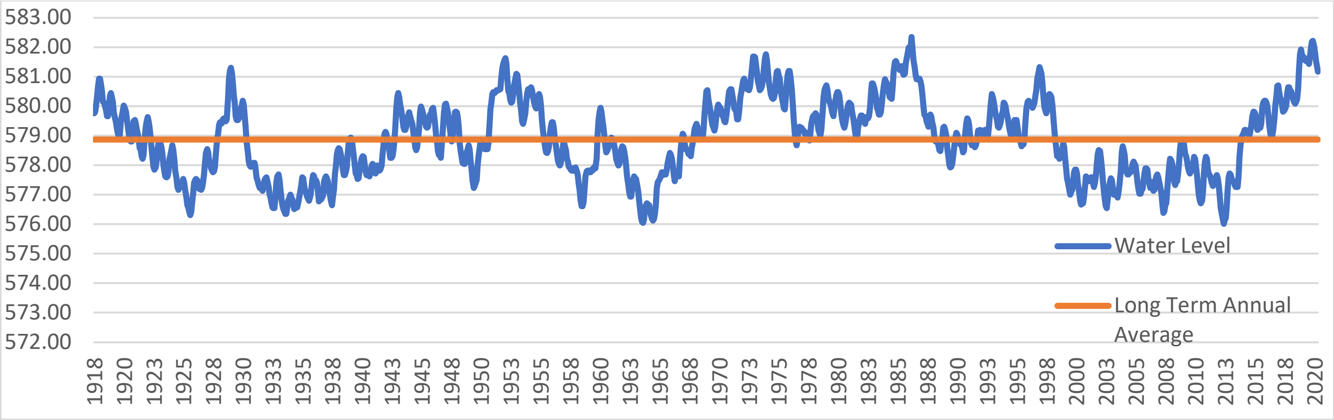

Figure 4 – Lake Michigan – Huron Monthly Mean Water Levels from 1918 to 2020 (USACE)

Historic Wind

Historic wind data informs solutions design, modeling scenarios and field observation windows during which researchers observe conditions and execute field work, seeking wind similar to the conditions at the time of the drowning events and at extremes. An analysis of wind data collected by the NOAA's offshore buoy off Atwater Beach (ATW20) between May 27, 2020 and October 28, 2020 revealed winds primarily from the south southeast as shown on the Wind Rose[6] plot below. When recently available data from the 2021 season was obtained, this data yielded a similar distribution.

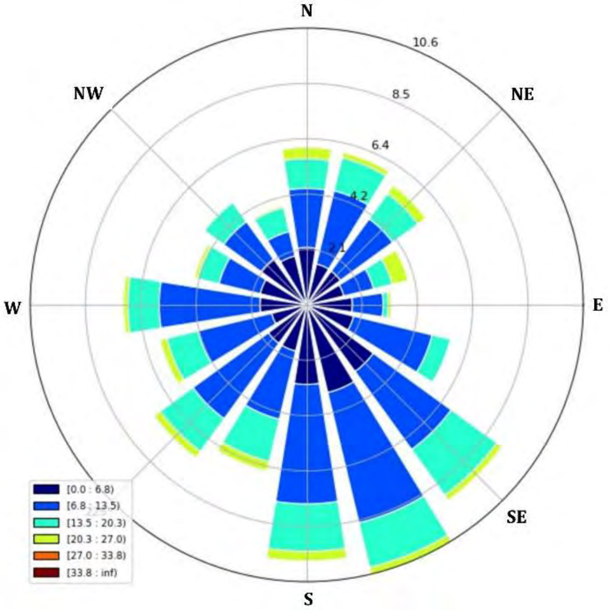

Figure 5 – Wind Rose, Milwaukee 2020 (ATW20)

Though wind data site specific to McKinley Beach from 2020 is not available, data from ATW20 can be used to represent the conditions during the 2020 drownings. Confirmation of the adequacy of the ATW20 data as a proxy for McKinley beach is discussed in the Hydrodynamic Modeling section of this report.

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[6] Wind (or Wave) Roses are interpreted by viewing the magnitude of each directional wedge as its proportion of occurrence with the data set.

Review of Existing Data

Existing Conditions

Beach & Swim Pocket

As previously discussed, the beach is a pocket beach with armored breakwaters and headland comprised of a compressed arc bounded by sand, a headland jetty and two breakwater with an opening between them.

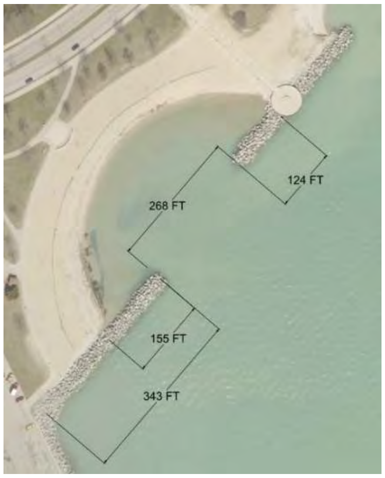

Figure 6 – McKinley Beach Dimensioned (2020 Aerial Photography Milwaukee County)

The beach and swim pocket appear to be in relatively good condition with little to no apparent incidents of stormwater beach scour. At time of study – the greatest width of the swim pocket was 547' from waters edge to waters edge and approximately 223' in the transverse direction from the breakwaters to the shore. During field visits algae and other bio-organic matter is often seen in the northeast corner of the beach.

Despite extreme high water in 2020 and varying water levels in the three decades since its construction, McKinley Beach has held up fairly well from a sustainabily standpoint. Referencing the original plans, found in Appenix B, and assuming the relative 0' elevation to be approximately, 580.87' on a comparative datum the beach appears to have lost about 0.87' or 10.5" of sand to erosion or currents.

Sediment grab samples were collected to perform grain size analysis from the locations shown below:

Figure 7 – Sediment Grab Sample Locations

The sand currently present, gradation shown below, appears to be slightly more fine in character than what was initially placed. This may be indicative of the ongoing effects of longshore currents. Sample #1, taken just off the north end of the southbreakwater is slightly larger in character than than the other samples takend from within the lake, a finding which complements the known scour hole and currents observed throughout the field study.

Sieve	Sieve Opening	Percent Passing					Wentworth Size Class	ASTM C144	ASTM C33
	(mm)	#1	#2	#3	#4	#5		Mason Sand	Torpedo Sand
2"	50.8	100	100	100	100	100	Pebble	100	100
1-1/2"	38.1	100	100	100	100	100		100	100
1"	25.4	100	100	100	100	100		100	100
3/4	19.05	100	100	100	100	100		100	100
3/8	9.525	100	100	100	100	100		100	100
#4	4.75	100	99.8	99.5	99.1	100		100	95-100
#8	2.32	100	99.6	99.1	98.1	100	Granule	95-100	80-100
#10	2	100	99.5	98.9	98	100	Very Coarse Sand	--	--
#16	1.18	100	99.4	98.3	97.3	100		70-100	50-85
#30	0.6	99.7	99	97.5	96.3	100	Coarse Sand	40-75	25-60
#40	0.425	98.9	98.5	96.7	95.3	99.7	Medium Sand	--	--
#50	0.3	90.3	95.2	93.4	91.5	89.3		10-35	10-30
#100	0.15	11.4	24.6	28.6	25.8	4.4	Fine Sand	2-15	0-10
#200	0.075	0.1	1.7	0.8	1.4	0.1		0-5	--

Figure 8 – Gradations of McKinley Grab Samples and Anticipated Gradations of Mason Sand and Torpedo Sand

The American Society for Testing and Materials (ASTM) standard gradation for mason sand and torpedo sand are shown in the columns at right for comparison to existing conditions. The gradation summary and graphs for each grab sample can be found in *Appendix C*.

North Breakwater

The north breakwater, measuring approximately 124' long by 22' wide on top and 56' feet wide at its base appears to be in good condition. The orientation is parallel to the shore and its north end abuts the jetty observation deck. The armor stone appears to be in good condition and is consistent in size, shape and material

South Breakwater

The south breakwater, measuring approximately 343' long by 22' wide on top and 56' feet wide at its base appears to be in good condition. Approximately 155' are exposed to water on both sides with the remainder abutting the south end of the beach. The orientation is parallel to the shore and its south end joins the armor stone of Government Pier. The armor stone appears to be in good condition and is consistent in size, shape and material.

Bathymetry & Topography

Seaworks utilized multibeam sonar data to collect from the gap in the breakwaters lakeward approximately 600' southeast. The survey area measured approximately 1,100' long by 1,300' wide with water depths varying from approximately 2' - 15'.

Within the beach area, a Z-boat drone equipped with single beam sonar was utilized to capture shallow water bathymetry and hard to visualize features.

The Lakebed appeared fairly unremarkable however some scour holes were noted near the ends of both breakwaters. These holes could cause become hazardous for inexperienced swimmers making their way around the breakwater. This scour may also be indicative of rip currents or undertow. Figure 9 below displays the obtained bathymetry data with depth increasing in order of rainbow sequence. The shallowest contour shown here on the red/orange border is 578' and the lowest in the purple at 566'.

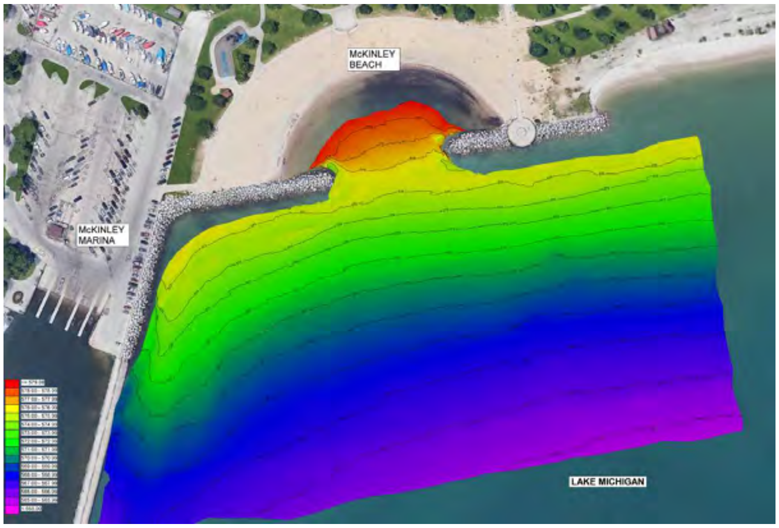

Figure 9 – Off-Shore and Shallow Water Bathymetry

The bathymetry shown in Figure 9 above portrays, an elevation of approximately 576' between the breakwaters – with a seaward grade of 1.5% and a shoreside grade of 2.5%. The surface produced informs modeling efforts of existing and proposed conditions

Additionally, this bathymetric survey enables an assessment of water depth at critical points in time and space, such as: the time of initial design and construction, the time of the recent drowning incidents and the current status. Figure 10 below shows the water depths calculated. The water depth between the breakwaters during the summer of 2020 is observed to be roughly 2.5 times what the initial design proposed.

Water Depths at Bathymetric Survey Extents & Critical Points					
	March 1989	**June 2020**	**July 2020**	**August 2020**	**April 2022**
Mean Water Elevation:	578.5'	582.2'	582.2'	582.1'	579.49'
High Contour (578') Depth:	0.5'	4.2'	4.2'	4.1'	1.5'
Between Breakwater Contour (576') Depth:	*2.5'	6.2'	6.2'	6.1'	3.5'
Low Contour (566') Depth:	12.5'	16.2'	16.2'	16.1'	13.5'
*Assuming between breakwater contour of 576' at time of construction. Original contouring is unknown, but McKinley Beach is estimated to have lost about 10.5" of sediment due to currents and erosion since construction. Accounting for this loss, the contour between the breakwaters may have been approximately 576.87' at time of construction which would have rendered a water depth between breakwaters of 1.63'.					

Figure 10 – Water Depths at Bathymetric Survey Extents & Critical Points

Grade differentials of approximately two feet were noted throughout the survey, indicating sediment transport[7], likely caused by high levels of wave energy.

This survey was supplemented with topographic shoreland survey as well as LiDAR and additional offshore bathymetry data obtained by our modeling team. These sources were then stitched together to create a base for an existing conditions model using hydrodynamic modeling software.

The report titled Hydrographic Survey Report, produced and delivered for this element, can be found *Appendix A* of this study.

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[7] Sediment transport is the transport of sand by currents; more precisely, the movement of granular solids by fluids.

Drowning Incident Reports

Review of the drowning incident reports provided insight into date, time and witness reports. This information was used to identify wind conditions this team sought to replicate during our field study and in our modeling considerations. For this section, only July 18, 2020 and August 8, 2020 are considered due to the fact that we have more information on the mechanics of what was witnessed. The June 3, 2020 event, though limited in information, is also considered in later sections of this report.

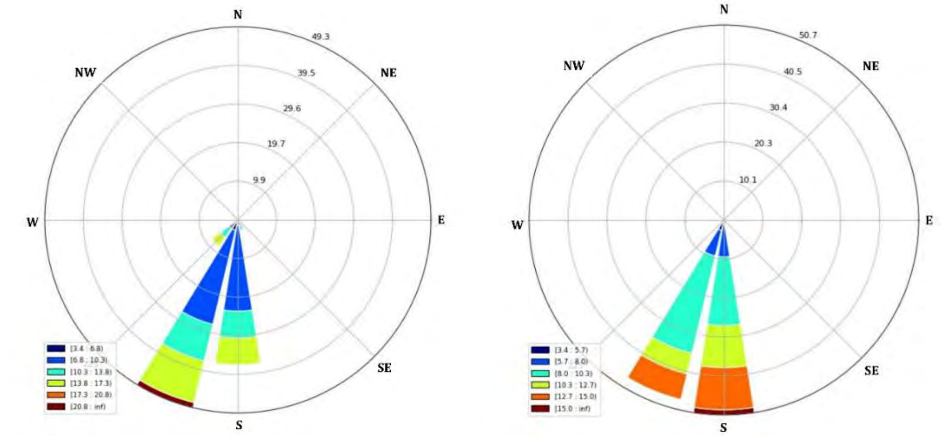

Figure 11 - Wind Rose Plot for 12 Hour Lead-Up to Each Drowning Event (July and August, respectively)

A note of caution on the wind data shown above. Recall that a buoy was not present at the time of the drownings. The data shown above is from the ATW20 which does not have the Government Pier and McKinley Marina immediately to its southwest flank. The effect of Government Pier, and the other breakwaters which define the marina is an impeded fetch length[8] and a resultant reduction in wind and wave energy.

Though a southwest wind was not encountered in our field study, this condition was accounted for in subsequent hydrodynamic modeling. The model used, relies on wave magnitude and direction input which are a product of sustained winds of a given direction.

Field Study

Wave Buoy

To validate wind and wave models and to provide real-time data throughout the course of this study, a Spotter Wave Buoy was deployed as a moored application. This buoy reports and logs wind and wave data from its location. The buoy was initially deployed approximately 300' off of the gap between the breakwaters (outlined in white in Figure 12 below, and was subsequently moved by wave action to a location approximately 100' off of the northern breakwater. Though this move was unanticipated, the research team determined data could still be collected and utilized for the course of this study. Based on location depth, and known wave characteristics, the resultant location of the buoy can still be utilized for data gathering because it is not believed to be within the surf zone[9] and therefore wave heights are not being reduced. The data from both locations can still be considered as both are valid placements.

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[8] Fetch Length is the area of lake surface over which the wind blows constant and relatively unimpeded, resulting in wave generation.
[9] Surf Zone is the zone off the foreshore where waves break as a consequence of depth limitation, reducing in height as they approach shore.

In the course of final design of whatever solution is chosen, the authors of this study would recommend deploying the buoy back out into the field in order to capture another season of data to better identify any seasonal discrepancies and to see how thins have changed given the dropping water level.

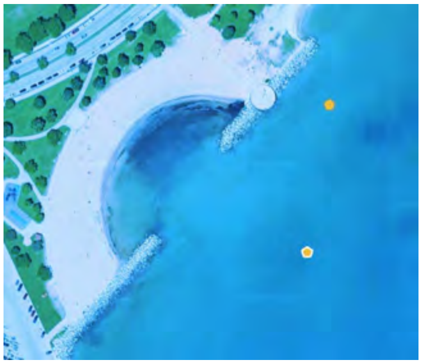

Figure 12 – Spotter Wave Buoy Deployment

The buoy was initially deployed in the on November 9, 2021 and remained in the water until January 13, 2022. During this time the maximum wave height encountered was approximately 14.3 feet and the minimum period encountered was 1.48 seconds. While these values are extreme for nearshore conditions, the average wave height registered around 1.6' and the average period registered 7.8 seconds. Wave height and direction, though not period[10], have been found to be significant in rip current development.

Buoy	Significant Wave Height	Wind
	(ft)	(mph)
Minimum	0.16	0.16
Q1	0.52	0.85
Median	1.05	1.79
Q3	2.26	6.26
Maximum	14.3	22.37
Average	1.59	4.29

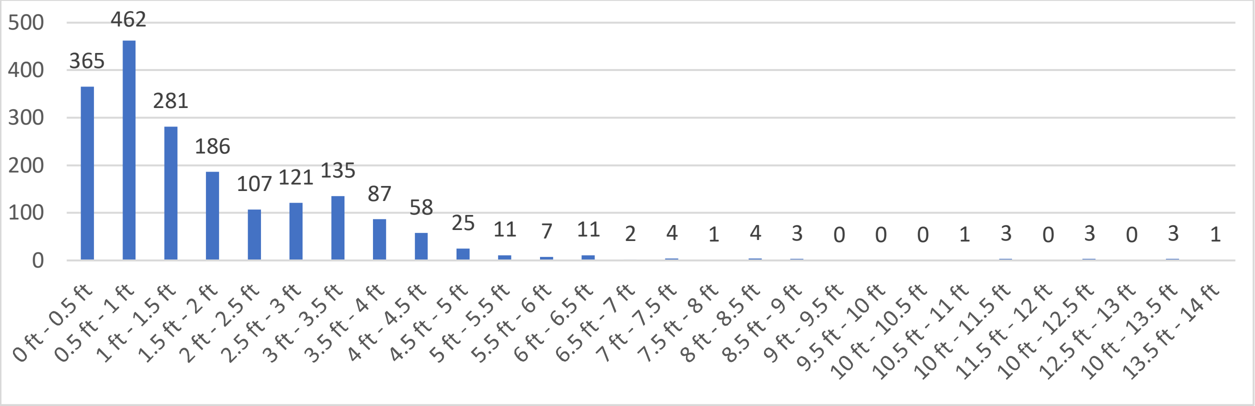

Figure 13 – Spotter Buoy Data Summary and Wave Magnitude Frequency Histogram

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[10] Wave Period is the time it takes for two successive crests to pass a specified point.

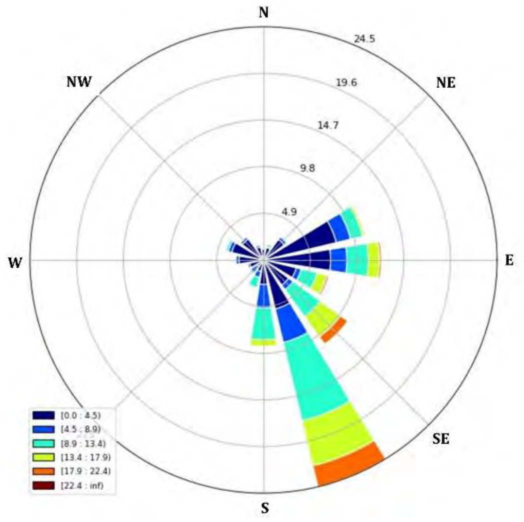

Figure 14 – Spotter Wind Rose, Buoy November 2021 to January 2022

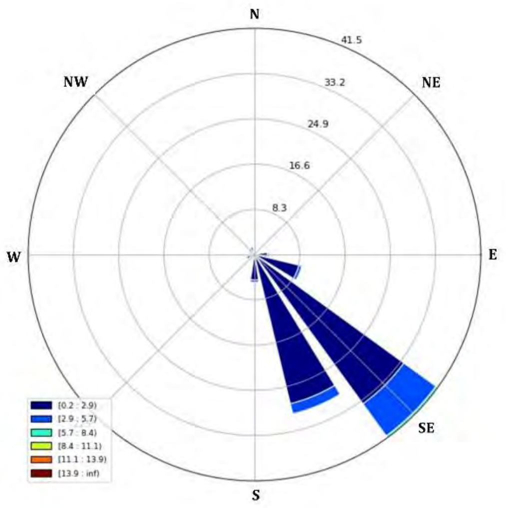

Figure 15 – Spotter Wave Rose, Buoy November 2021 to January 2022

This data was used to validate wave transformations and modeling and future design of conceptual solutions. Additionally, the real-time data was found to identify times when conditions were similar to those of the drowning incidents or met conditions during which this team expected to see rip currents.

Dye Testing

Using the data from the police reports and our knowledge of what conditions can facilitate the creation of rip currents, this team completed several dye tests over a period of three site visits. Current conditions were observed via real-time reporting from the buoy and meteorological reporting.

A fluorescent red liquid tracer dye manufactured by KingsCote chemicals was utilized. This dye is non-toxic, bio-degradable and disappears within about fifteen minutes. “FWT Red” was utilized mixing roughly one pint of dye with one gallon in-situ lake water. This solution was then shaken to evenly disperse the chemical.

Prior to undertaking this effort, this team conferred with a permitting specialists to ensure no additional permits were required in order to execute this task.

Due to seasonal infrequency, this team was not able to capture a dye test during a period of sustained south-southwest winds – however, currents were observed which aligned with model results and drowning incident observations.

The results of the dye testing are shown below. Photos and videos were captured using a DJI Phantom 4 Drone, flown during the time of dye testing.

Dye Test #1 – Dye deposited at ends of breakwaters and straight across gap
December 10, 2021 – 10:30 AM
Wave: 0.98’ at 109° (SE) Wind: 13.42° at 91° (E)

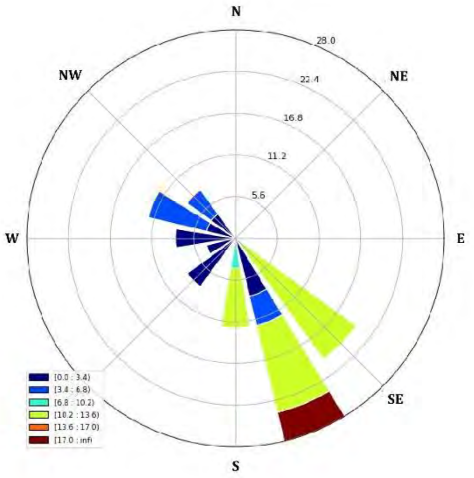

Figure 16 - Wind Data from the 12 Hour Lead-up

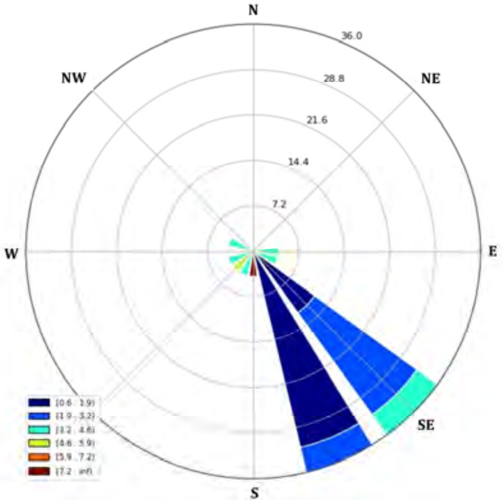

Figure 17 – Wave Data from the 12 Hour Lead-Up

Lakeward[11] dispersion of the dye is observed from the north end of the south breakwater. Methodology was modified to hold the drone in a static position for future tests.

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[11] Lakeward indicates towards the open water, as opposed to inwards towards the beach.

Dye Test #2 – Dye deposited at ends of breakwaters and straight across gap.
December 17, 2021 – 10:00 AM
Wave: 0.33’ at 139° (SE) Wind: 0° at 62° (E)

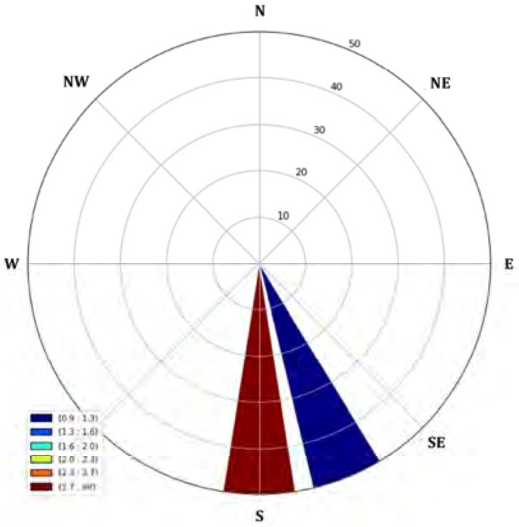


Figure 18 - Wind Data from the 12-Hour Leadup

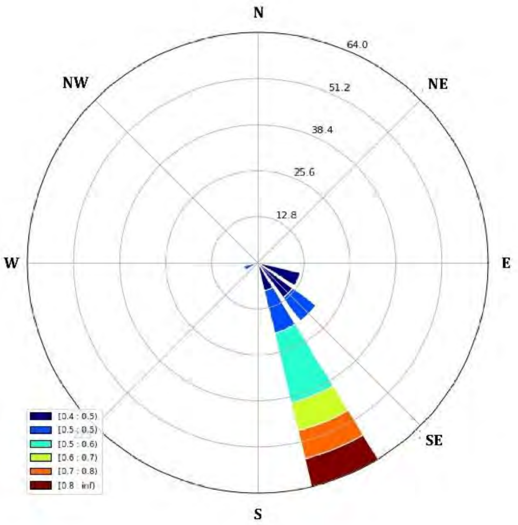
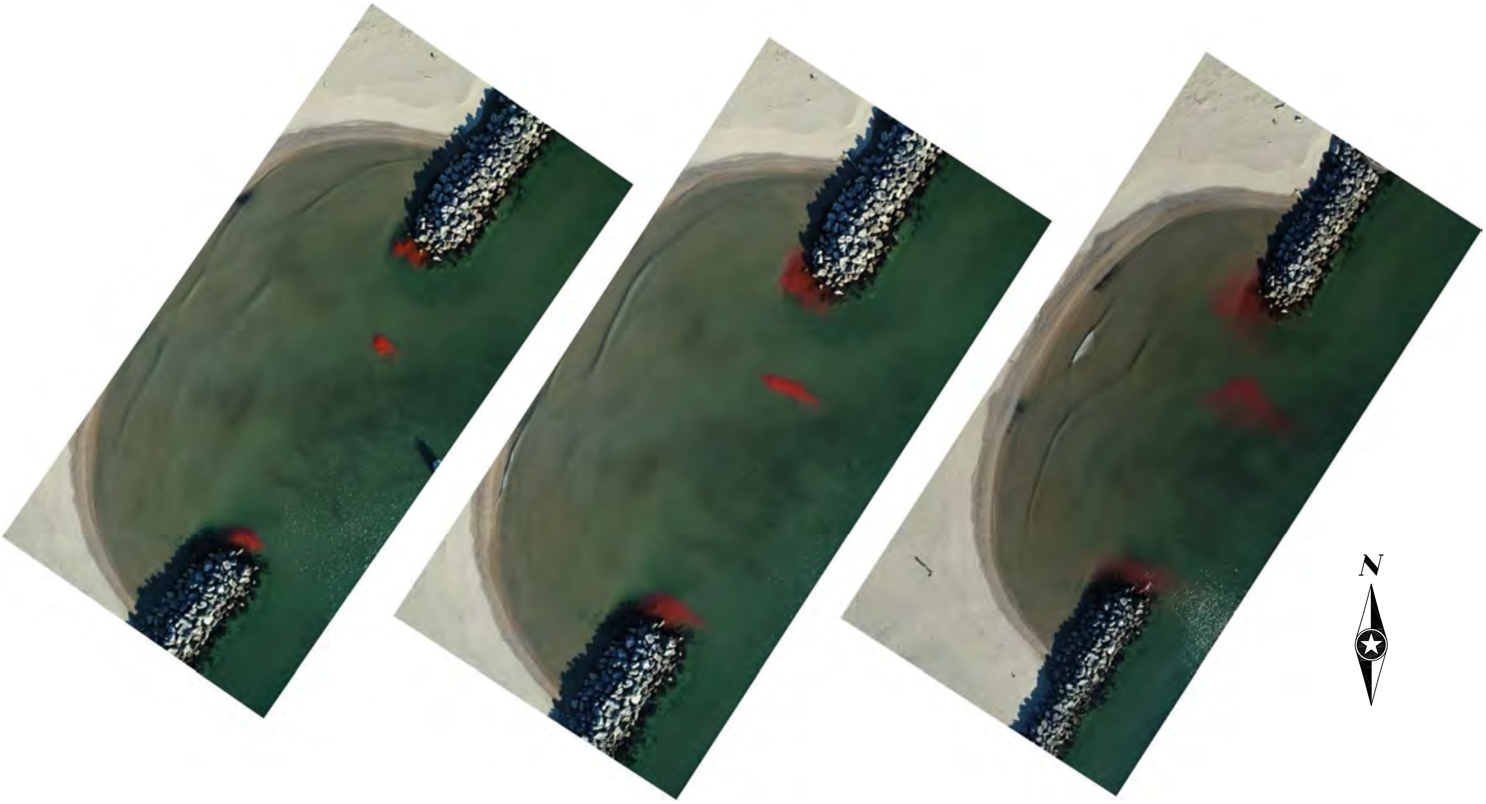


Figure 19 – Wave Data from the 12-Hour Leadup



Lakeward dispersion of the dye was observed from the south breakwater and the northern-most quartile of the gap. This was current activity was replicated in the hydrodynamic modeling.

Dye Test #3 – Dye deposited at north end of southern breakwater.
December 27, 2021 – 10:00 AM
Wave: 2.33’ at 143° (SSE) Wind: 5.37 mph at 308° (WNW)

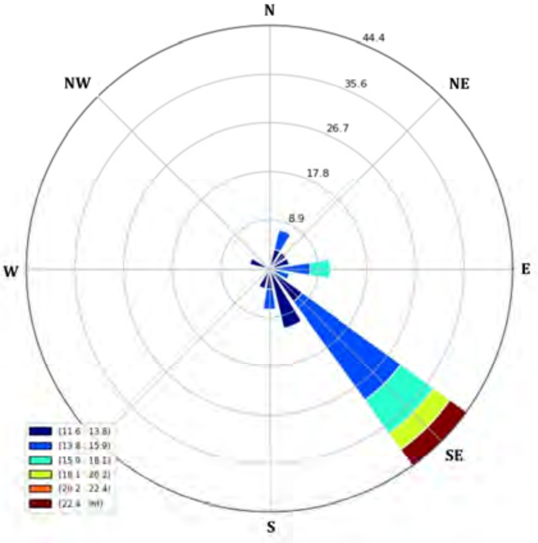


Figure 20 - Wind Data from the 12-Hour Leadup

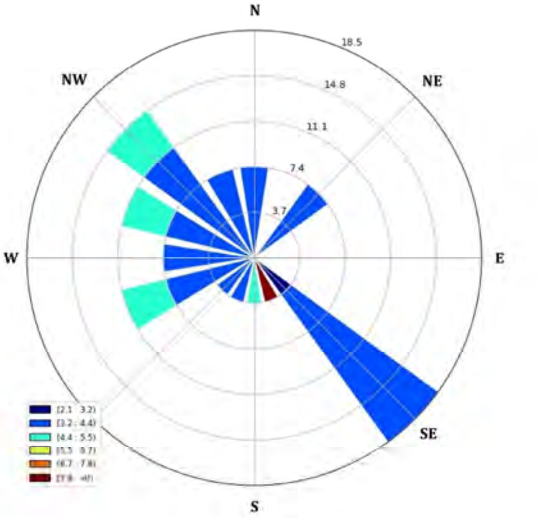


Figure 21 – Wave Data from the 12-Hour Leadup

The dye front is moving from southwest to northeast at speed of approximately 1.76 ft/s despite significant wave energy to the contrary. A current of roughly 2 ft/s in a wave that is 2 ft tall is generally accepted to challenge an inexperienced swimmer. This was current activity was replicated in the hydrodynamic modeling.

Dye Test #4 – Dye deposited at north end of southern breakwater.
December 27, 2021 – 10:00 AM
Wave: 2.33’ at 143° (SSE) Wind: 5.37 mph at 308° (WNW)

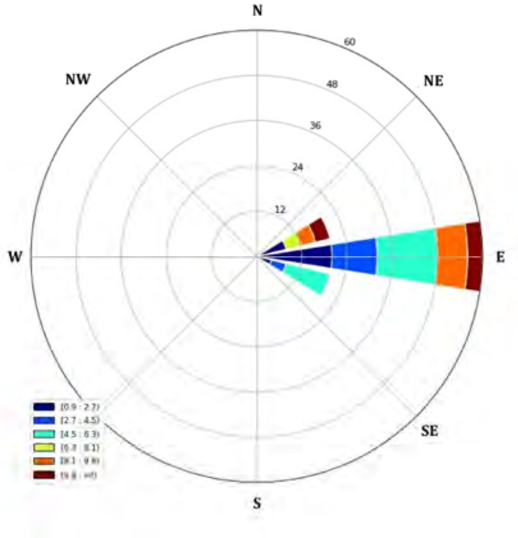


Figure 22 - Wind Data from the 12-Hour Leadup

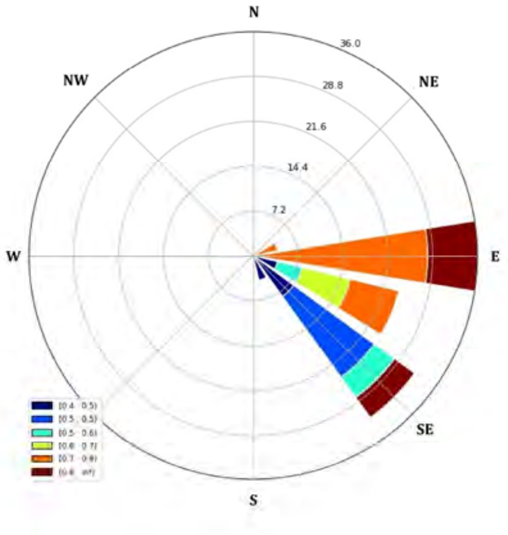


Figure 23 – Wave Data from the 12-Hour Leadup

Dispersion from the north end of the south breakwater was observed.

Conditions Observed

During field conditions, it was noted there was, at times, a seiche-like effect. A seiche is formed when to a sudden change in direction of wind or wave energy collects water at one end of an enclosed system and causes vertical oscillations in a the standing body of water. This seiche effect could be particularly dangerous to novice swimmers who may lose their footing and subsequently be overtaken by waves.

Waves which appeared to reflect off of Government Pier were also observed. These waves then traveled due north and met other waves, crossing at oblique angles creating a cross sea effect. This geometry is one of many factors which complicates the analysis and solutions for McKinley Beach. This superimposition is demonstrated in the images below. Both images show the effect of wave action coming in from the east-southeast and being met nearly perpendicular (left) or at an obtuse angle(right), and superimposing on top of one another – this can create a scary situation for swimmers.

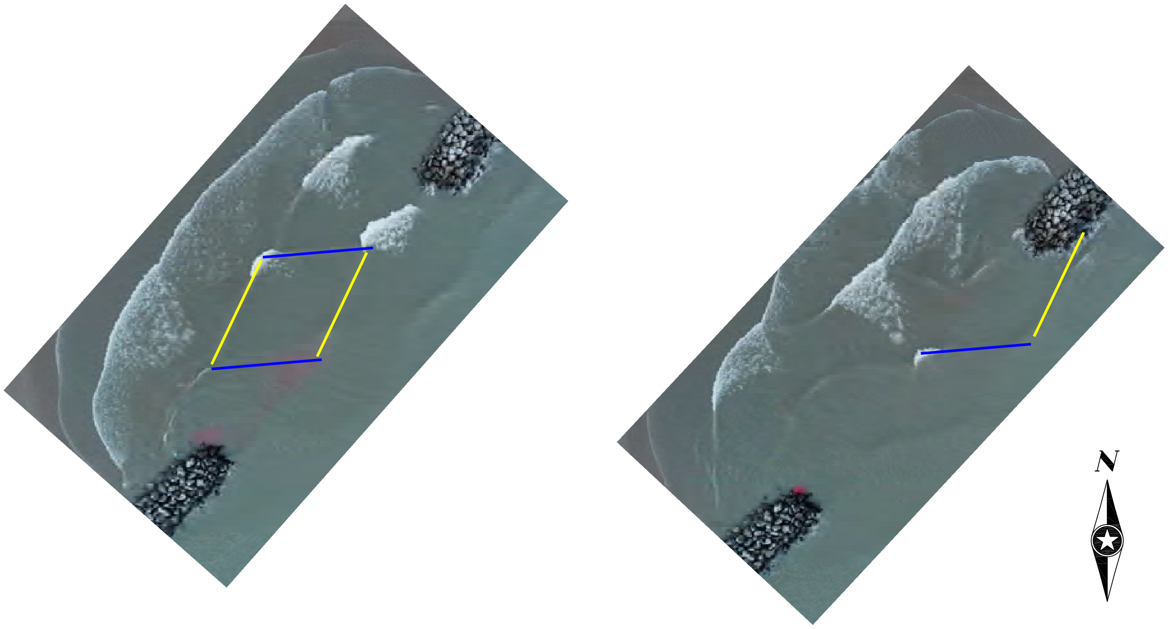


Figure 24 - Wave Formations Observed

In the image on the left, the red lines are waves reflected off of Government Pier while the yellow lines are the long-fetch waves coming in from the south-southeast. In the image on the right, the S-shape of the wave denoted by the blue line is the product of a superimposition of the waves from transverse directions.

Hydrodynamic Modeling & Wave Study

In addition to collection of field data and observation, detailed three-dimensional models were created to better understand the near shore conditions at McKinley Beach. These models utilize available bathymetry, LiDAR and beach topography to create an accurate representation of the physical forms beneath the water surface. Data inputs from transformations of off shore wind and wave data will inform the analysis of how currents move through the site and interact with the existing structures and beach materials. Future iterations will see proposed conceptual solutions appended into the design model and simulations run to understand the effect of modifications on currents, water quality and beach safety and sustainability.

Wind-wave model simulations were conducted to compute wave-induced current speeds by LimnoTech. A technical memorandum of findings was produced, is excerpted here, and can be found in *Appendix E*. Recent drownings have occurred during moderate onshore wind conditions of about 12 miles per hour and moderate wave conditions of about two feet. These waves can produce strong currents that sweep parts of the swim area.

Wave heights and wave-induced current speeds were predicted at a 0.3-meter (~1-foot) scale using a SWASH (Simulating Waves to SHore) model. This model explicitly represents finer-scale wind-wave processes than what can be represented in its companion model, SWAN. SWAN is a component of the industry-leading Delft3D model. It is a coarser-resolution, spectrally-averaged wave model which resolves fewer processes in the surf zone and uses more approximations than SWASH. SWAN is most useful for predicting wave conditions at intermediate to deep water conditions and SWASH is most useful for predicting wave conditions in the surf zone (i.e., in shallower water).

Simulations were conducted for four wind directional conditions spanning the directional envelope of long-fetch onshore winds. These conditions produce the strongest currents at McKinley Beach. Wind and wave directions were varied at a 30-degree interval from 190 degrees nautical (winds out of the south with a slight easterly component) counterclockwise to 100 degrees nautical (winds out of the east with a slight northerly component). Model simulations represent a time frame of 18 minutes which is sufficiently long for the model to transition from zero wave action to steady wave action. Water levels were simulated at 582.5 feet IGLD85 which was approximately the water level condition during each event. Significant wave heights12 were held steady at two feet which was approximately the condition during all three drowning events. Of course, actual wind, wave, and current conditions can be much more complex than what is represented in these simulations, but the simulations are a useful proxy for the actual, more dynamic, and complex conditions.

A bathymetric digital elevation model was developed based on survey data from Seaworks obtained in 2021. Water level inputs were developed from the nearby NOAA gage #9087057 (Milwaukee, WI). Wind data were developed from the nearby NOAA buoys MLWW3 (Port of Milwaukee) and ATW20 (Atwater Park, WI). Wave conditions were developed from USACE Wave Information Study (WIS) output at Station #94050 and from NOAA buoy ATW20. The map below illustrates locations of key datasets.

Figure 25 – Key Observed Data Locations Supporting the Wave Model

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[12] Significant Wave Height is the average height of the highest one-third of all waves measured.

The primary wave data source (NOAA station ATW20) represents offshore conditions approximately 3.5 miles northeast of the site, so it was important to confirm whether wave conditions closer to the site are similar. The confirmation was done by evaluating whether the McKinley Beach buoy data collected by SEH from November 2021 through mid-January 2022 are consistent with wave data at the ATW20 offshore buoy, specifically for the type of wind conditions preceding the drownings. The ATW20 offshore buoy was retrieved before November 2021 so the data periods do not overlap and a direct comparison is not possible.

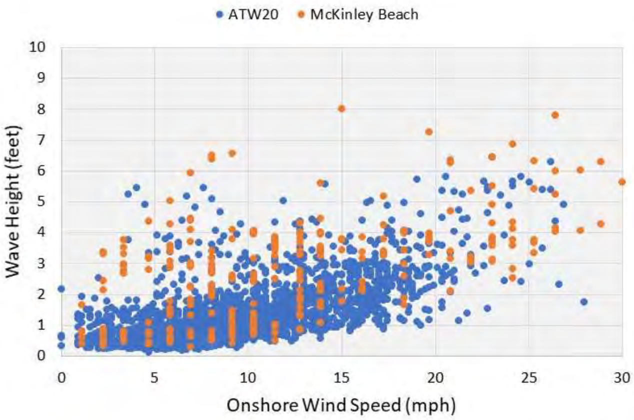

Figure 26 – Correlation Wave Data ATW20 and Spotter Buoy

For wind conditions that are similar to those that preceded the drownings, the McKinley Beach buoy registers similar wave heights to the ATW20 offshore buoy. This confirms the adequacy of using the ATW20 buoy to represent conditions during the 2020 drownings. Figure 27 displays a substantial portion of the record of data at the Spotter Buoy. Vertical dashed lines represent periods when onshore wind speeds are nearly 12 miles per hour. Wind speeds of this magnitude preceded the drownings, and wave heights at ATW3 were approximately two feet. Site data are also approximately two feet when onshore wind speeds approach 12 miles per hour, indicating that wave observations at the offshore buoy (ATW20) can be a good proxy for wave conditions near the site.

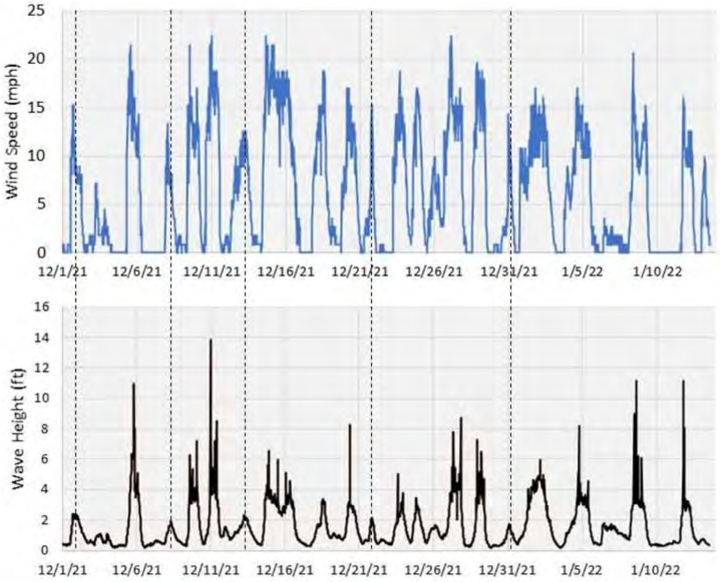

Figure 27 - Recent Wave Data Offshore at McKinley Beach

Date	Time	Peak Wind Speed	Wind Directional Range	Wave Height	Representative Model Figure
		mph	*degrees nautical*	*feet*	
3-Jun-20	Before 7:00 AM	16	180-360	2	Figure 32
18-Jul-20	Before 8:30 PM	23	130-210	2	Figure 33
8-Aug-20	Before 6:30 PM	17	130-210	2	Figure 33

Figure 28 - Wind and Wave Conditions Preceding the Three 2020 Incidents

Before dawn on June 3 there were strong winds out of the northwest which set up a seiche on Lake Michigan (i.e., rapid oscillation of water levels in the lake). Based on calculations of seiche-induced currents, the seiche was not likely to have been a significant factor causing the drowning. Estimated currents from the seiche were approximately 0.2 feet per second, while modeled wave-induced currents for two-foot onshore winds are higher than 2 feet per second. Winds preceding the drowning were variable in direction, quickly shifting from out of the northwest to out of the south. Waves were about two feet high.

The model simulation with waves at a 190-degree angle (out of the south) are considered most representative of this event (Figure 29 below).

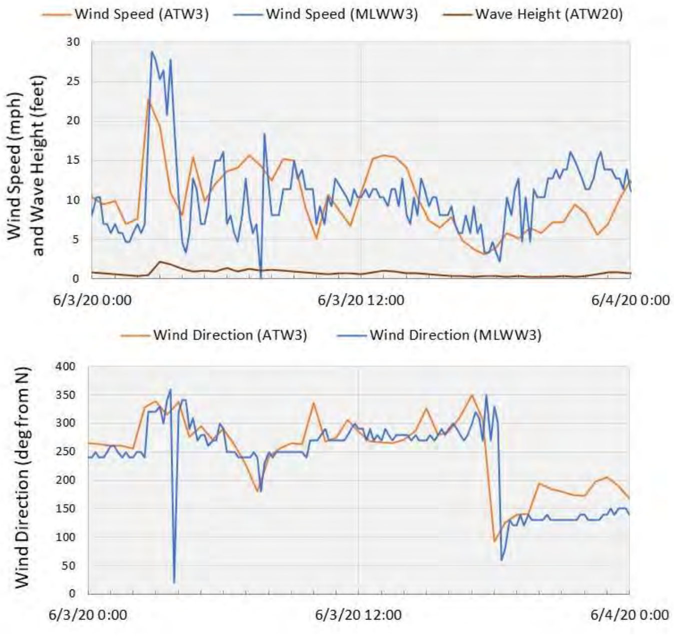

Figure 29 - June 3, 2020 Wind and Wave Conditions at Two Stations near McKinley Beach

Winds during the July 18 event steadily increased during the day and peaked at about 20 miles per hour two hours before the drowning which occurred before 8:30 PM. Wind direction was steady for much of the day until winds peaked and were more regionally focused toward the northwest and north (directions 150 to 200 degrees). Significant wave heights built to about two feet by mid-day through evening as observed at the ATW3 buoy.

The model simulation with waves at a 160-degree angle (out of the southeast) are considered most representative of this event (Figure 30 below).

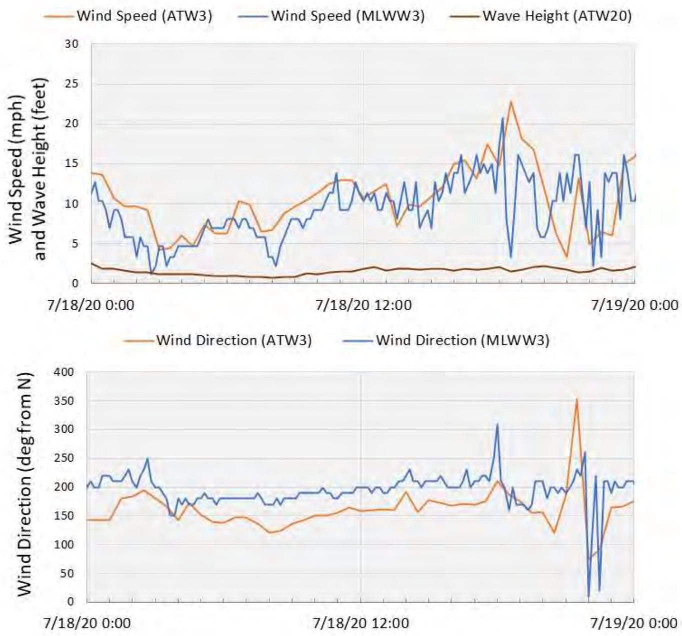

Figure 30 - July 18, 2020 Wind Conditions and Similar Conditions from WIS Record

Winds during the August 8 event were steady and out of the South-Southeast, occasionally approaching about 15 miles per hour just before the drowning (6:30 PM). Significant wave heights had built to about two feet at that time at offshore buoy ATW20.

The model simulation with waves at a 160-degree angle (out of the southeast) are considered most representative of this event (Figure 31 below).

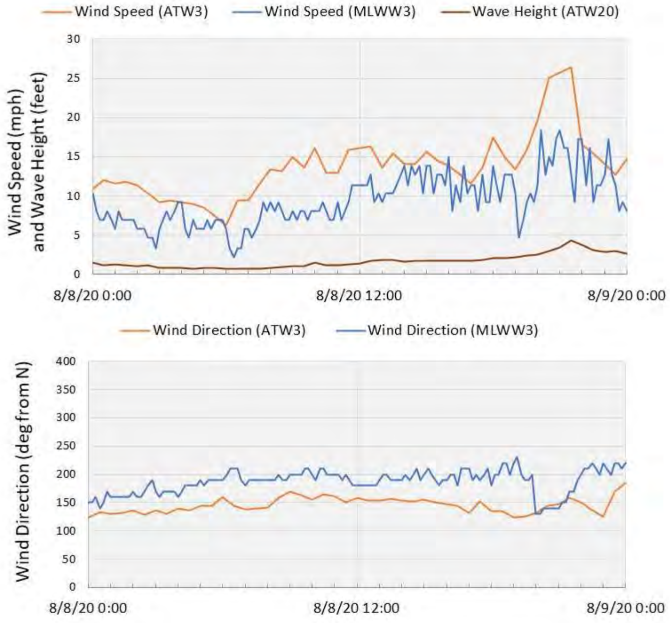

Figure 31 - August 8, 2020 Wind Conditions and Similar Conditions from WIS Record

Results from the four directional wave simulations are illustrated below. As noted above, two of these conditions—the 130- and 160-degree direction conditions—are good proxies for the three drowning events. Each simulation yielded a current pulling away from the south end of the south breakwater.

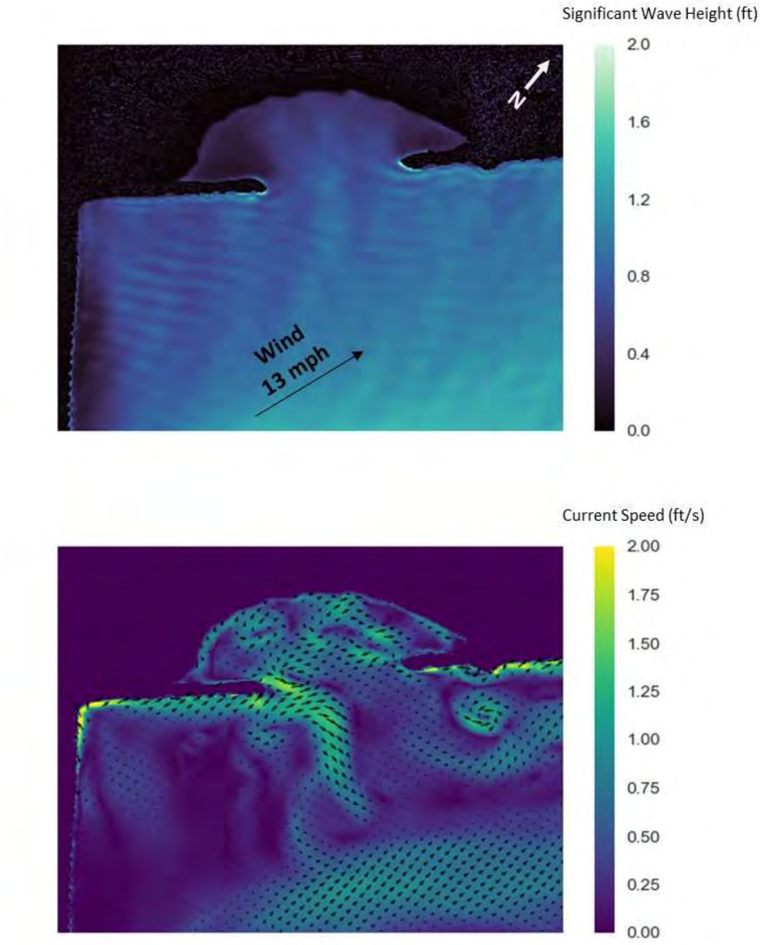

Figure 32 - Simulated Wave Heights and Current Speeds, 2-foot Waves, 190-deg direction (out of south) as indicated by the black arrow. Proxy for the June 3 event

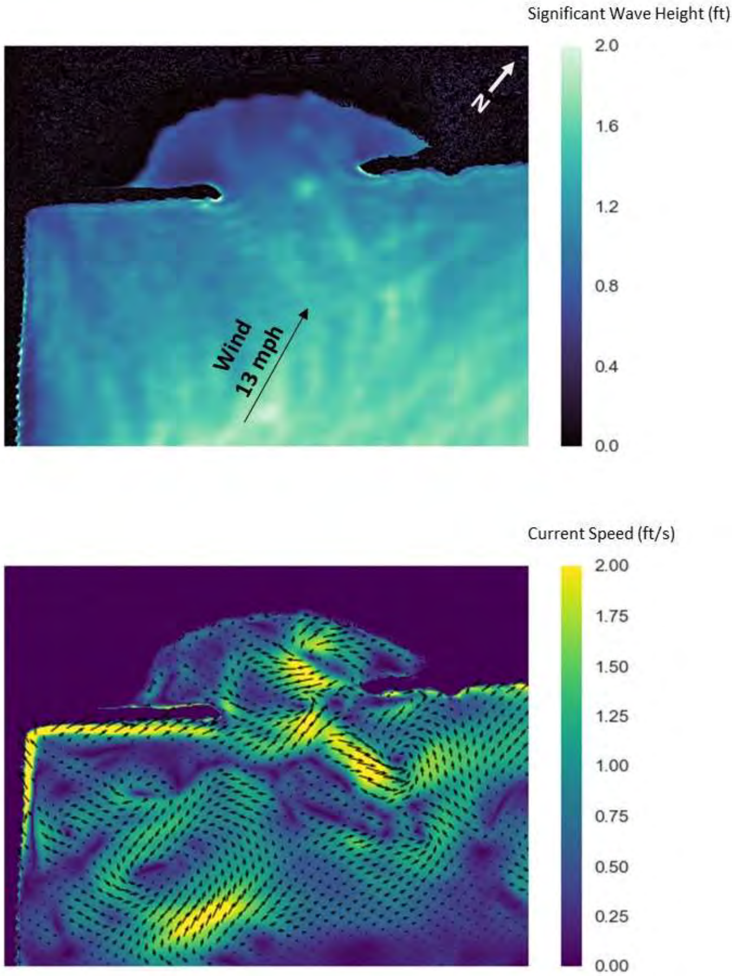

Figure 33 - Simulated Wave Heights and Current Speeds, 2-foot Waves, 160-deg direction (out of south-southeast) as indicated by the black arrow. Proxy for the July 18 and August 18 events.

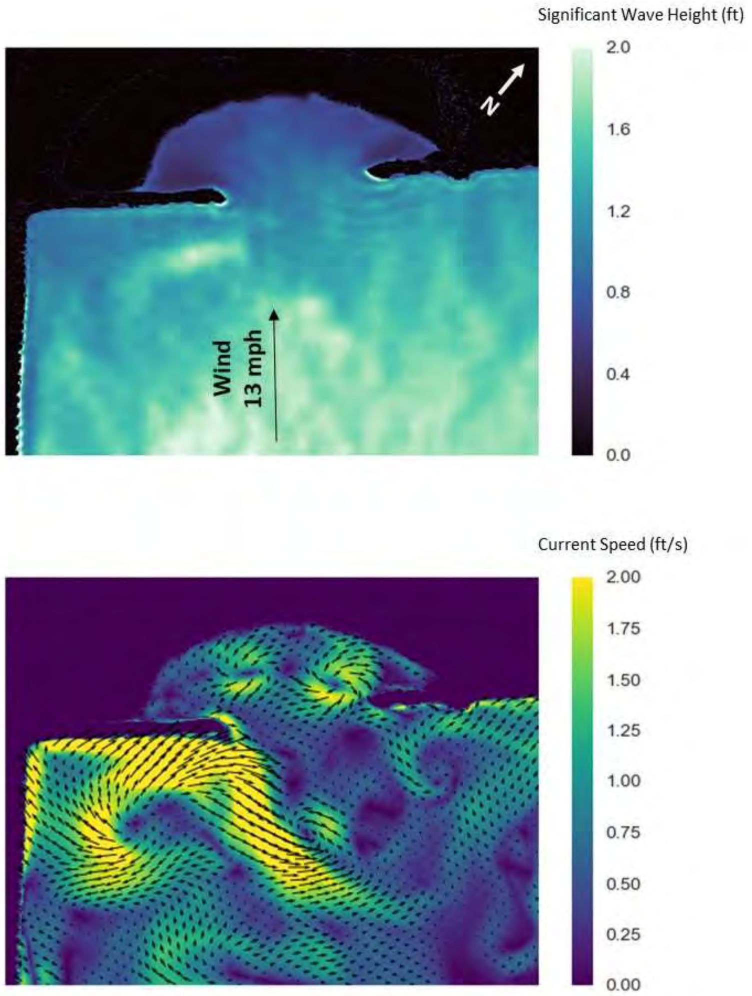

Figure 34 - Simulated Wave Heights and Current Speeds, 2-foot Waves, 130-deg direction (out of southeast) as indicated by the black arrow.

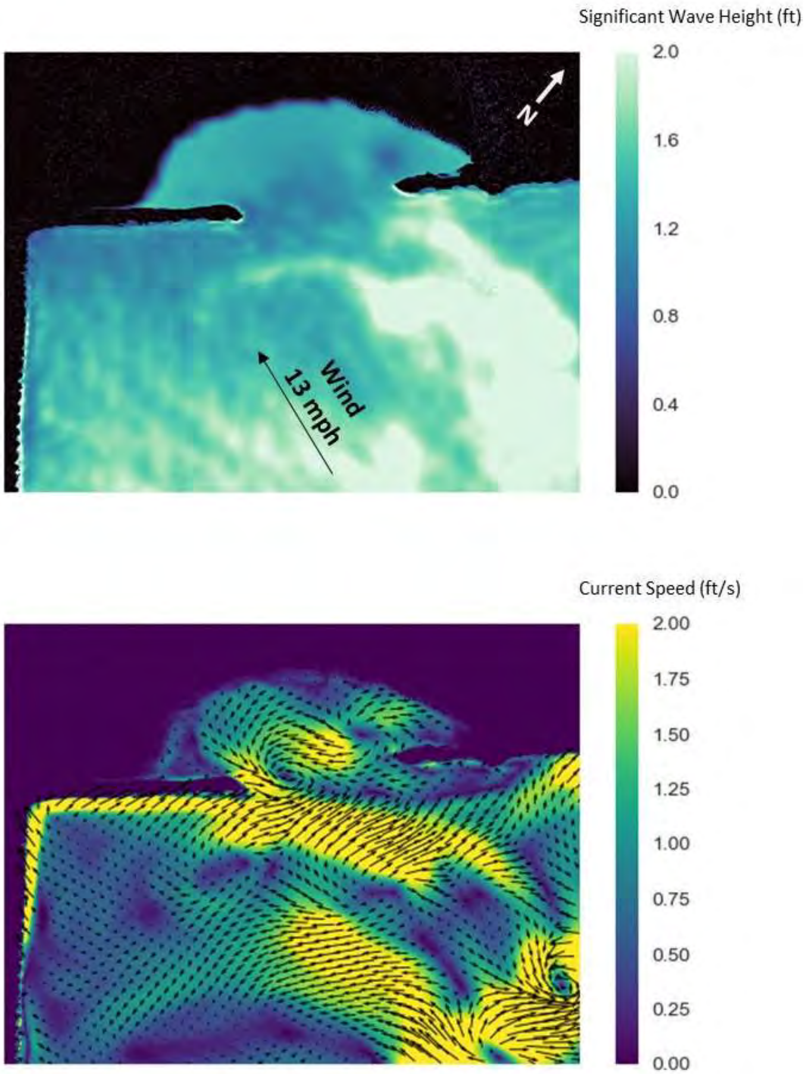

Figure 35 - Simulated Wave Heights and Current Speeds, 2-foot Waves, 100-deg direction (out of east-southeast) as indicated by the black arrow

This dye test most closely correlates to what was seen in the field in Dye Test #3.

Additional simulations were conducted to better understand the factors contributing to rip currents at McKinley Beach. These tests help address the following questions:

1. To what extent does the seawall to the west of McKinley Beach reflect waves and contribute to rip currents at McKinley Beach?
2. Are currents at McKinley Beach less hazardous during lower water conditions?

A test simulation indicates that wave reflection off the seawall west of McKinley Beach is a moderately significant factor contributing to rip currents in the swim area. In the existing conditions wave model, waves reflect off the seawall which begins about 300 feet from shore and extends farther lakeward (closer to shore is a rock revetment which is much less reflective). A test simulation was conducted which absorbs wave energy at the seawall rather than reflecting wave energy. This simulation is useful for evaluating the degree to which wave reflection off the seawall effects currents at McKinley Beach. The simulation showed some reduction in current speeds in the McKinley Beach swim area relative to the more realistic reflective condition, but the effect was only moderately significant and a solution involving “softening” the seawall, which can actually be done through adding roughness may not pass a cost-benefit analysis.

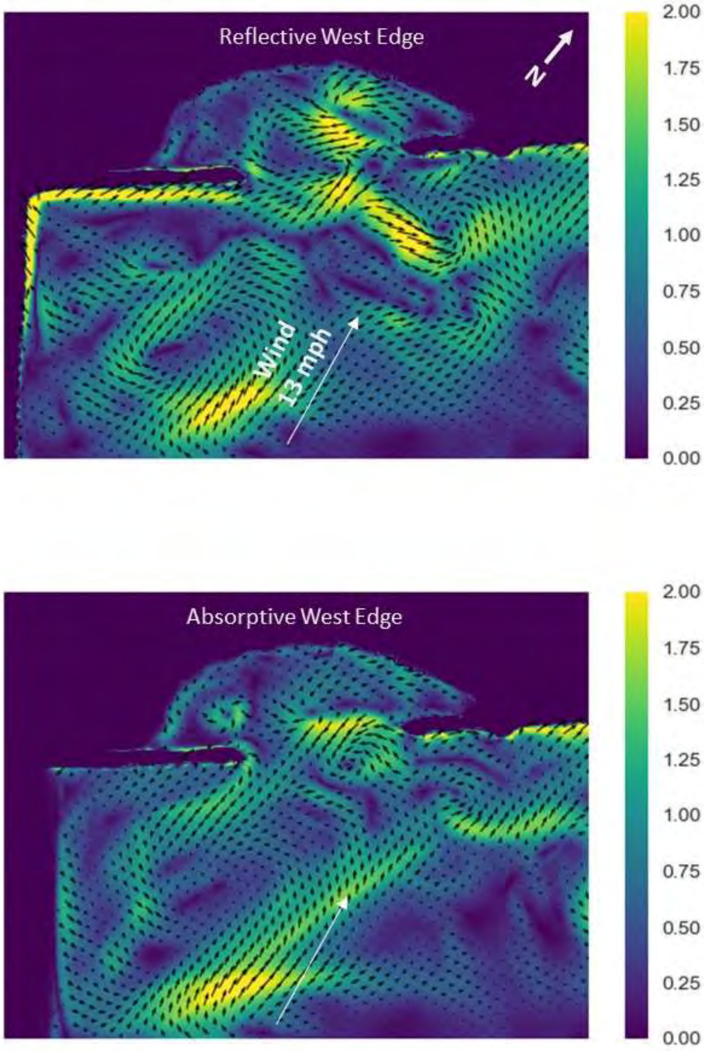

Figure 36 – Model Analysis of the Effect of an Absorptive (Roughened) West Edge (Government Pier)

Another test simulation indicates that recent high water contributed significantly to the presence of rip currents at McKinley Beach. For this simulation, modeled water levels were reduced from 582.5 feet (high water level conditions during summer 2020) 579.2 feet (a moderate lake level). Predicted swim area currents for the moderate lake level condition are appreciably lower and are illustrated in Figure 37 below. During lower lake level conditions, wave energy dissipates farther offshore than during high water conditions. This helps explain the large difference in current speeds within the swim area for the two simulated lake level conditions.

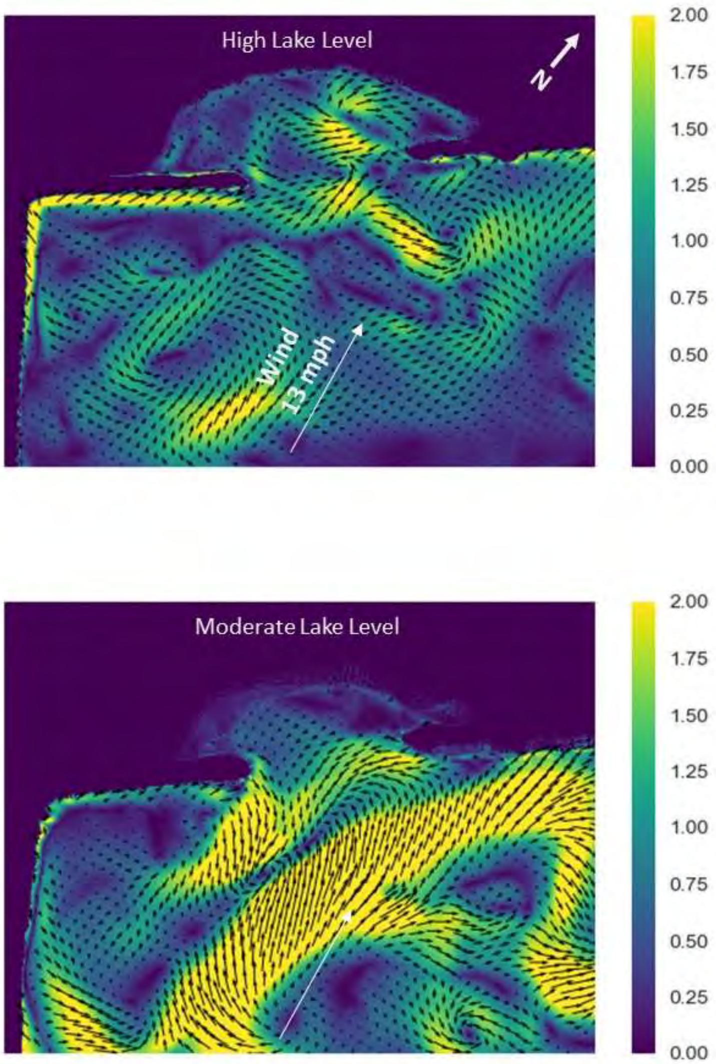

Figure 37 – Model Analysis of the Effect of a High Water Condition and a Moderate Water Level Condition

Comparison of Current Speeds (feet/second) during summer 2020 high water conditions (top) and moderate lake level conditions (bottom)

There are two key caveats to these results which are explained further in the last section of this source text of the memorandum (found in *Appendix E*): 1) the model's extent was set to the extent of the detailed and current bathymetric data. For future use of the model, it should be evaluated whether the model extent is sufficiently large for providing a robust estimate of wave and current conditions at McKinley Beach for all wave directional conditions of interest and 2) a comparison of modeled currents with observed current data would strengthen the confidence in the results. Modeled current speeds were found to be sensitive to details of the numerical solution scheme used to produce the wave predictions and the best choice of these parameters is not obvious based on theory alone.

Despite these caveats, these results indicate the potential for strong currents to form within and just outside of the swim area at McKinley Beach. Current speeds exceeding two feet per second were predicted within the swim area for onshore winds directed toward the beach. Two feet per second has been identified as a dangerous wave height. The waves don't appear to be so large as to deter a novice or intermediate swimmer, but they are large enough to lose footing and induce panic. Winds that are directed nearly perpendicular to shore produce especially hazardous currents: not only are current speeds elevated in the swim area, but they are also elevated in the open water area just outside the swim area. Wave reflection off the seawall appears to be a factor influencing currents just outside the swim area and is likely influencing currents within the swim area.

Water Quality

Water quality is a known issue at McKinley beach and has been documented in previous literature. A 2005 study by the Great Lakes Water Institute titled *Identification and Quantification of Bacterial Pollution At Milwaukee County Beaches* found *E. Coli* concentrations at McKinley Beach of 90 – 3060 CFU/100 mL, approximately 53% of which were greater than 235 CFU / 100 mL, the threshold at which beaches are considered unsuitable for recreational activities by the US Environmental Protection Agency (USEPA). E Coli sources may include combined sewer overflows, stormwater runoff, wildlife and domestic pets; the study also noted that concentrations doubled following rain events, suggesting runoff or combined sewer overflows, however they also registered concentrations greater than the threshold on dry days indicating additional sources.

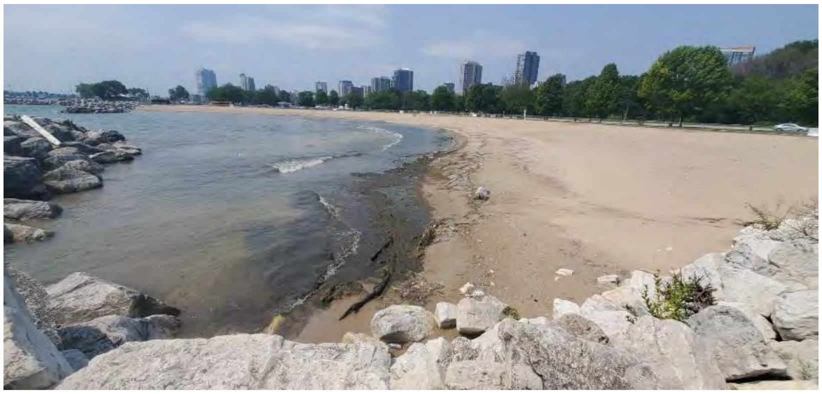

Figure 38 - Biomatter at McKinley Beach, August 2021

Water stagnancy issues can exacerbate water quality issues related to E Coli if they are being caused by animals as floating green algae can attract seabirds which then contribute. Heavy sludge of filamentous algae was seen in the northeast corner of the pocket on site visits in August 2021 as well as at times of our field study in December 2021. A stormsewer outfall is noted at the southwest extent of the beach, however this has not been located.

Consideration of proposed solutions should highlight impacts to water quality so as to not create additional problems. Solutions which aim to reduce currents and wave energy may also inadvertently reduce water circulation to the point of stagnancy. Stagnant water can create unpleasant, even harmful, conditions beach-goers as well as wildlife and aquatic plants and animals. Due to its stillness and lack of turbulence, stagnant water typically has less oxygen which can lead to an aerobic environment not conducive to aquatic life and may encourage the growth of blue-green algae which is capable of producing toxins harmful to humans and pets. Buildup of dead biomatter and algae can also become odiferous and lead to a reduction in water clarity and quality.

McKinley Beach and adjacent shorelines are also included in the Milwaukee Estuary Area of Concern as designated by the Environmental Protection Agency (EPA). The Area of Concern (AOC) was designated in 1987 as part of the Great Lakes Water Quality Agreement. The areas of concern focus on the identification, remediation and implementation of plans to mitigate the impact of point and nonpoint pollution from throughout the urbanized watershed. Recent AOC work group recommendations have focused on reducing the presence of seagulls and other shorebirds in order to reduce E Coli loads. Regular sand grooming is anticipated to reduce aggregate E Coli.

Causation Summary

The current hypothesis remains that rip currents, if present, are occurring due to the geometry of the site. The aggregated wave energy of waves from two directions drives water into the pocket beach area and then funnels back towards Lake Michigan through the gap in the breakwaters. This energy, paired with a narrowing exit channel can create a rapid funneling of water.

This hypothesis is currently supported through observed beach sand contouring, dye testing and field visit observations as well as modeling results.

High water has also been shown to be a significant factor in increased magnitude of currents present in the swim area. Lower water allows waves to break further out into the lake and reduce in magnitude (and energy) prior to entering the swim area.

Conceptual Solutions and Desired Outcomes

Coastal resiliency and beach safety are primary objectives of any conceptual solutions. There may be hardscape solutions such as modification to breakwater geometry, implementation of a submerged reef system, addition of armored headlands; or there may be more "soft" solutions such as wind and wave warning lights as seen in Port Washington, public information and education, especially to underserved communities or a permanent beach closure.

As in any design, we cannot design for all extremes of all possible conditions, so a thoughtful analysis of what makes good swimming conditions should help to prioritize solutions. For example, are people more likely to want to swim in a seiche condition? Are big waves tolerable? Do some seek a sheltered beach for small children?

Conceptual solutions will be modeled into the hydrodynamic model in the next phase of this report. In addition to the numeric and graphical outputs of this model, consideration of the conditions which entice beachgoers into the water should also be considered.

As conceptual solutions are considered, it is important to recognize there may be no (feasible) structural reconfiguration which completely eliminates rip currents given the complex geometry of the site.

Geometric Modifications to Existing Breakwater

Geometric modifications to the existing breakwater could include lengthening or shortening spurs, varying the width or side slopes, or removing one or both breakwater spur. This potential solution would likely maintain existing maintenance obligations would likely carry minimal regulatory or permitting burden as it is simply modification to existing and lies within the lake bed. Aesthetically and functionally, the breakwater would appear the same, aside from modified geometry.

As part of assessment of this proposed solution, we'll consider the impact on currents between and around the structure, as well as the impact of those current on water mobility or stagnancy.

Submerged Stone Reef

The concept of a submerged reef is also being explored. A submerged reef can be of similar shape and geometrics to the existing breakwater with the top elevation slightly below the water's surface. This reef could be placed just outside of the existing breakwater gap and would serve to dissipate wave energy coming into the beach, thereby reducing the aggregate energy of the outflow of water. The geometrics of the reef would need to be designed such that police other emergency watercraft can still access the swimming area from the lake and permanent warning buoys would need to be installed to avoid creating hazardous conditions for watercraft. Tapering the ends of the breakwater and the reef which interface with each other could help to reduce wave energy while still allowing enough transmission to avoid scouring the lakebed.

A submerged reef may alleviate the magnitude of wave heights, however it is unlikely to reduce instances of seiche development.

Sandbar / Pebblebar

A sandbar or pebble bar further out in the lake, but in front of the gap in in the breakwater could help to dissipate wave energy while staying visible to watercraft. In early consideration of this, concerns arose that this may become an attractive nuisance, enticing inexperienced swimmers out beyond the breakwater or seemingly inviting people into the water from Government pier.

Buoy Rope

Augmenting the existing breakwaters with a rope which spans the gap could be a viable temporary solution. A rope with several buoys on it spanning the gap provides a visual boundary and something to grab on to should someone be carried by a current. This would require daily maintenance and an observation of its presence and condition in order to be effective.

Buoy ropes have been widely used in order to delineate swimming areas on a variety of water bodies. No precedent has been found, however, for using a buoy rope as a in order to reduce negative events caused by rip currents.

Swim Warning System

Regardless of hardscape modifications, a swim warning system, such as that installed in Port Washington, Wisconsin could also be considered. The precedent system uses blinking red green and yellow lights to alert potential swimmers to conditions. If the light is green, conditions have been deemed safe, red if rip currents have been identified and yellow if conditions are favorable for the development of rip currents or other hazards. It is important to note here that the 2020 drownings at McKinley Beach occurred during conditions with wave heights of two feet or smaller.

The challenge of this is depending on the public to recognize their own ability levels, adhere to the guidance provided by the lights and for the design team to identify data thresholds which trigger the yellow or red lights. Coastal monitoring technology is abundant and utilizes buoys, an underwater sensor and a camera supplemented by National Weather Services reports.

A swim warning system presents challenges to the operator for determining the criteria which define each warning level. As discussed in this report, McKinley Beach is unique and complex in many ways which makes it challenging to identify which factors should be considered and what their thresholds should be. Interestingly, and as seen in 2020, most open water drownings take place with waves of significant wave height of two feet or less as that is small enough for even the most inexperienced swimmer to feel like they can enter the water.

Ultimately, the risk to swimmers is inversely proportional to their swimming abilities. The conditions observed in the field and corroborated by hydrodynamic modeling elevate the risks to swimmers, especially novice or intermediate.

Public Outreach & Education

Public outreach & education also complement hardscape solutions and provide learning opportunities which reach far beyond McKinley Beach. Knowledge and understanding of how to recover from a rip current could save lives in Milwaukee County and beyond.

Additionally, ensuring the message gets out across social media and other outlets which capture wide audiences should help to ensure connection. Special consideration could be taken to connect with schools in neighborhoods where socioeconomics have deterred access to water, whether lakes, streams or pools.

In addition to outreach activities, signage at the beach should take two approaches. The most basic signs, as currently present, should identify that dangerous currents may exist and include graphics and multiple languages. Another set of signs, much more similar to "attraction based" signs should include pictures, schematics and explanations in multiple languages which draw a reader in. Piquing an interest to what's going on at the beach should encourage not only caution, but perhaps an interest in improving swimming skills or environmental consciousness. That is to say, helping people realize they are part of the system that is "The Great Lakes" may even spark a little bit of extra pride.

Beach Closure

A final option is to permanently close McKinley Beach in its present form. Removal of the breakwaters completely, while still providing adequate armoring around the jetty, would allow Lake Michigan to take back McKinley Beach. Over time, if not expedited by humans, it would likely fill in with sand once again and become a straight line beach. Alternatively, Milwaukee County could team up with an environmental organization to facilitate McKinley Beach's transition into a natural asset whether a migratory bird stopover, wetland or sand dune system. If the breakwaters were removed it would be recommended create some landforms at the top of the present day sand/grass interface or even a wave-return wall[13] to ensure storm surges don't impact Lincoln Memorial Drive.

Impacts Considerations

Each proposed solution should take into account how it affects the overall fluid dynamics of the site, whether or not it significantly increases O&M costs and how swim safety and beach sustainability are impacted. In theory, a reduction in currents should be the result of a reduction in wave energy entering and leaving the site in a channelized fashion. This reduction in wave energy should reduce the loss of sand throughout the beach pocket, which will minimize the need for replenishment. Additionally, each solution should be considered for any adverse effects it may have on water quality (though stagnancy) or beach access.

Regulatory / Permitting burden may be encountered – as several agencies are involved including the City of Milwaukee, Milwaukee County, the U.S. Army Corps of Engineers and potentially the Wisconsin Department of Natural Resources. Some of this burden could be lessened by practices such as:

- Keeping excavated materials on site
- Not further impacting the existing lake bed
- Using fill dredged/excavated from adjacent lake project (assuming no contamination)

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[13] A wave-return wall is a kneewall with a concave hollow designed to receive waves and dissipate energy within its cavity

Visual exhibits for each of the following conceptual solutions can be found in *Appendix F*.

Conceptual Solution 1

This solution offers a hybrid approach of a partial beach closure, partial revetment removal and development of emergent and submergent marsh/wetland features in the littoral zone at the north end of the beach. There are five key components:

- Constructed Wetlands with Viewing Boardwalks
- Small-statured Rubblemound Breakwater
- Retaining Steps with Kneewall Wave Return
- Removal of Southern Breakwater
- One-time Renourishment of Remaining Beach

This solution considers the current conditions and issues at the beach including safety and water quality. The north end of the beach appears to be stagnant as organic matter and algae buildup were noted during several site visits during and prior to this study. Utilizing a small statured rubblemound style revetment to help contain organic matter, soils and plants while still allowing some passage and circulation of water may address this issue and enhances the littoral zone[14] of the north end. Plant selection will be key here to sustainability as well as synergy with E Coli reducing initiatives. Plants must be resilient and able to thrive in fluctuating water levels. Plants such as tall grasses cold be selected to further deter seagulls.

In order to provide further access, educational opportunities and connectivity, a boardwalk could be constructed from the existing center plaza, over the constructed wetlands and connecting to the South Jetty.

The southern half of the beach would remain a beach, but could undergo a one-time re-nourishment with a new layer of torpedo sand (unless another gradation composition is suggested by further modeling efforts). Construction of retaining steps round the exterior edge of the southern half could provide seating and protect upland features and amenities from storm surges.

Removing the southern breakwater could allow deposition of sand resultant to longshore transport and may resolve some of the rip currents currently being observed off the end of this breakwater.

Maintenance obligations to the beach side may not change much from what is currently employed (and has been suggested by the AOC). Maintenance obligations to a boardwalk over a wetland could increase comparatively.

Adding natural areas and using nature-based solutions could open this project up to additional funding opportunities from agencies and organizations such as the US Fish and Wildlife Service (USFWS), Natural Resources Conservation Service (NRCS) or the National Resilience Fund Grant.

The contouring used to evaluate a hydrodynamic model of concept 1 is shown in Figure 39 below.

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[14] Littoral Zone – The shallow area of transition between dry land and open water. The littoral zone can be home to submergent and emergent marsh and wetlands.

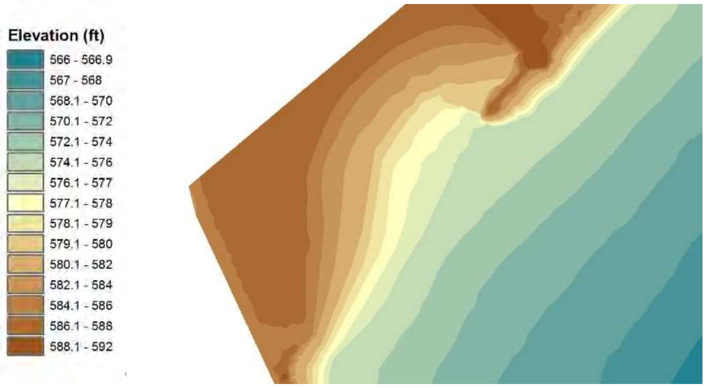


Figure 39 – Concept 1 Model Surface Contouring

This conceptual solution appears to reduce structural rip currents which had been induced in part by the ends of the breakwater. Currents of approximately 2 ft/s do still occur, mostly parallel to the shore and along the small breakwater – this could result in beach erosion and may be detrimental to beach sustainability.

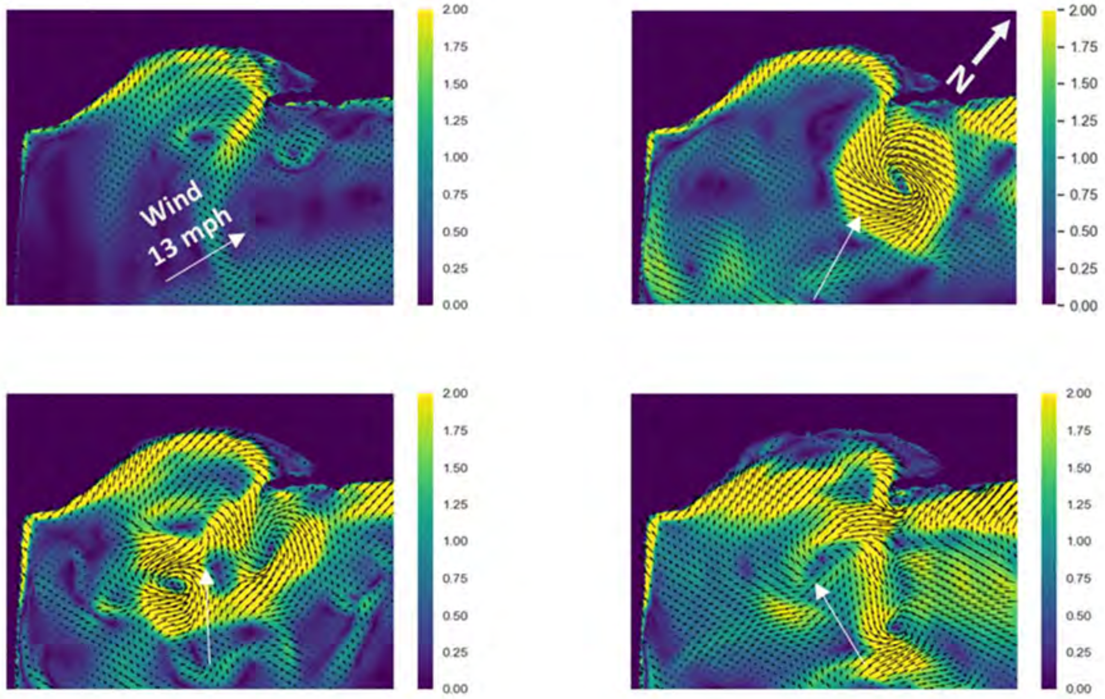


Figure 40 - Concept 1, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

Concept 1 - Nature-Based Design / Hard Infrastructure Hybrid	
Miniature Rubblemound Breakwater	$400,000
Natural Areas Restoration	$130,000
Stepped Retaining Wall	$405,000
South Breakwater Removal	$200,000
Boardwalk	$170,000
16% Contingency	$208,800
Total:	**$1,513,800**

Figure 41 - Concept 1, Conceptual Cost

Conceptual Solution 2

This solution implements a third breakwater or a submerged reef on the lakeward side of the current breakwater. The advantages and pitfalls of each are discussed above. The major concerns with this implementation are two-fold:

1. The breakwater could become an attractive nuisance, enticing people out even further
2. The rip currents currently observed may persist as structural rip currents around the edges of the breakwater(s).

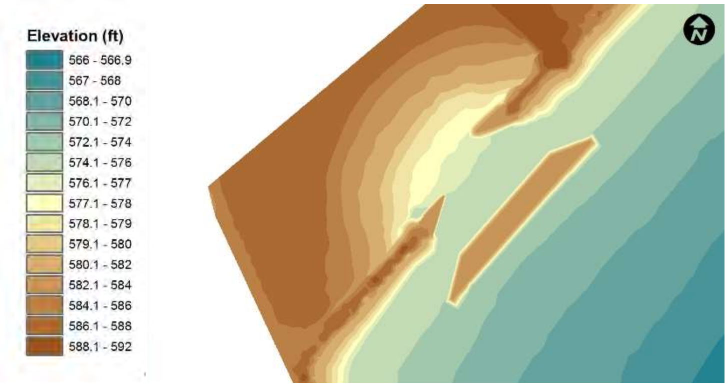


Figure 42 – Concept 2 Model Surface Contouring

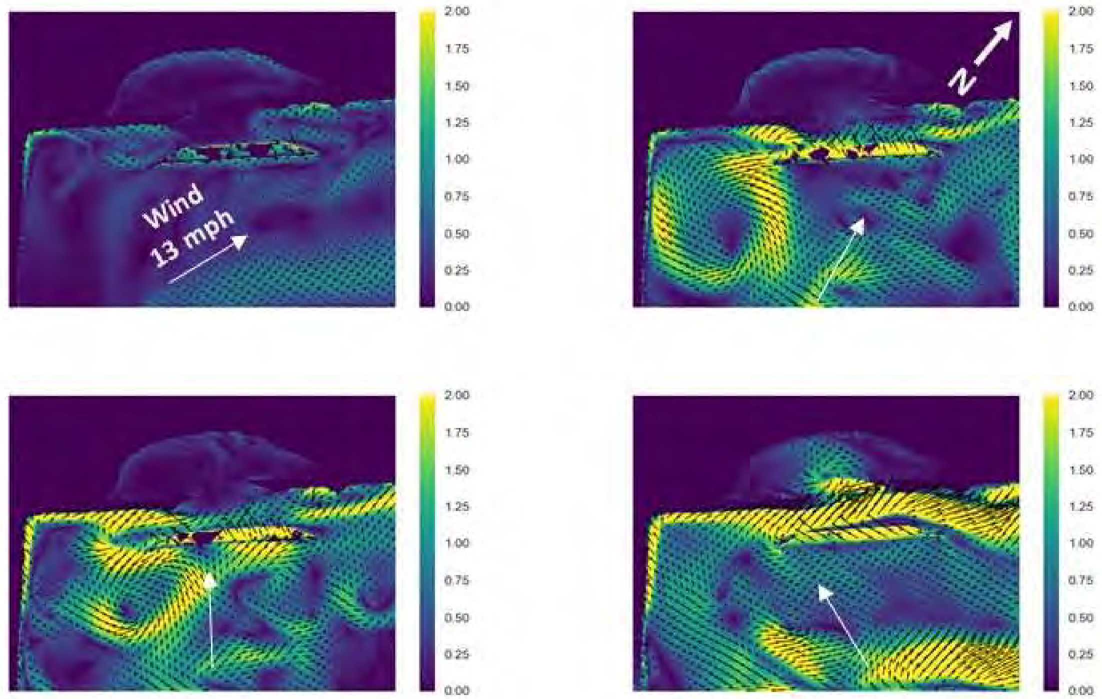


Figure 43 - Concept 2, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

This solution results in reduced circulation and water stagnancy. Structural rip currents parallel to the new breakwater and near the ends of the existing breakwater remain.

Concept 2 - Offshore Breakwater & Modifications to Existing	
Offshore Breakwater	$2,200,000
Natural Areas Restoration	$1,500,000
16% Contingency	$592,000
Total:	**$4,292,000**

Figure 44 - Concept 2, Conceptual Price

Conceptual Solution 3

This solution offers a total closure of McKinley Beach. Building a structural mound-style breakwater between the gap of the north and south existing breakwaters, the beach could be closed off completely. The level of fill and allowable drainage desired could dictate the aesthetic and function of the space beyond that. An organic fill with a clay base could be developed into a constructed wetland. A well drained fill to the elevation of top of the existing breakwater could provide a prairie like or dune like meadow. Migratory birds and pollinators could benefit from this. There may also be funding available for the nature-based solution. The boardwalk and educational opportunities described in Conceptual Solution 1 could also be implemented here.

This solution was not modeled as there were no implications to beach safety.

Concept 3 – Connected Breakwater and Natural Restoration	
Connected Breakwater	$1,900,000
Natural Areas Restoration	$210,000
Beach Fill	$200,000
16% Contingency	$369,600
Total:	**$2,679,600**

Figure 45 - Concept 3, Conceptual Price

Closing McKinley Beach may result in an even more crowded Bradford Beach. This could be mitigated by investigating the opening of the pebble beach immediately north of McKinley Beach as a swimming beach. The current bathymetric survey and hydrodynamic models did not cover this section but could be easily appended to include this. This beach does not have all of the geometric complexities of McKinley and may act, hydrodynamically, more similar to Bradford Beach.

Conceptual Solution 4

This solution restores McKinley beach to its intended design of a roughly 5% slope by re-nourishing the beach with torpedo sand, grading and grooming. The finished grade of the interior of the beach would lie approximately 1 vertical foot higher than the existing condition at a STA 2+00 as shown on the alignment. Grading to restore design intent could begin at elevation 587.5’ down to a finished grade 1’ above the existing condition at STA 2+00 as shown on the alignment in the exhibits, then project that grade down to meet the existing grade. It is likely, however, that without changes to structural geometry on and around McKinley Beach similar problems could occur if the same patterns of water level fluctuation repeat themselves over the next thirty years.

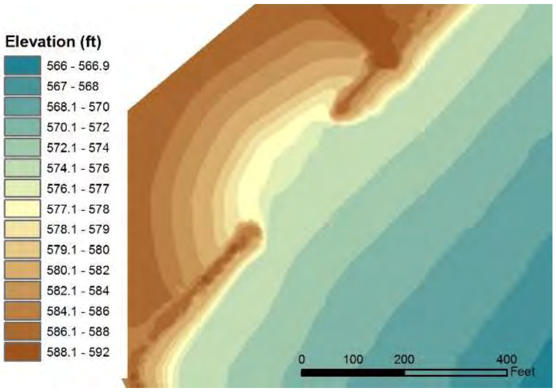


Figure 46 – Concept 4 Model Surface Contouring

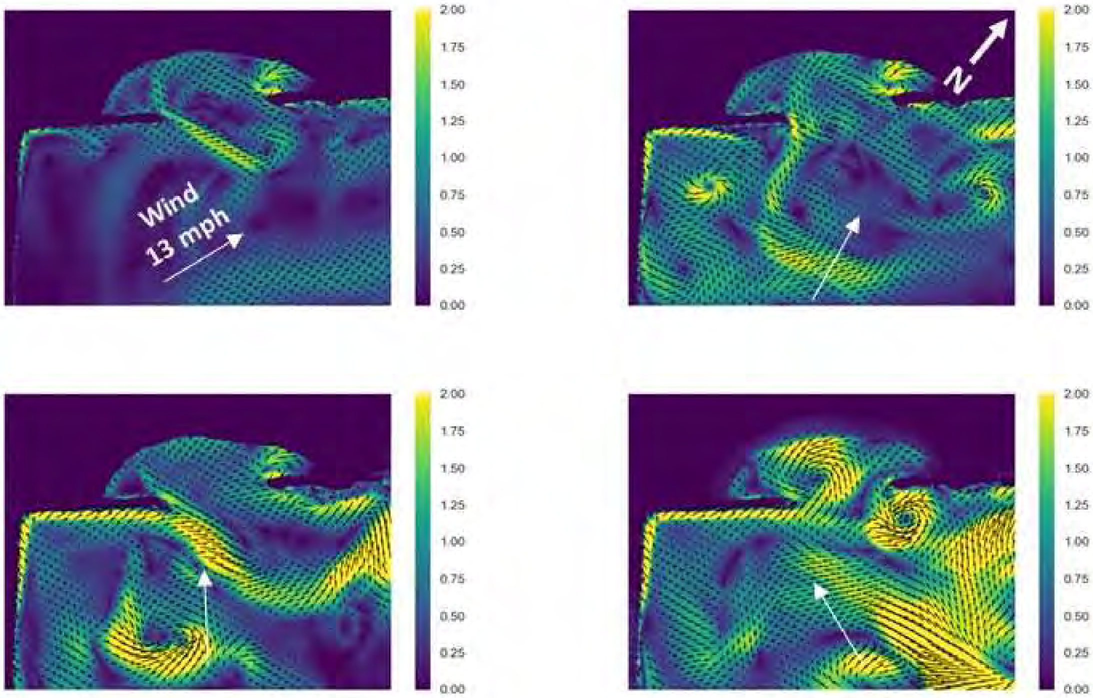


Figure 47 - Concept 4, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

Concept 4 – Beach Restoration to Intended Design	
Torpedo Sand Fill	$200,000
Structural Fill Scour Holes	$50,000
16% Contingency	$40,000
Total:	**$290,000**

Figure 48 - Concept 4, Conceptual Price

This concept results in a slight reduction in lakeward rip currents when modeled at a water level of 582.5’, and an appreciable reduction in currents within the swim area when modeled at 579.2’.

Conceptual Solution 5

This solution is modeled after the LaJolla, California Children's Pool and proposes to remove both breakwaters and reconstruct a reconfigured breakwater as a southern boundary of the beach area. This would be a very sustainable beach with little opportunity for sediment transport out of the area. Over time, the sand from the beach would migrate around the edge of the breakwater forming an open ended swimming cove.

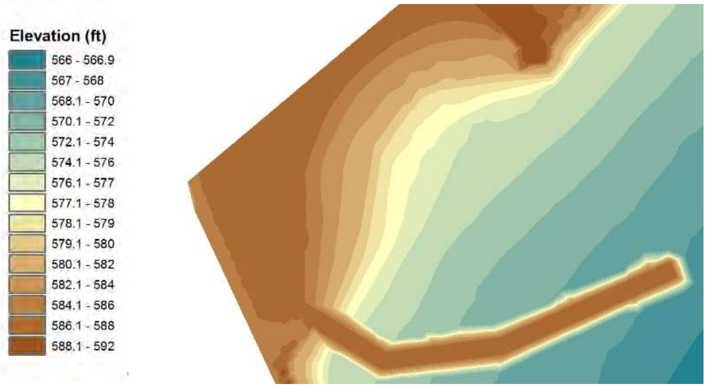


Figure 49 – Concept 5 Model Surface Contouring

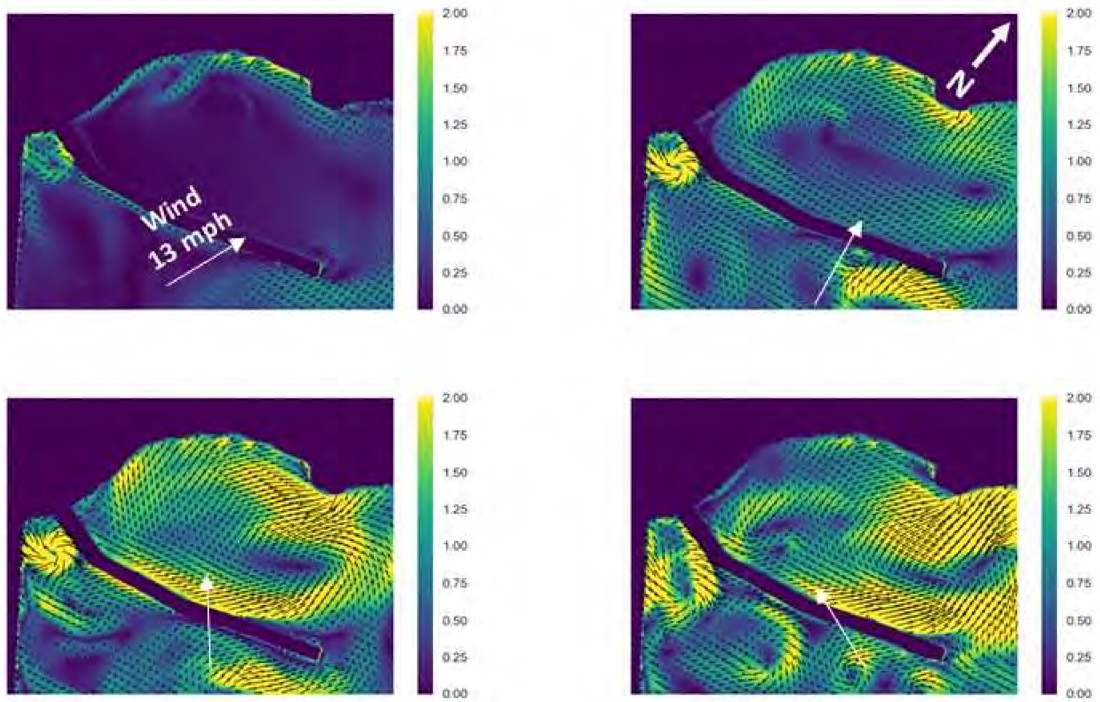


Figure 50 - Concept 5, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

This concept results in structural rip currents along the proposed breakwater which could be both dangerous to swimmers taking refuge along the breakwater and could impede beach sustainability or increase erodibility.

Concept 5 - Offshore Breakwater, Reconfigured	
Remove Existing Breakwater	$760,000
Construct New Breakwater	$4,140,000
16% Contingency	$784,000
Total:	**$5,684,000**

Figure 51 - Concept 5, Conceptual Price

Maintenance Implications

All conceptual solutions, and even a do nothing approach, require on-going maintenance obligations.

Alternative	Maintenance Obligations
Concept 1 - Nature-Based Design / Hard Infrastructure Hybrid	On-Going Seasonal Vegetation Management
	Bi-annual Invasive Species Removal
	Annual Inspection of Retaining Steps and Kneewall
	Quinquennial Bathymetric Survey of Breakwater and Swim Area
	Semi-annual Beach Grooming
	Beach Replenishment
Concept 2 - Offshore Breakwater & Modifications to Existing	Quinquennial Bathymetric Survey of Breakwater and Swim Area
	Semi-annual Beach Grooming
	Beach Replenishment
Concept 3 – Connected Breakwater and Natural Restoration	On-Going Seasonal Vegetation Management
	Bi-annual Invasive Species Removal
	Quinquennial Bathymetric Survey of Breakwater
Concept 4 – Beach Restoration to Intended Design	Quinquennial Bathymetric Survey of Breakwater and Swim Area
	Semi-annual Beach Grooming
	Beach Replenishment
Concept 5 - Offshore Breakwater, Reconfigured	Quinquennial Bathymetric Survey of Breakwater and Swim Area
	Semi-annual Beach Grooming
	Beach Replenishment

Figure 52 - Maintenance Obligations

Conclusion

The Great Lakes are unpredictable bodies of water subjected to forces beyond the control of any one jurisdiction. Swimming in the Great Lakes remains an inherently dangerous activity. Beachgoers to McKinley Beach should be informed of the inherent dangers and educated with possible avoidance measures through signage and public outreach.

With regard to modifications to physical infrastructure, Concept 4, restoring McKinley Beach to its original design appears to most readily balance swim safety, beach sustainability and cost. Hydrodynamic models noted an appreciable reduction in currents within the swim area was observed when the concept simulation was run at water levels of 579.2’, which is nearly 4” above the long-term average of Lakes Michigan-Huron. Prior to, or as part of final design, this study team recommends a sediment transport analysis of the recommended alternative to establish project limits, identify ideal gradation and consider analysis of in place modifications to the breakwater section to further reduce potential structural rip currents in the event of record high water levels.

A cost-benefit matrix can be seen in *Appendix G*.

The existing beach design concept served Milwaukee County well for nearly 30 years, was free of significant erosion, relatively stable, and saw few drowning incidents prior to the record high water of 2020. The current water level aligns almost perfectly with the water level of 1989 so restoration should be strongly considered.

In order to enhance the sustainability of the permeable pavers soon to be installed in the McKinley Marina Parking lot immediately south of McKinley Beach, also consider integrating a series of sand dunes with native plants to help keep the beach sand on the beach.

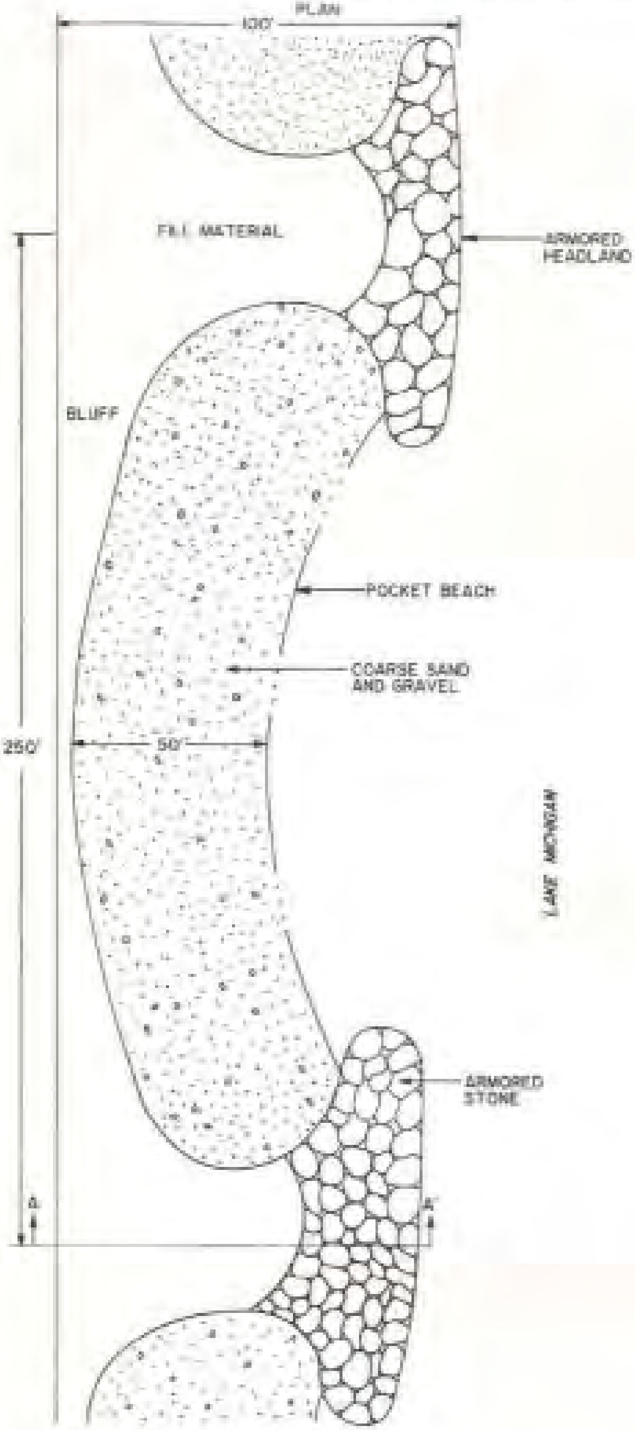
Summarily, Milwaukee County will have to balance the impact of maintaining McKinley Beach in its current form as a beach-use asset with the inherent risk of swimming in the Great Lakes.

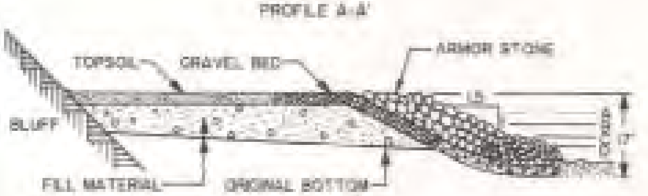
Appendix A

Excerpt: *A Lake Michigan Shoreline Erosion Management Plan for Northern Milwaukee County Wisconsin*

Figure 110

TYPICAL ARMORED HEADLAND AND POCKET BEACH SYSTEM





LEGEND

DESIGN WATER LEVELS

A DESIGN HIGH STILL WATER LEVEL PLUS WIND SETUP 584.5 FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM

B DESIGN HIGH STILL WATER LEVEL 582.9 FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM

C 1860 TO 1985 ANNUAL MEAN WATER LEVEL 579.3 FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM

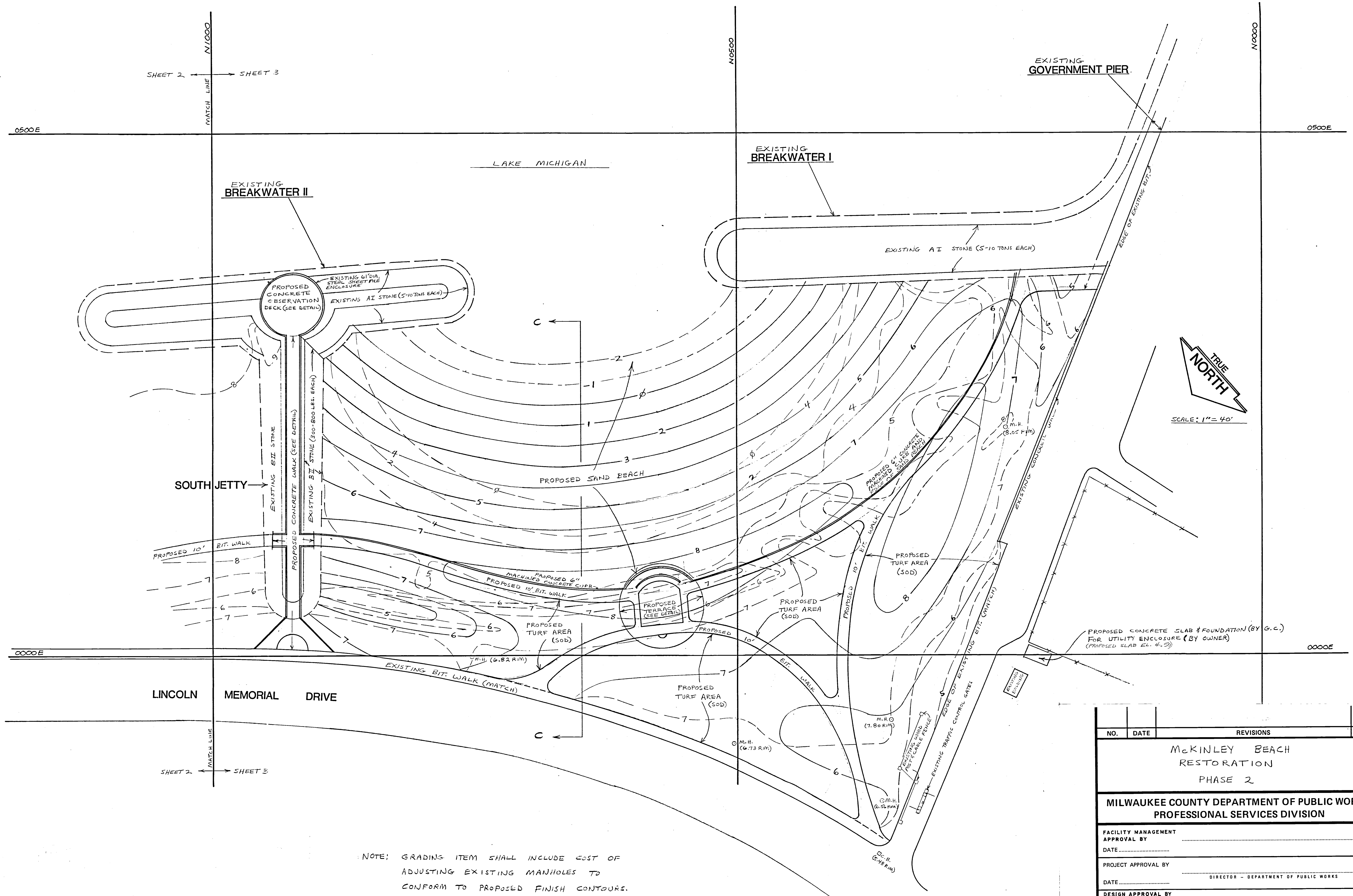
D LOW WATER DATUM 578.1 FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM

NOTE: THE DESIGN SPECIFICATIONS SHOWN HEREIN ARE FOR A TYPICAL STRUCTURE. THE DETAILED DESIGN OF SHORE PROTECTION MEASURES MUST BE BASED ON A DETAILED ANALYSIS OF WAVE CLIMATE, COST AND AVAILABILITY OF CONSTRUCTION MATERIAL, SPECIFIC GRAVITY AND QUALITY OF THE STONE, TYPE OF LAKEBED MATERIAL, AND EXISTING SHORELINE GEOMETRY.

Source: Warzyn Engineering, Inc., and SEWRPC.

Appendix B

McKinley Beach Plan & Section View



NOTE: GRADING ITEM SHALL INCLUDE COST OF ADJUSTING EXISTING MANHOLES TO CONFORM TO PROPOSED FINISH CONTOURS.

NO.	DATE	REVISIONS	BY

McKINLEY BEACH
RESTORATION
PHASE 2

MILWAUKEE COUNTY DEPARTMENT OF PUBLIC WORKS
PROFESSIONAL SERVICES DIVISION

FACILITY MANAGEMENT APPROVAL BY ....

DATE ....

PROJECT APPROVAL BY ....
DIRECTOR – DEPARTMENT OF PUBLIC WORKS

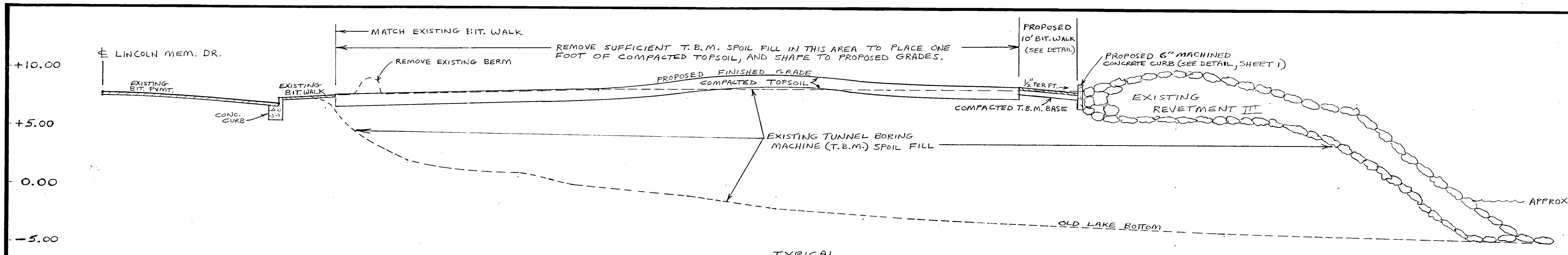
DATE ....

DESIGN APPROVAL BY

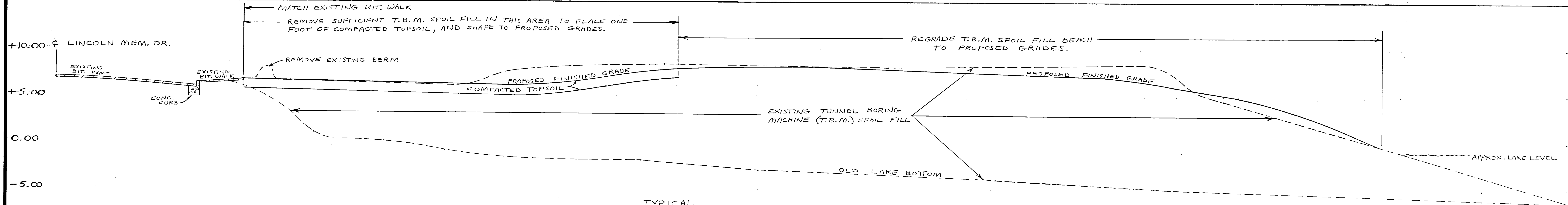
DATE ....

SURVEY BY		DRAWN BY	G.A.L.	DATE MARCH, 1989	SHEET 3 OF 7
NOTES		TRACED BY		FILE NO. 173-B-15	PROJ. NO. 89-06-3022
DATE		CHECKED BY	R.W.F.		

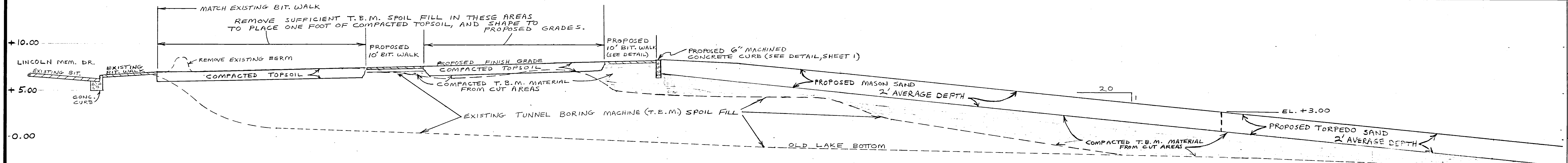
77312



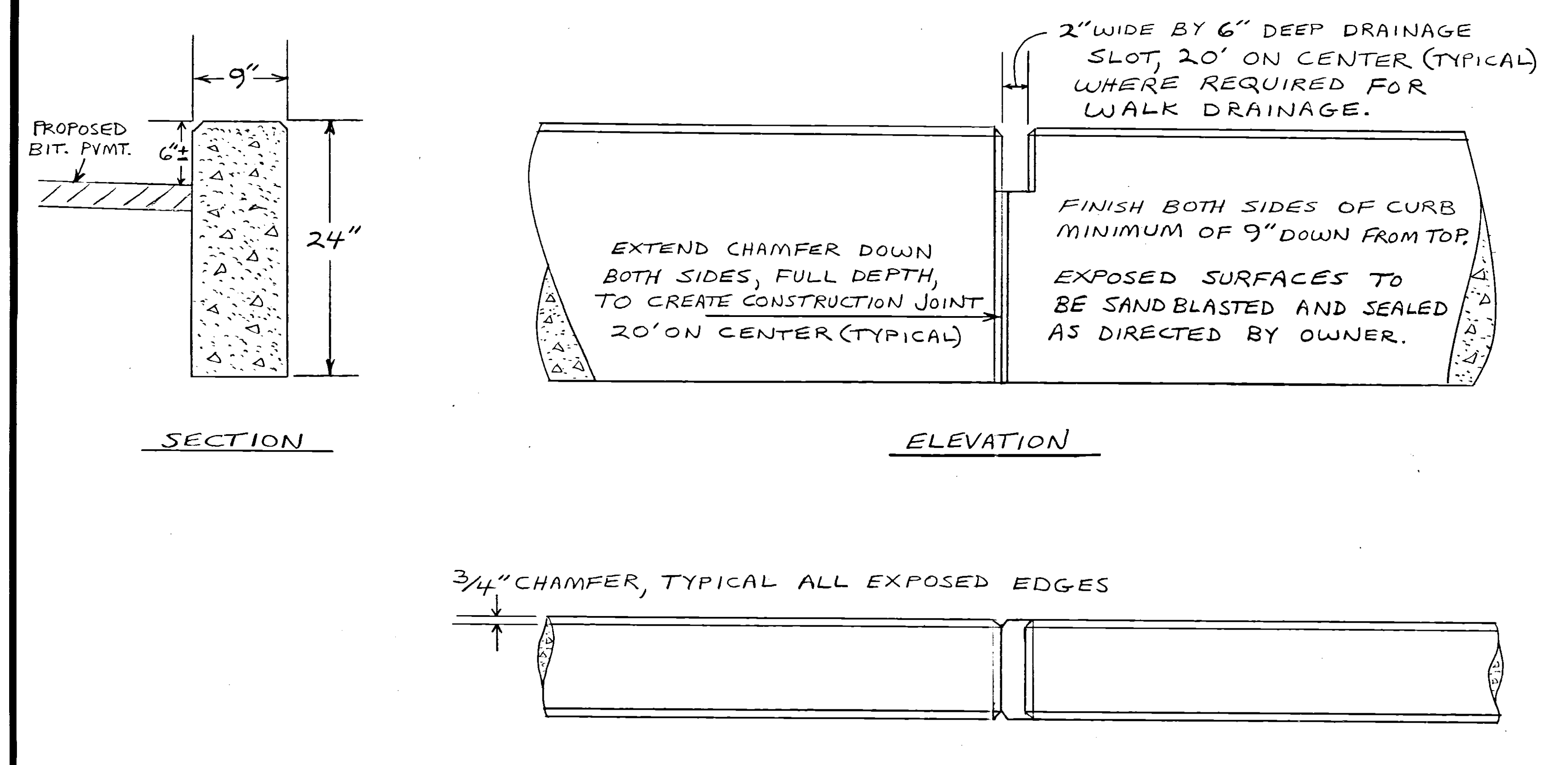
TYPICAL
SECTION A-A (SHEET 1)
SCALE: 1" = 10' HORIZONTAL 1" = 5' VERTICAL



TYPICAL
SECTION B-B (SHEET 2)
SCALE: 1" = 10' HORIZONTAL 1" = 5' VERTICAL



TYPICAL
SECTION C-C (SHEET 3)
SCALE: 1" = 10' HORIZONTAL 1" = 5' VERTICAL

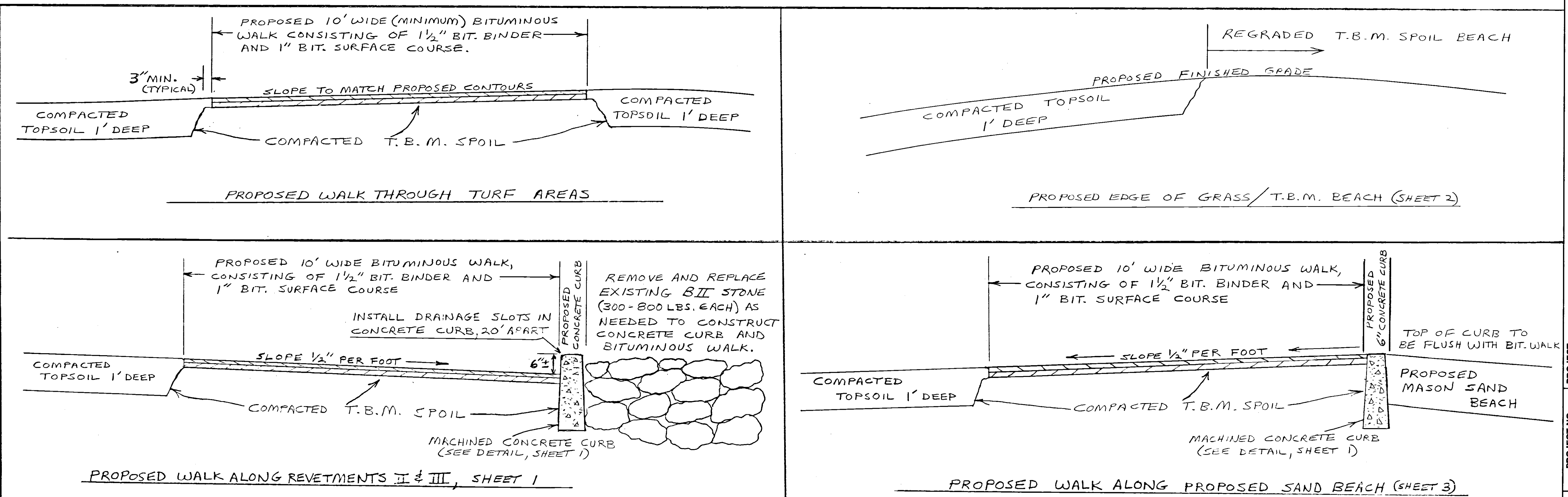


SECTION

ELEVATION

TOP

10"
~~8"~~ DECORATIVE
CONCRETE CURB DETAIL
SCALE 1" = 1'-0"



PROPOSED WALK THROUGH TURF AREAS

PROPOSED EDGE OF GRASS/T.B.M. BEACH (SHEET 2)

PROPOSED WALK ALONG REVETMENTS II & III, SHEET 1

PROPOSED WALK ALONG PROPOSED SAND BEACH (SHEET 3)

TYPICAL BITUMINOUS WALK DETAILS
SCALE ½" = 1'-0"

MILWAUKEE COUNTY DEPARTMENT OF PUBLIC WORKS
PROFESSIONAL SERVICES DIVISION
COURTHOUSE ANNEX 907 NORTH 10TH STREET MILWAUKEE, WISCONSIN 53233

REVISIONS

SCALE:	DRAWN BY:
AS SHOWN	G.A.L.
DATE: MARCH, 1989	CHECKED BY: R.W.F.

PROJECT TITLE: McKINLEY BEACH RESTORATION - PHASE 2
SHEET DESCRIPTION: SECTIONS AND DETAILS
PROJECT NO. 89-06-3022
SHEET NO. 4 of 7
FILE NO.

173-B-16 77313

Appendix C

Gradation Summary & Graphs

GESTRA

191 W. Edgerton Ave
Milwaukee, WI 53207
(414)933-7444

Report On: **Test Report Attachment**

Lab No: **22-00276**
Report No: 22-00276

Project No: 22056-40 **Cust No:** 0020

Page 1 of 6

Client: SEH
Heather Stabo
316 North Milwaukee Street
Suite 302
Milwaukee, WI 53202

Project: McKinley Beach Study

Report Date: 03/14/2022

Location:

Sample Date: 03/14/2022
Sampled By: Thomas Stevens

Remarks: Please see attached 5 sieve analysis from McKinley Beach Study

Test Methods (If Applicable):C136

Orig: SEH Attn: Heather Stabo (1-ec copy)
1-cc Laboratory

Respectfully Submitted,

Thomas Stevens

Thomas Stevens, Lab Manager

GESTRA Engineering, Inc
191 W. Edgerton Ave
Milwaukee, WI 53207
Phone: (414) 933-7444; Fax: (414) 933-7844

Laboratory Test Results of
Mechanical Analysis of Soil or Aggregate

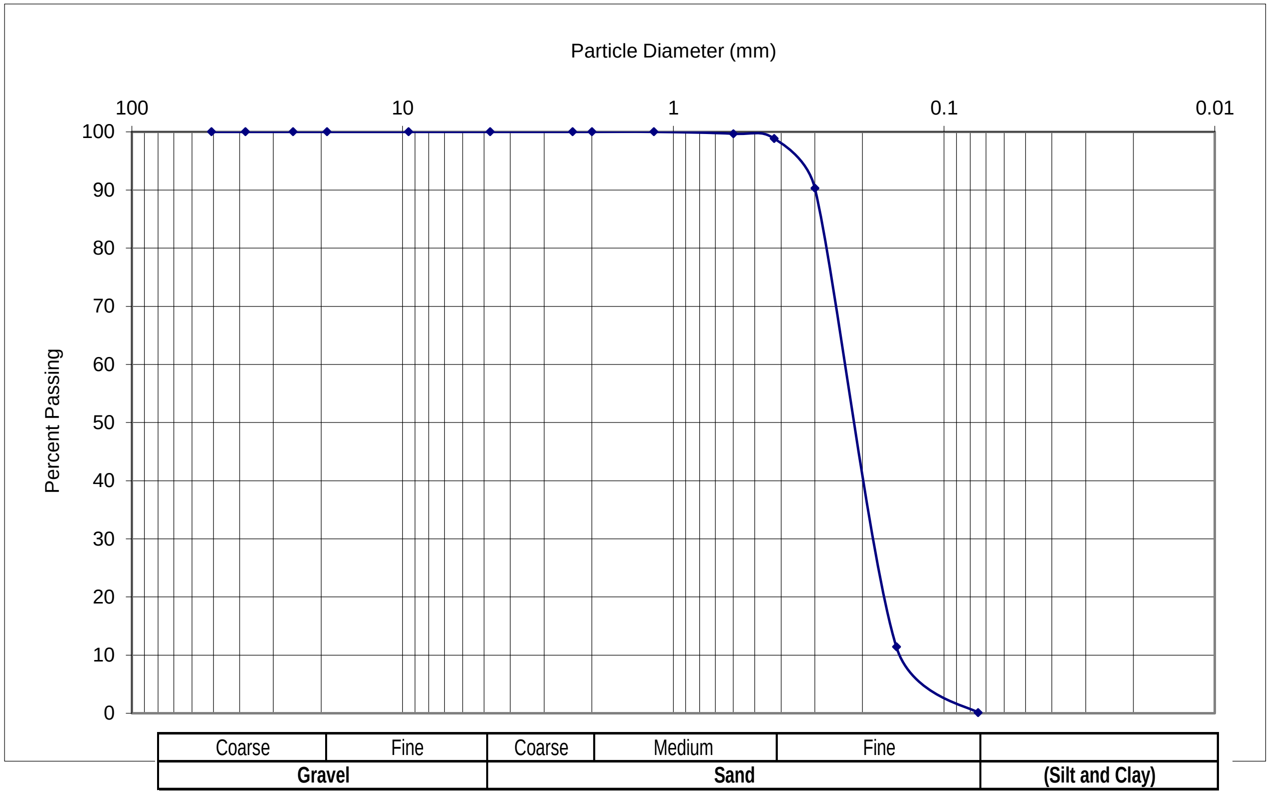
Project Name:	McKinley Beach Study	Date:	March 3, 2022
Project Number:	22056-40	Reported To:	S E H
Project Location:	Milwaukee, WI		
ASTM Designation:	**C136, D422, T-27**		

Sample Information

Type of Sample:	Bag	Sample Number:	1
Boring Number:		Depth of Sample:	

Mechanical Analysis Data

Sieve	Sieve Opening (mm)	Percent Passing (%)
2	50.8	100.0
1 1/2	38.1	100.0
1	25.4	100.0
3/4	19.05	100.0
3/8	9.525	100.0
#4	4.75	100.0
#8	2.36	100.0
#10	2	100.0
#16	1.18	100.0
#30	0.6	99.7
#40	0.425	98.9
#50	0.3	90.3
#100	0.15	11.4
#200	0.075	0.1



Moisture Content 20.4 %

Remarks: Gravel 0.0 % Sand 99.9 %
Passing #200 Sieve (Silt & Clay) 0.1 %

Reviewed by: D. Dettmers
GESTRA Engineering, Inc.

Performed by: TS/B. Bills

GESTRA

GESTRA Engineering, Inc
191 W. Edgerton Ave
Milwaukee, WI 53207
Phone: (414) 933-7444; Fax: (414) 933-7844

Laboratory Test Results of
Mechanical Analysis of Soil or Aggregate

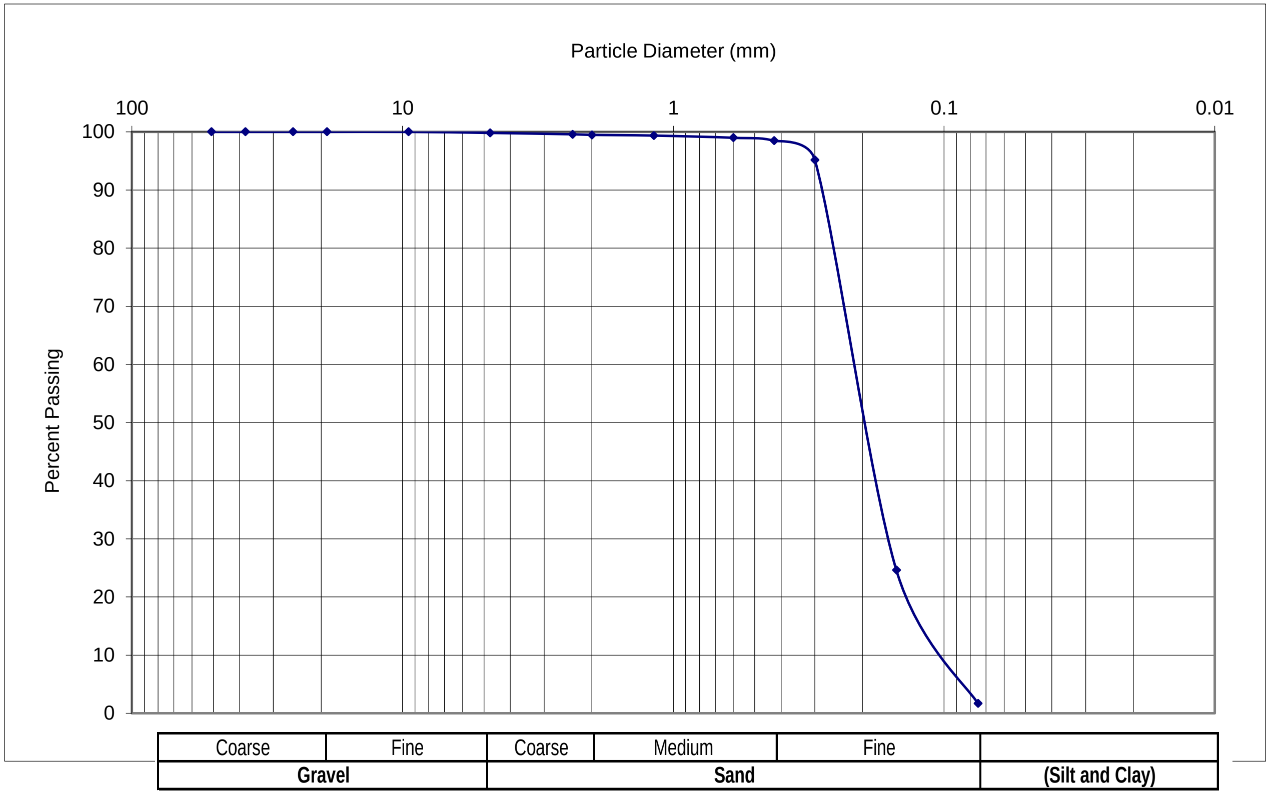
Project Name:	McKinley Beach Study	Date:	March 3, 2022
Project Number:	22056-40	Reported To:	S E H
Project Location:	Milwaukee, WI		
ASTM Designation:	**C136, D422, T-27**		

Sample Information

Type of Sample:	Bag	Sample Number:	#2
Boring Number:		Depth of Sample:	

Mechanical Analysis Data

Sieve	Sieve Opening (mm)	Percent Passing (%)
2	50.8	100.0
1 1/2	38.1	100.0
1	25.4	100.0
3/4	19.05	100.0
3/8	9.525	100.0
#4	4.75	99.8
#8	2.36	99.6
#10	2	99.5
#16	1.18	99.4
#30	0.6	99.0
#40	0.425	98.5
#50	0.3	95.2
#100	0.15	24.6
#200	0.075	1.7



Moisture Content 20.8 %

Remarks: Gravel 0.2 % Sand 98.1 %
Passing #200 Sieve (Silt & Clay) 1.7 %

Performed by: TS/B. Bills

Reviewed by: D. Dettmers
GESTRA Engineering, Inc.

Geotechnical-Structural-Pavement-Construction Material

GESTRA

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191 W. Edgerton Ave
Milwaukee, WI 53207
Phone: (414) 933-7444; Fax: (414) 933-7844

Laboratory Test Results of Mechanical Analysis of Soil or Aggregate

Project Name: McKinley Beach Study
Project Number: 22056-40
Project Location: Milwaukee, WI
ASTM Designation: **C136, D422, T-27**

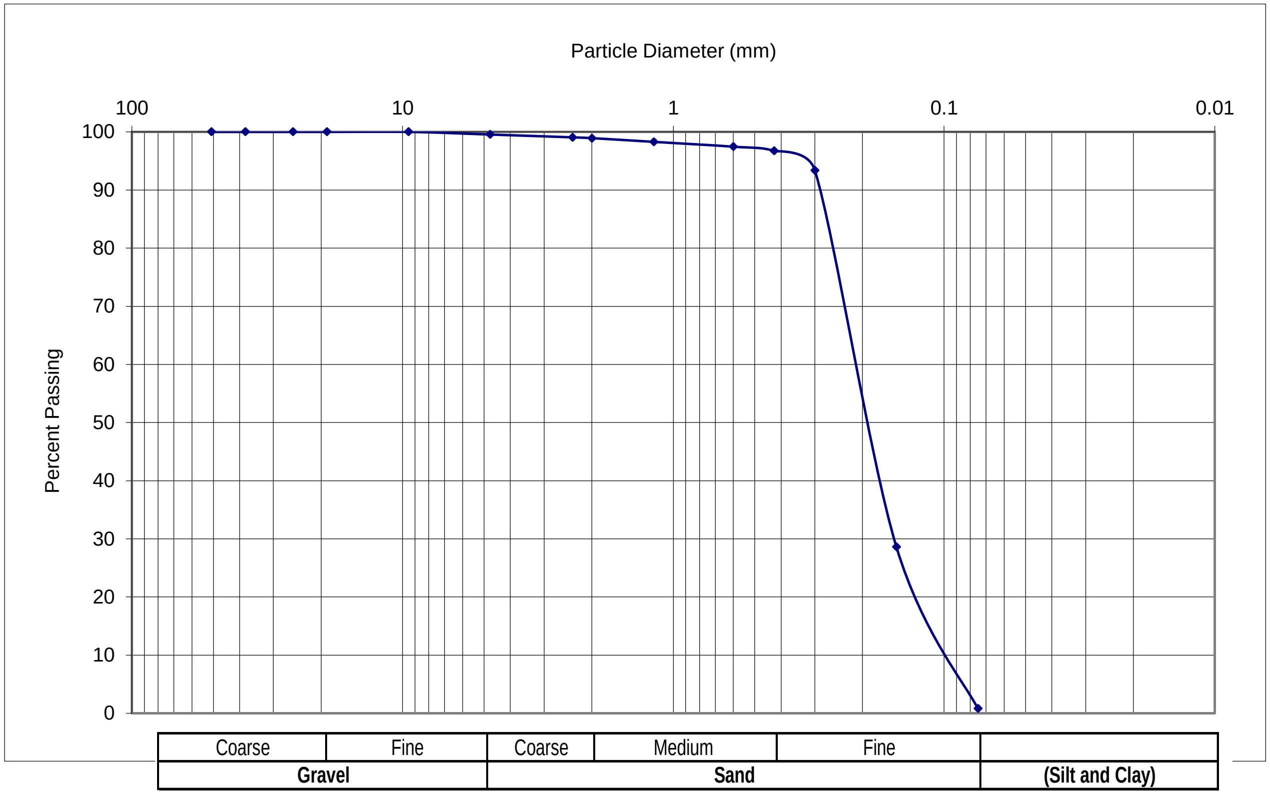
Date: March 3, 2022
Reported To: S E H

Sample Information

Type of Sample: Bag
Boring Number:
Sample Number: #3
Depth of Sample:

Mechanical Analysis Data

Sieve	Sieve Opening (mm)	Percent Passing (%)
2	50.8	100.0
1 1/2	38.1	100.0
1	25.4	100.0
3/4	19.05	100.0
3/8	9.525	100.0
#4	4.75	99.5
#8	2.36	99.1
#10	2	98.9
#16	1.18	98.3
#30	0.6	97.5
#40	0.425	96.7
#50	0.3	93.4
#100	0.15	28.6
#200	0.075	0.8



Moisture Content 21.2 %

Remarks: Gravel 0.5 % Sand 98.7 %
Passing #200 Sieve (Silt & Clay) 0.8 %

Performed by: TS/B. Bills

Reviewed by: D. Dettmers
GESTRA Engineering, Inc.

Geotechnical-Structural-Pavement-Construction Material

GESTRA

GESTRA Engineering, Inc
191 W. Edgerton Ave
Milwaukee, WI 53207
Phone: (414) 933-7444; Fax: (414) 933-7844

Laboratory Test Results of
Mechanical Analysis of Soil or Aggregate

Project Name: McKinley Beach Study
Project Number: 22056-40
Project Location: Milwaukee, WI
ASTM Designation: **C136, D422, T-27**

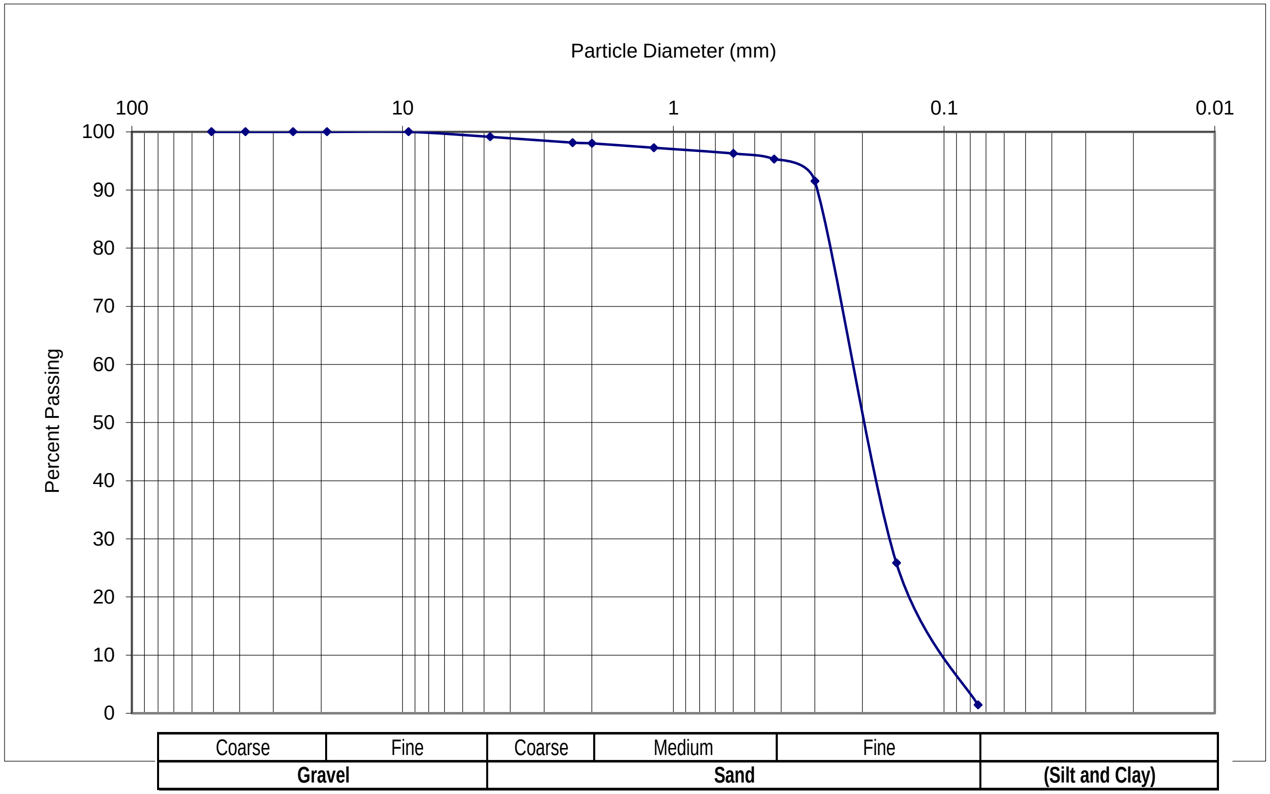
Date: March 3, 2022
Reported To: S E H

Sample Information

Type of Sample: Bag
Boring Number:
Sample Number: 4
Depth of Sample:

Mechanical Analysis Data

Sieve	Sieve Opening (mm)	Percent Passing (%)
2	50.8	100.0
1 1/2	38.1	100.0
1	25.4	100.0
3/4	19.05	100.0
3/8	9.525	100.0
#4	4.75	99.1
#8	2.36	98.1
#10	2	98.0
#16	1.18	97.3
#30	0.6	96.3
#40	0.425	95.3
#50	0.3	91.5
#100	0.15	25.8
#200	0.075	1.4



Moisture Content 19.6 %

Remarks: Gravel 0.9 % Sand 97.7 %
Passing #200 Sieve (Silt & Clay) 1.4 %

Performed by: TS/B. Bills

Reviewed by: D. Dettmers
GESTRA Engineering, Inc.

Geotechnical-Structural-Pavement-Construction Material

GESTRA

GESTRA Engineering, Inc
191 W. Edgerton Ave
Milwaukee, WI 53207
Phone: (414) 933-7444; Fax: (414) 933-7844

Laboratory Test Results of
Mechanical Analysis of Soil or Aggregate

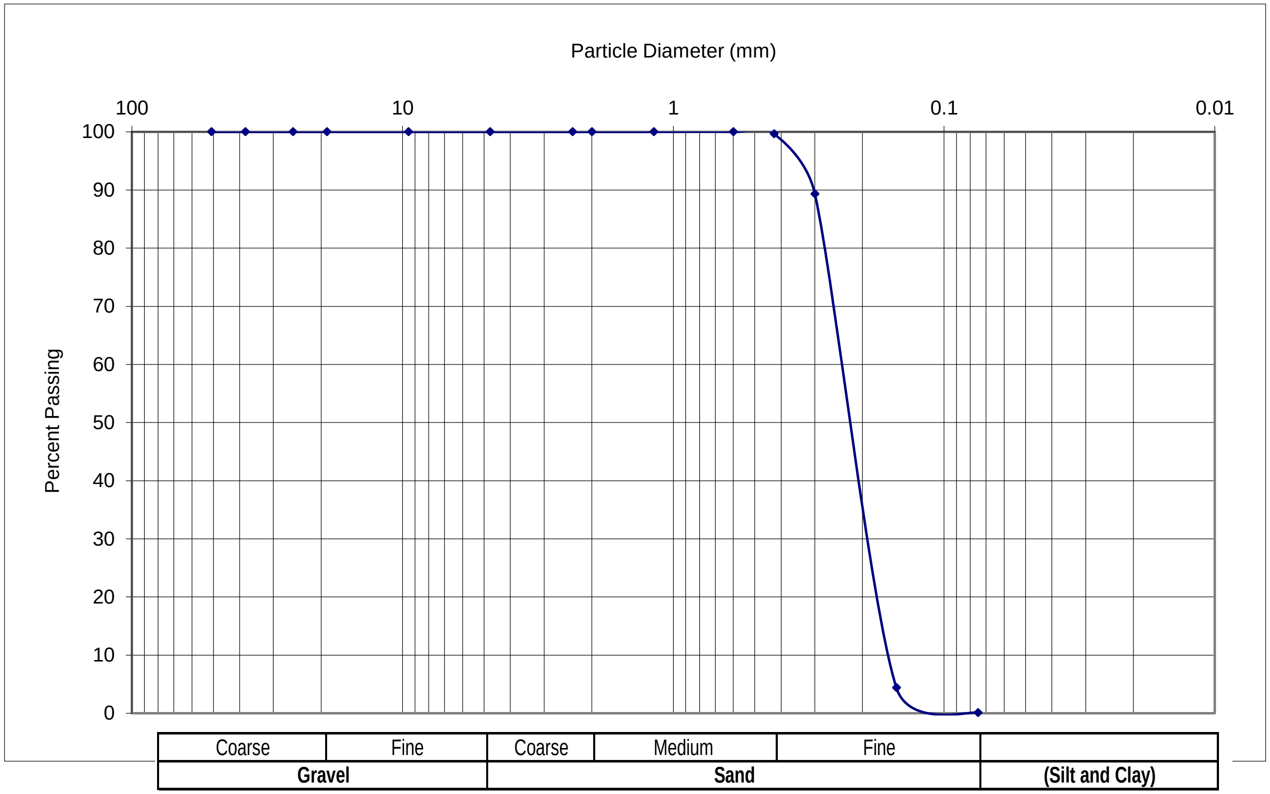
Project Name:	McKinley Beach Study	Date:	March 3, 2022
Project Number:	22056-40	Reported To:	S E H
Project Location:	Milwaukee, WI		
ASTM Designation:	**C136, D422, T-27**		

Sample Information

Type of Sample:	Bag	Sample Number:	5
Boring Number:		Depth of Sample:	

Mechanical Analysis Data

Sieve	Sieve Opening (mm)	Percent Passing (%)
2	50.8	100.0
1 1/2	38.1	100.0
1	25.4	100.0
3/4	19.05	100.0
3/8	9.525	100.0
#4	4.75	100.0
#8	2.36	100.0
#10	2	100.0
#16	1.18	100.0
#30	0.6	100.0
#40	0.425	99.7
#50	0.3	89.3
#100	0.15	4.4
#200	0.075	0.1



Moisture Content 21.4 %

Remarks: Gravel 0.0 % Sand 99.9 %

Passing #200 Sieve (Silt & Clay) 0.1 %

Performed by: TS/B. Bills

Reviewed by: D. Dettmers
GESTRA Engineering, Inc.

Geotechnical-Structural-Pavement-Construction Material

Appendix D

Hydrographic Survey Report

Final Report for

HYDROGRAPHIC SURVEY
MCKINLEY BEACH, MILWAUKEE, WI

Prepared for:

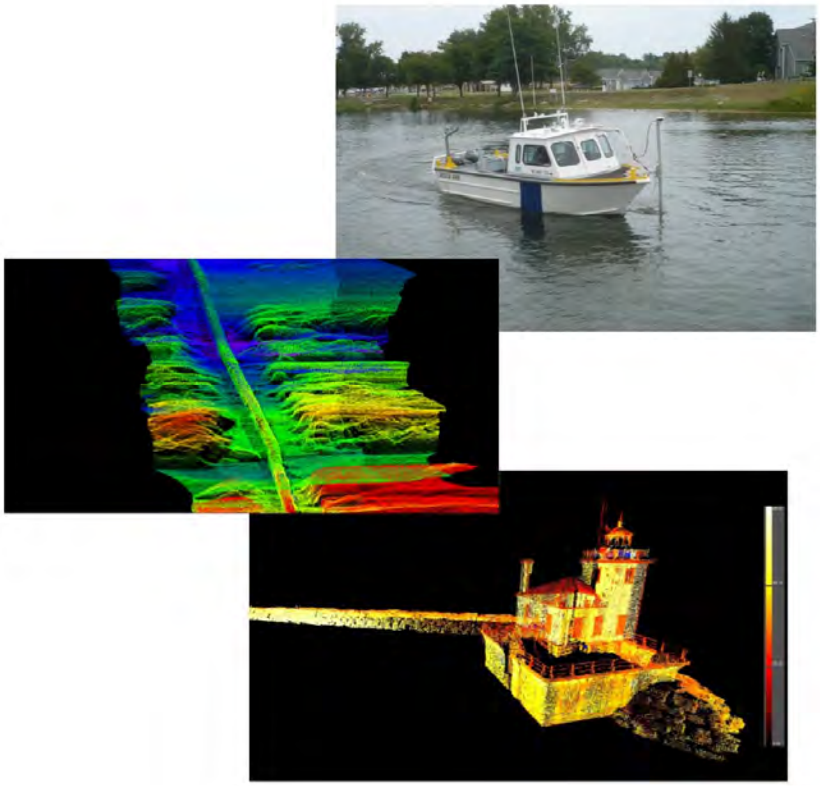
SEH

316 North Milwaukee St.
Suite 302
Milwaukee, WI 53202

Prepared By:

SEAWORKS GROUP, LLC

185 E. Main, Suite 414, Benton Harbor, MI 49022 269-277-3005



seaworks
HYDROGRAPHIC • GEOPHYSICAL • ENVIRONMENTAL

HUBZone
Historically Underutilized Business Zone
CERTIFIED

TABLE OF CONTENTS

1.0 Project Details

1.1 Project Description

Seaworks was tasked by SEH Inc. with performing a bathymetric investigation in Milwaukee, WI. The area of interest was the McKinley Beach cove and surrounding lakebed. The purpose of the survey was to assess conditions for a coastal engineering study. Seaworks collected multibeam sonar data from the opening of the cove out to the lakeward extents of the survey area. Inside the cove area a Z-boat drone equipped with single-beam sonar was utilized to capture shallow water data.

The survey area measured approximately 1,100' long by 1,300' wide with water depths varying from approximately 2'-15'. The survey area was located in the open waters of lake Michigan and was bounded by several breakwater and groin structures. Hydrographic data was collected by Seaworks between November 8th and November 30th of 2021. Ponar sand samples were also collected on December 17th.

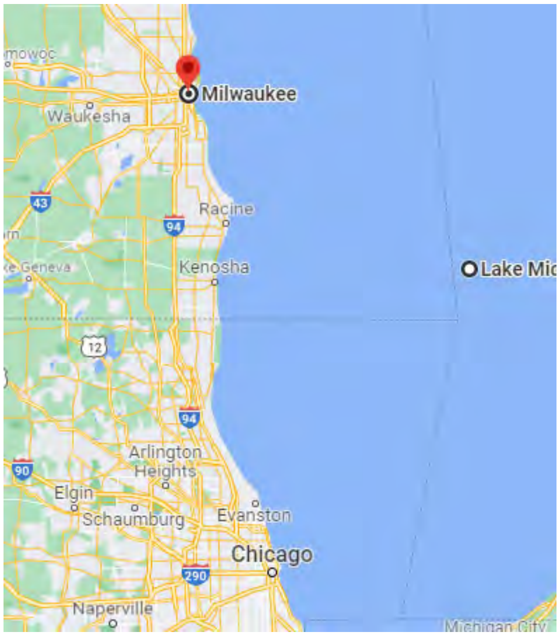


Figure 1.1 – Project Location

Figure 1.2 – Survey Area (green)

1.2 Project Datums

Horizontal

Datum: North American Datum of 1983 (NAD83)
Grid: Wisconsin Coordinate System, South Zone
Units: US Survey Feet

Vertical
Datum: International Great Lakes Datum of 1985 (IGLD85)
Geoid: Continental US (CONUS) 2018

The following offset was computed using NOAA's NAVD88 - IGLD85 Height Conversion Tool Kit for Milwaukee, WI:

577.5' IGLD85 = 578.00' NAVD88

1.3 Survey Control

Seaworks previously established two control points in Veterans Park using RTK GPS with corrections from the WISCORS VRS network, as well as NGS OPUS methods. The WISCORS network was used for RTK GPS vessel positioning corrections during survey operations. Daily QC checks were performed against the SW1 and SW2 control points using a Trimble R8 GNSS rover.

Figure 1.3 – Seaworks Established Control Points (SW-1 & SW-2)

2.0 Equipment

2.1 Survey Vessel

Survey Vessel Mary Rose
The 25' Mary Rose is a heavily-built aluminum, DGPS-equipped, automated hydrographic survey vessel with an environment-controlled cabin capable of transporting up to 6 passengers. The Mary rose also features push knees, extra-large fuel tanks, twin 150hp 4-stroke outboards, and a 3000W generator.

Specifications:
Length: 25’
Horsepower: 300
Cruising/max speed: 25/35kts
Generator: 3,000W
Fuel Capacity: 150 gallons
Passenger capacity: 6
Trailer: Galvanized, twin axle


Figure 2.1 – Mary Rose

Z-Boat 1800-RP

The Z-Boat 1800-RP is a small, remote-controlled, “drone” survey vessel capable that can be equipped with most of the same survey technologies as Seaworks’ large survey vessels. It’s portability and compact size make it ideal for shallow-water surveying, difficult to access areas, and protected waters of any depth. Seaworks’ boat has a “ruggedized package” upgrade which features a single lifting eye, a dual- GPS/GNSS antenna mount frame, and an interchangeable sensor mount well.


Figure 2.2 – Z-Boat

Specifications
- Length: 6’
- Width: 3’
- Height: 3’
- Survey/max speed: 3/8kts
- Boat weight: 85lbs
- Payload capacity: 65lbs

2.2 Sonar Equipment

R2Sonic 2020

The R2Sonic 2020 multibeam sonar system scans underwater features using a high-resolution swath of 256 beams with beam widths of 1° across-track and 1° along-track (1° x 1° system). The system can be operated in either equidistant or equal-angle operating modes, with a swath coverage angle of up to 130°. The sonar operates at user-selectable frequencies between 200kHz and 400kHz.


Figure 2.3 – R2Sonic 2020

A continuous sound velocity profile is normally measured by velocity probe casts and then corrected for within the processing software. Additionally, real-time sound velocity is monitored at the sonar head using a head-mounted SV probe.

Sonar Equipment & Accessories

- Multibeam Echosounder: R2Sonic 2020
- SV Profiler: Teledyne Odom Digibar Pro
- Sonar Head SV: AML MicroX Sensor

Odom CV100

The Teledyne Odom CV100 Echosounder is a rugged, waterproof, dual-frequency single-beam echosounder. It is capable of digital chart (Echogram) output via an ethernet interface which is logged in Hypack software as .bin files. It operates at a frequency range of 24-340Khz at up to 20Hz ping rates. Typical resolution is 0.01m and accuracy is 0.01m +/-1% of water depth (at 200Khz).

Figure 2.4 – Odom CV100

Seaworks configuration utilizes a 200/33Khz dual-frequency transducer with beam angles of 8° and 23° for the high and low-frequency, respectively. The 200Khz high-frequency data is used for general-purpose surveying, with the low-frequency data used as a backup if vegetation or fluid mud are encountered.

A sound velocity profile is measured prior to each survey using an Odom Digibar Pro, which is used to correct sonar data during collection and processing.

Sonar Equipment

- Teledyne Odom CV100 Echosounder
- Teledyne Odom Digibar Pro

2.3 Positioning & Orientation System

Applanix POS MV 120

Horizontal and vertical positioning were accomplished using an Applanix POS MV 120 Position & Orientation system. The POS MV 120 package uses RTK (Real Time Kinematic) GPS technology which is capable of receiving both L1 & L2 frequencies as well as the GLONASS satellites. Equipment is capable of achieving positioning accuracies of up to +/-0.10’, both horizontally and vertically. The RTK positioning equipment is be capable of rapid update rates >5Hz, allowing it to be used for real-time heave compensation.

Figure 2.5 – POS MV 120

A two-antenna “moving baseline RTK” system is used by the POS to provide high-accuracy heading in addition to vessel position. Heading sensing equipment is capable of maintaining at least +/-0.10° heading accuracy under most conditions.

The final component of the system is a precision motion sensor which is used for vessel pitch and roll corrections. The sensor was calibrated/zeroed with the vessel at rest, and then mounting offsets were determined by a patch test performed prior to mobilization. Motion sensing equipment is capable of angular measurement accuracy of at least +/-0.04°.

3.0 Personnel

Chris Ebner, P.E. (MI & IL) was the Project Manager and Lead Hydrographer for the operation. Chris is a Hydrographer certified by the Hydrographic Society of America and the National Society of Professional Surveyors (THSOA/NSPS) with 14 years of experience in hydrographic surveying.

Ed Lopez and Tom Howe were the Project Surveyors for field data collection and processing. Ed and Tom have relevant education backgrounds, work experience, and extensive hands-on experience using the hydrographic systems described above.

4.0 Procedures

4.1 Calibrations & Checks

Immediately prior to the survey, a sound velocity profile was measured using the Digibar Pro. The Digibar cast recorded velocities throughout the water column at 1’ increments, which were applied to sonar data during collection and processing. Additionally, sound velocity at the sonar head was measured and applied in real-time using the head-mounted AML MicroX probe. A new Digibar cast was performed every 2 hours.

Pre and post-survey water level checks were performed by comparing RTK elevation outputs from the POS MV to water level shots from the Trimble RTK GPS Rover.

Bar checks for the Survey Vessel are performed regularly, by measuring returns off an aluminum plate held at a known depth below the sonar head. This is done to confirm the sonar head draft value as well as provide a documented physical check against Seaworks’ electronic soundings.

Multibeam patch tests for the Survey Vessel are performed regularly in order to measure and confirm sensor mounting offsets. This is done by running survey lines in a predetermined pattern over a recognizable object such as a slope or pipeline. The data is then processed using a software routine to compute the pitch, roll, and heading angular offsets.

4.2 Field Procedures

After initial checks and calibrations, bathymetry lines were run parallel to shore at line spacings of 30’. Survey line spacing was selected in order to provide complete bottom coverage by the multibeam swath at varying water depths. Generally 50% overlap (150% coverage) was desired between passes in order to provide redundant data for QC purposes, although this was not possible in very shallow water due to narrow swath widths.

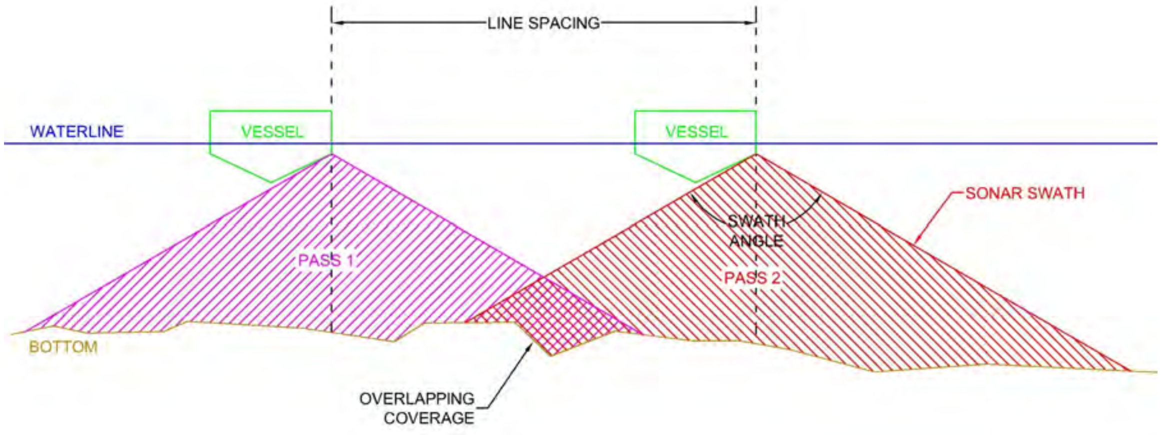


Figure 4.1 – Survey Layout

Along the shoreline starboard beams were electronically adjusted outward to maximize coverage in shallow water and along breakwalls wherever possible.

Sonar operating parameters - Bathymetry

- Sonar Frequency: 400Khz
- Swath Angle: 30° port/70° starboard
- Sonar Mode
  - Equi-Distant Beams
  - Down/Bathy/Normal
- Survey Speed: 3.5-4.0Kts

4.3 Processing & Deliverables

Following data collection, survey data was processed using the Hypack/Hysweep 2020 software package. Raw data was pre-filtered, then manually cleaned of unsuitable data and sonar noise. Positioning and motion sensing corrections were applied, then data was saved in Hypack Edited Data format for additional post-processing.

Data was exported in a 1’ x 1’ XYZ grid file format, reduced using Average sounding selection. The XYZ grid was used in Hypack’s TIN utility to generate contours and geotiff files in attachments.

The single beam dataset was merged with multibeam data using Hypack XYZ Manager to produce a complete TIN surface that included the shallow water off the beach.

5.0 Site Conditions

Site conditions were challenging due to the open water locations and Fall weather. During the first round of surveying on November 8 the crew was forced to demobilize before work was completed due to poor weather. The crew returned on November 29 to collect the multi-beam data closer to the breakwaters. The weather again deteriorated before the Z-Boat work could be completed. Finally on November 30 conditions were calm enough to collect the shallow water data using the single-beam Z-boat.

Survey Conditions:

November 8th, 2021

- Sea: 1-2’
- Sky: Clear
- Wind: 10Kts SE
- Temperature: 65°F

November 29th, 2021

- Sea: 1-4’ (building)
- Sky: Snow
- Wind: 10-25 Kts S
- Temperature: 30°F

November 30th, 2021

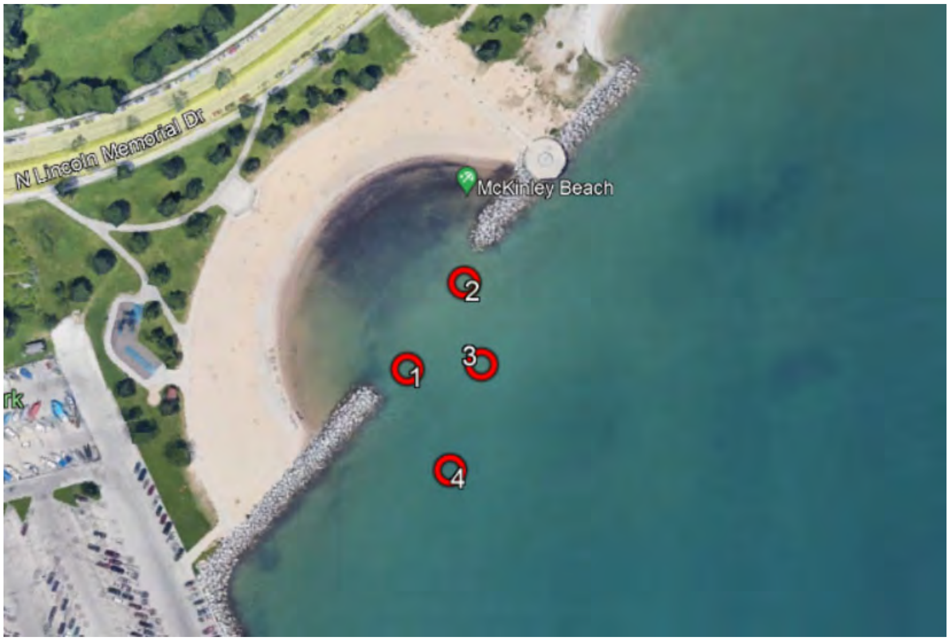
- Sea: 1’
- Sky: Clear
- Wind: 10 Kts W
- Temperature: 25°F

While processing the multibeam data some sand movement was noted between the two survey days in shallow water due to wave action from storms. When merging the files, the newer data was favored, and the transitions between the two datasets was “softened” with manual processing and TIN modelling to give the best appearance.

6.0 Results & Discussion

Survey results are depicted in the plan view plots provided. Lakebed conditions are fairly typical, however some deep scour holes were observed near the ends of the stone groins protecting the beach, particularly along the Southwest groin. These holes could be a potential hazard to swimmers.

4 grab samples were collected on December 17th and provided to SEH for laboratory analysis. Samples were collected using a Wildco Ponar Grab sampler. Sample locations and coordinates are provided in the figure below.



Sample	Easting	Northing
1	2,534,704	390,949
2	2,534,787	391,093
3	2,534,840	390,963
4	2,534,733	390,788

Figure 6.1 – Sand Sample Locations

DRAWING NOTES:

1. INFORMATION DEPICTED ON THIS DRAWING REPRESENTS RESULTS OF SOUNDINGS ON DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.

2. DATA REDUCED TO 1.0' X 1.0' SORT FILE USING AVERAGE SOUNDING SELECTION.

3. BACKGROUND IMAGE GENERATED FROM GOOGLE EARTH AND SHOULD BE CONSIDERED APPROXIMATE.

4. CONTOURS REPRESENT ELEVATION ABOVE IGLD85.

5. SHALLOW WATER AREA DATA WAS COLLECTED USING SINGLEBEAM Z-BOAT.

Scale: 1 Inch = 60.00 Feet
50 100 200 300 400 Feet

INFO / EQUIPMENT

SURVEY DATE: 11/08/21, 11/29/21 - 11/30/21
PERSONNEL: EL TH CE
VESSEL: MARY ROSE & Z-BOAT
ECHOSOUNDER: R2SONIC 2020 & ODOM CV200
SONAR FREQUENCY: 400 KHZ/ 200 KHZ
SOUND VELOCITY: VARIES
POSITIONING: APPLANIX POS MV
RTK POSITIONING

PROJECT DETAILS

HORIZONTAL DATUM: NAD83
GRID: WISCONSIN SOUTH
VERTICAL DATUM: IGLD85
REFERENCE PLANE: N/A
UNITS: US SURVEY FT
BASE POINT: SW1
W/L REFERENCE PT: ROVER SHOT

REVISIONS
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185 E. MAIN ST, STE 414, BENTON HARBOR, MI 49022
269-277-3005

CLIENT:
SEH

DATE: 12/08/21
DRAWN BY: SPM
APPROVED BY: CFE
SCALE: 1:60
JOB #: 10136
FILE: MCKINLEY_24x36

JOB TITLE:
MCKINLEY BEACH
MILWAUKEE HARBOR, MILWAUKEE, WI

DRAWING TITLE:
HYDROGRAPHIC SURVEY
PLAN VIEW PLOT

SHEET #:
P1

PAGE 1 OF 1

Appendix E

Wind & Wave Analysis Memorandum

Memorandum

From:	Jeremy Grush, PE Craig Taylor, PE Jason Rutyna, PE	**Date:**	2/25/2022
		Project:	McKinley Beach Study
To:	Heather Stabo, PE Jeremy Walgrave, PE		

SUBJECT: McKinley Beach Wave Analysis

COMPLETE DRAFT

Introduction

Wind-wave model simulations were conducted to compute wave-induced current speeds at McKinley Beach. Two of the three recent drownings have occurred during moderate onshore wind conditions of about 12 miles per hour and moderate wave conditions of about two feet. These waves can produce strong currents that sweep parts of the swim area. Future simulations will evaluate conceptual alternatives for mitigating the strong currents.

Wave heights and wave-induced current speeds were predicted at a 0.3-meter (~1-foot) scale using a model called SWASH (Simulating Waves to SHore). This model explicitly represents finer-scale wind-wave processes than what can be represented in its companion model, SWAN. SWAN is a component of the industry-leading Delft3D model. It is a coarser-resolution, spectrally-averaged wave model which resolves fewer processes in the surf zone and uses more approximations than SWASH. SWAN is most useful for predicting wave conditions at intermediate to deep water conditions and SWASH is most useful for predicting wave conditions in the surf zone (i.e., in shallower water).

Methods and results for existing condition wave simulations are described in more detail in the following section. The section titled “Conceptual Designs Analysis” will later describe model results for engineering concepts that may reduce the occurrence of strong currents at McKinley Beach (these model simulations have yet to be conducted). Finally, a section titled “Caveats and Recommendations for Future Analysis” describes uncertainty and caveats associated with this analysis, and recommendations for future work to increase confidence in the model results and in the effectiveness of potential designs.

Existing Conditions Analysis

This section describes the following items:

- Data sources used to support wind-wave modeling of McKinley Beach;
- Wind and wave conditions preceding the drowning events;
- Model inputs and assumptions for simulating these events; and,
- Model-predicted wave heights and current speeds near McKinley Beach.;

Data Sources

Several data sources were used to characterize local conditions. A bathymetric digital elevation model was developed based on survey data from Seaworks obtained in 2021. Water level inputs were developed from the nearby NOAA gage #9087057 (Milwaukee, WI). Wind data were developed from the nearby NOAA buoys MLWW3 (Port of Milwaukee) and ATW20 (Atwater Park, WI). Wave conditions were developed from USACE Wave Information Study (WIS) output at Station #94050, from NOAA buoy ATW20. The map below illustrates locations of key datasets.

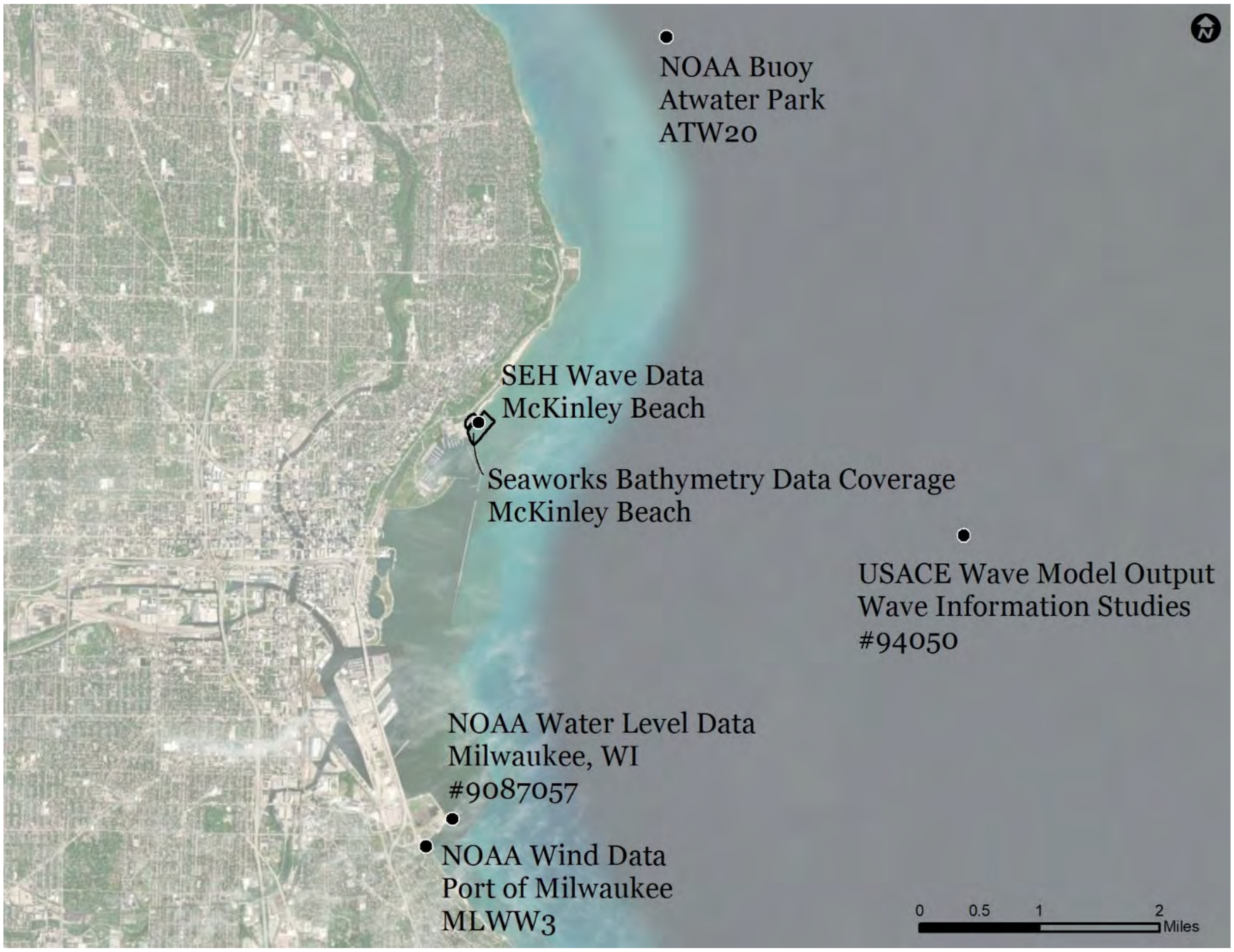


Figure 1: Key Observed Data Locations Supporting the Wave Model

The primary wave data source (NOAA station ATW20) represents offshore conditions approximately 3.5 miles northeast of the site, so it was important to confirm whether wave conditions closer to the site are similar. The confirmation was done by evaluating whether the McKinley Beach buoy data collected by SEH from November 2021 through mid-January 2022 are consistent with wave data at the ATW20 offshore buoy, specifically for the type of wind conditions preceding the drownings. The ATW20 offshore buoy was retrieved before November 2021 so the data periods do not overlap and a direct comparison is not possible.

The McKinley Beach buoy registers similar wave heights to the ATW20 offshore buoy. This confirms the adequacy of using the ATW20 buoy to represent conditions during the 2020 drownings. Figure 2 compares the relationship between wind speed and wave height for these two locations and shows the high level of similarity. Wave observations at the offshore buoy (ATW20) can be a good proxy for wave conditions near the site if wind conditions are relatively uniform over the lake area from which the wind is approaching the shore.

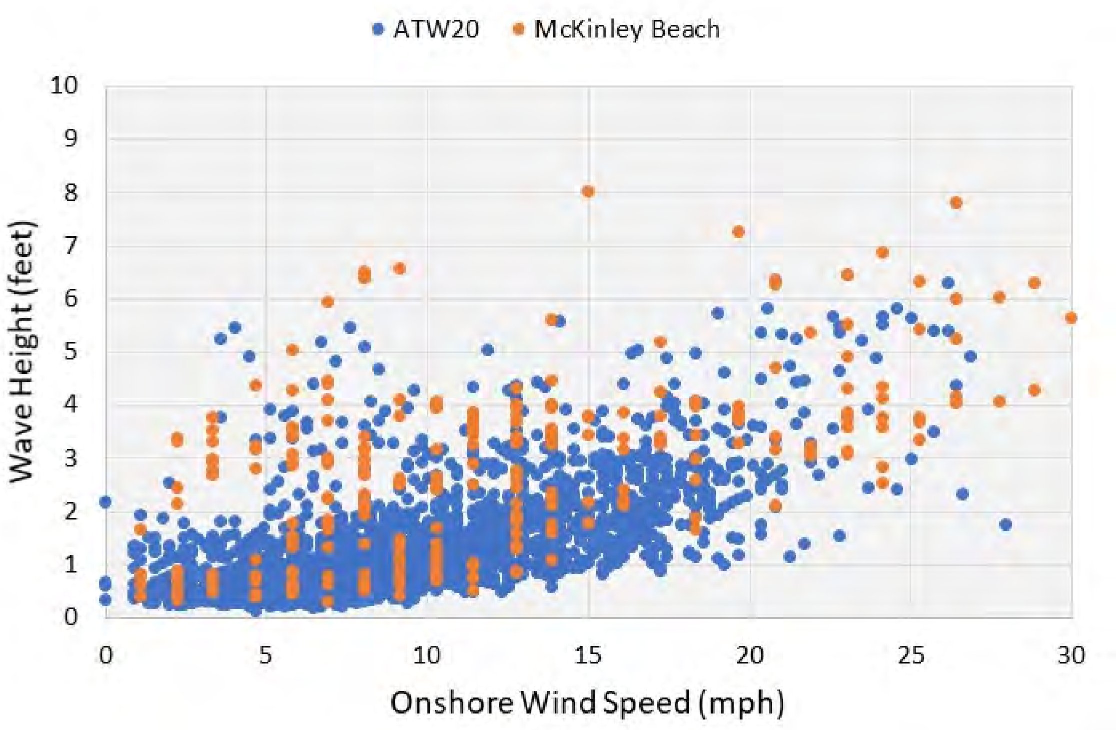


Figure 2: Similarity in Wave Response to Onshore Wind Conditions at ATW20 and the McKinley Beach buoy

Conditions Preceding Drownings

Included below are more detailed descriptions of weather and wave conditions preceding the three dates when drownings occurred in summer 2020: June 3 (7:00 AM), July 18, and August 8.

Before dawn on June 3 there were strong winds out of the northwest which set up a seiche on Lake Michigan (i.e., rapid oscillation of water levels in the lake). Based on calculations of seiche-induced currents, the seiche was not likely to have been a significant factor causing the drowning. Estimated currents from the seiche were approximately 0.2 feet per second, while modeled wave-induced currents for two-foot onshore winds are higher than 2 feet per second. Winds preceding the drowning were variable in direction, quickly shifting from out of the northwest to out of the south. Waves were about two feet high.

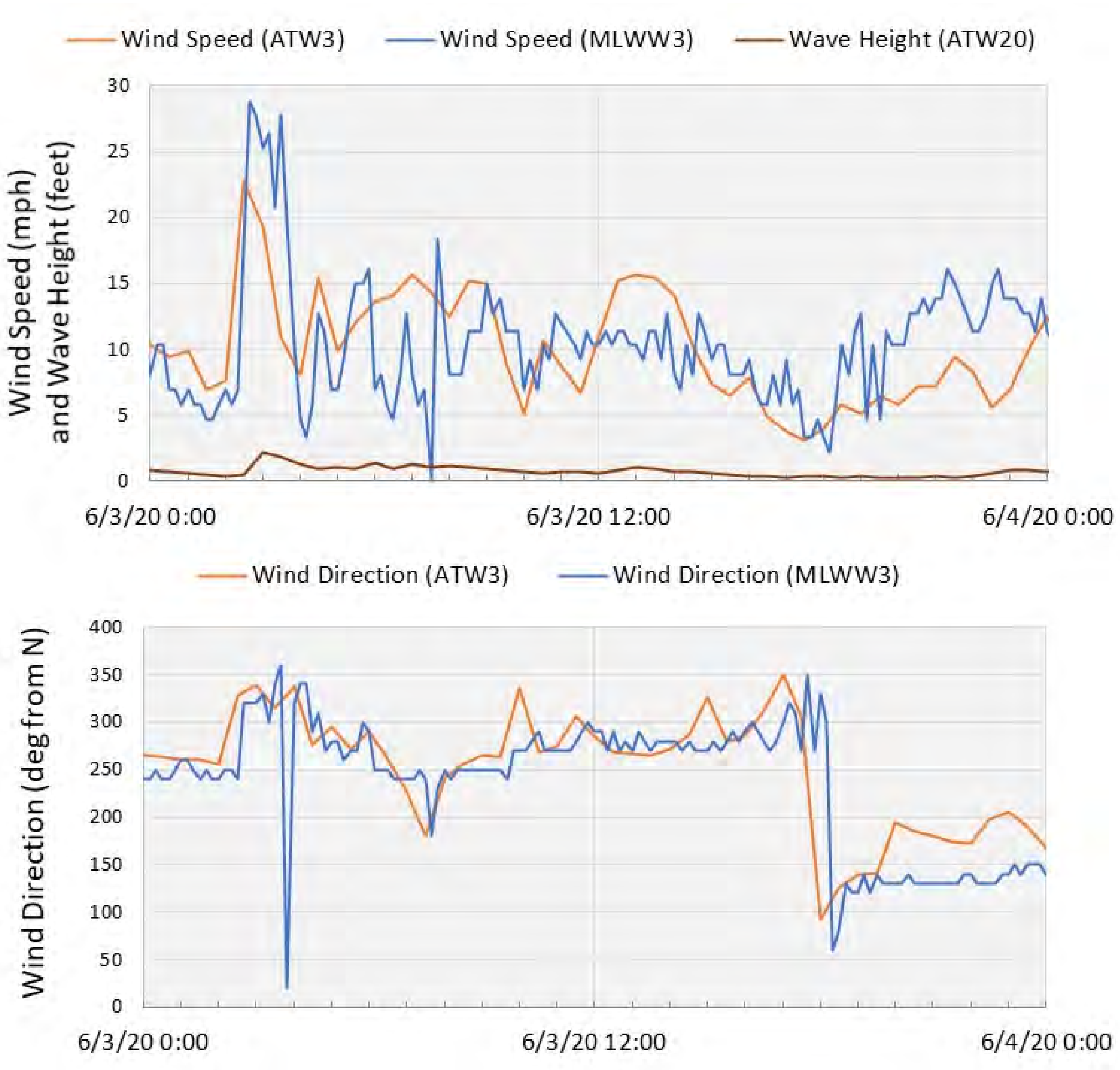


Figure 3: June 3, 2020 Wind and Wave Conditions at Two Stations near McKinley Beach

Winds during the July 18 event steadily increased during the day and peaked at about 20 miles per hour two hours before the drowning which occurred before 8:30 PM. Wind direction was steady for much of the day until winds peaked and were more regionally focused toward the northwest and north (directions 150 to 200 degrees). Significant wave heights built to about two feet by mid-day through evening as observed at the ATW3 buoy.

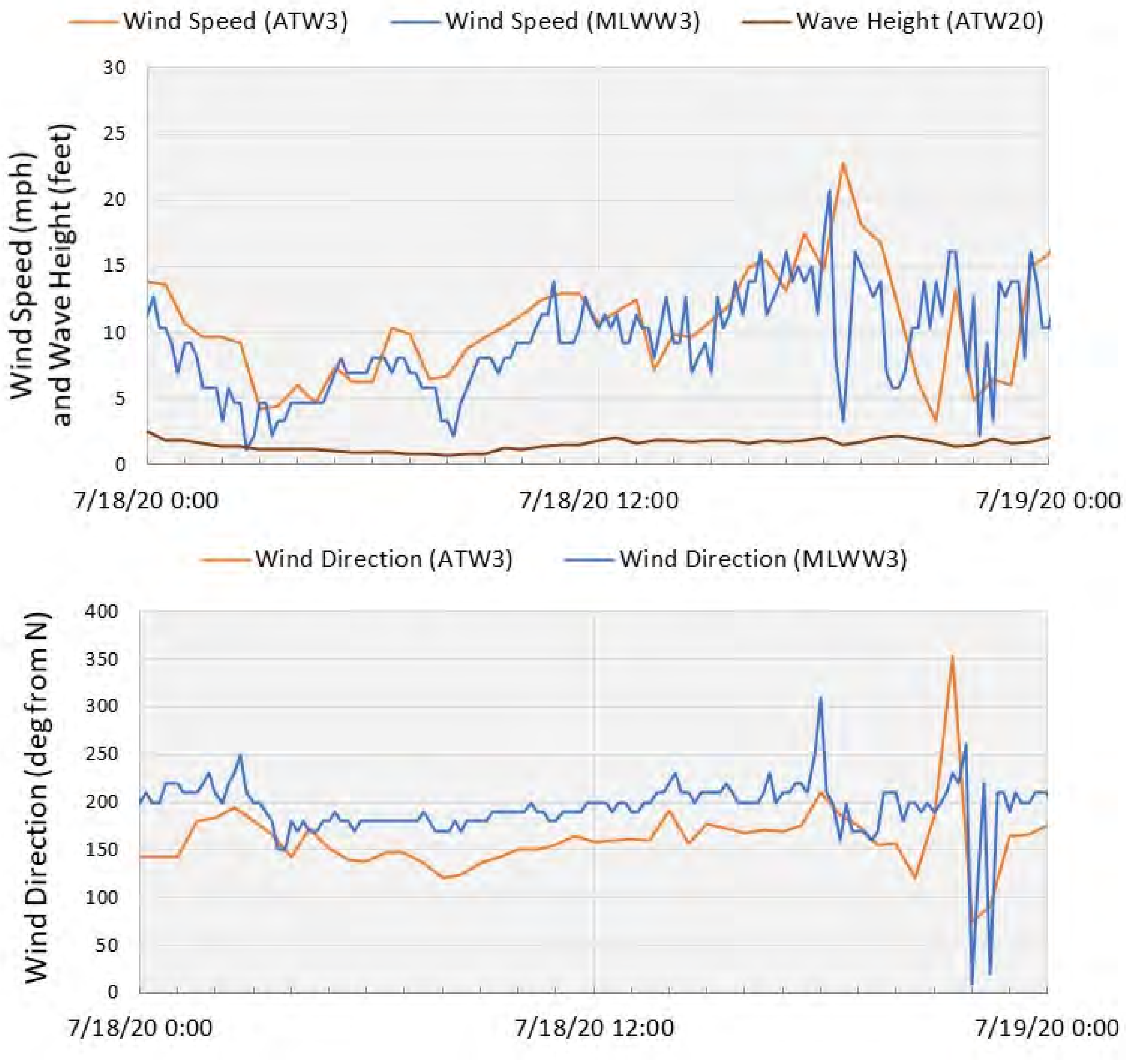


Figure 4: July 18, 2020 Wind Conditions and Similar Conditions from WIS Record

Winds during the August 8 event were steady and out of the South-Southeast, occasionally approaching about 15 miles per hour just before the drowning (6:30 PM). Significant wave heights had built to about two feet at that time at offshore buoy ATW20.

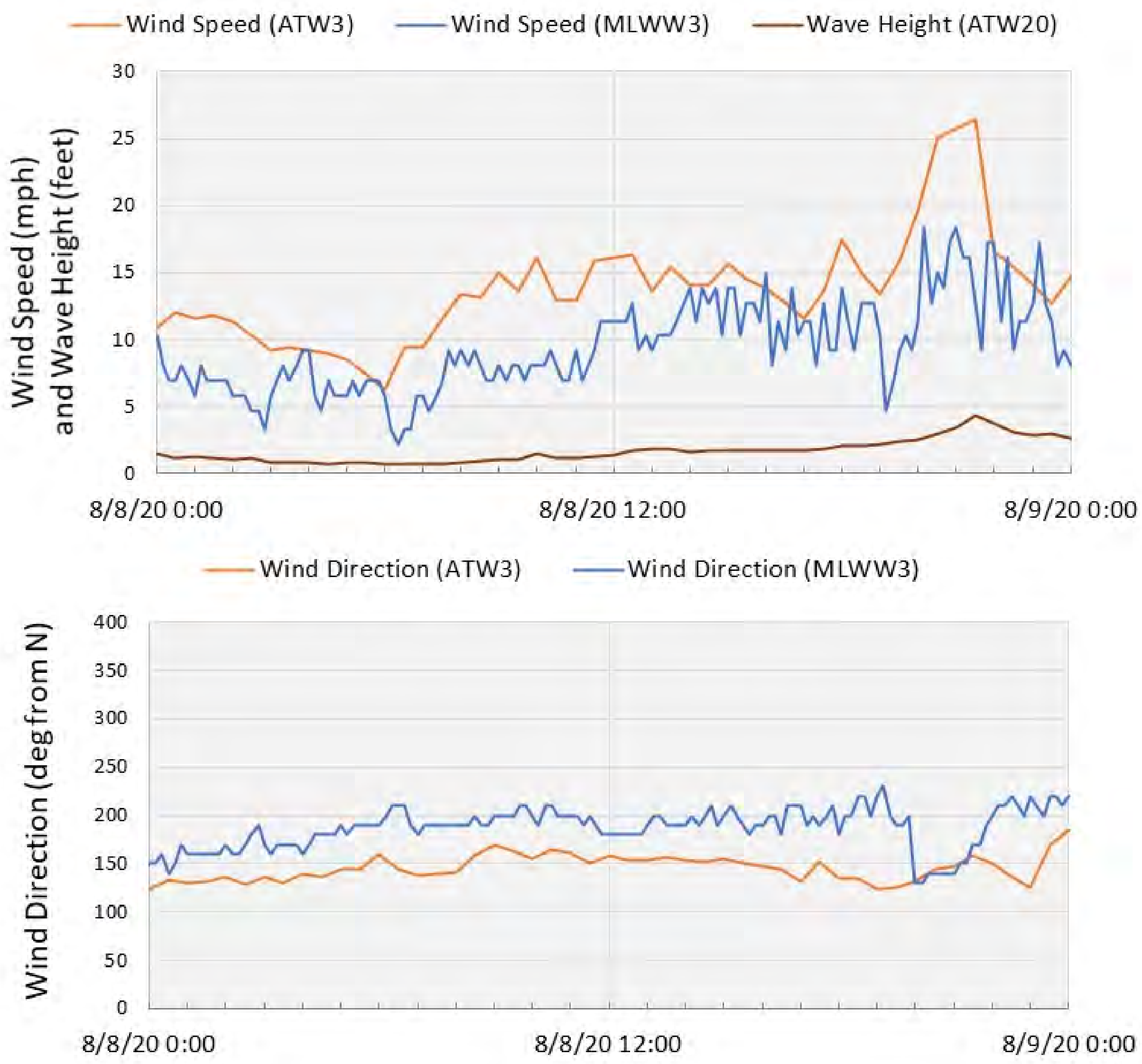


Figure 5: August 8, 2020 Wind Conditions and Similar Conditions from WIS Record

Model Inputs and Assumptions

Simulations were conducted for four wind directional conditions evenly spanning the directional envelope of long-fetch onshore winds. These conditions produce the strongest currents at McKinley Beach. Wind and wave directions were varied at a 30-degree interval from 190 degrees nautical (winds out of the south with a slight easterly component) counterclockwise to 100 degrees nautical (winds out of the east with a slight northerly component). Model simulations represent a time frame of 18 minutes which is sufficiently long for the model to transition from zero wave action to steady wave action. Water levels were simulated at 582.5 feet IGLD85 which was approximately the water level condition during each drowning event. Significant wave heights were held steady at two feet which was approximately the condition during each drowning event. Although actual wind, wave, and current conditions are likely more complex than what is represented in these simulations, the simplifications facilitate interpretation of the model results to better understand the types of conditions that can lead to strong currents.

Modeled Wave Heights and Current Speeds

Results from the four directional wave simulations are illustrated below. Two of these conditions—the 130- and 160-degree direction conditions—are good proxies for the three drowning events, as noted in the figure titles. Modeled current speeds represent average conditions over a six-minute period at the end of the 18-minute simulation. Because these are time-averaged conditions they do not look like rip currents, which are narrow, transient bands of fast-moving water directed offshore. Instantaneous results were reviewed, and these do show transient rip currents. Time-averaged results are included in this memorandum instead of instantaneous results because the time-averaged results allow for a more direct comparison between different simulation conditions.

There are two key caveats to these results which are explained further in the last section of this memorandum: 1) the model's extent was set to the extent of the detailed and current bathymetric data. For future use of the model, it should be evaluated whether the model extent is sufficiently large for providing a robust estimate of wave and current conditions at McKinley Beach for all wave directional conditions of interest and 2) a comparison of modeled currents with observed current data would strengthen the confidence in the results. Modeled current speeds were found to change depending on the numerical solution scheme used to produce the wave predictions and the best choice of these parameters is not obvious based on theory alone.

Despite these caveats, these results indicate the potential for strong currents to form within and just outside of the swim area at McKinley Beach. Current speeds exceeding two feet per second were predicted within the swim area for onshore winds directed toward the beach. Winds that are directed nearly perpendicular to shore produce especially hazardous currents: not only are current speeds elevated in the swim area, but they are also elevated in the open water area just outside the swim area. Similar wave conditions have produced rip currents at beaches in the Miami area (REF).

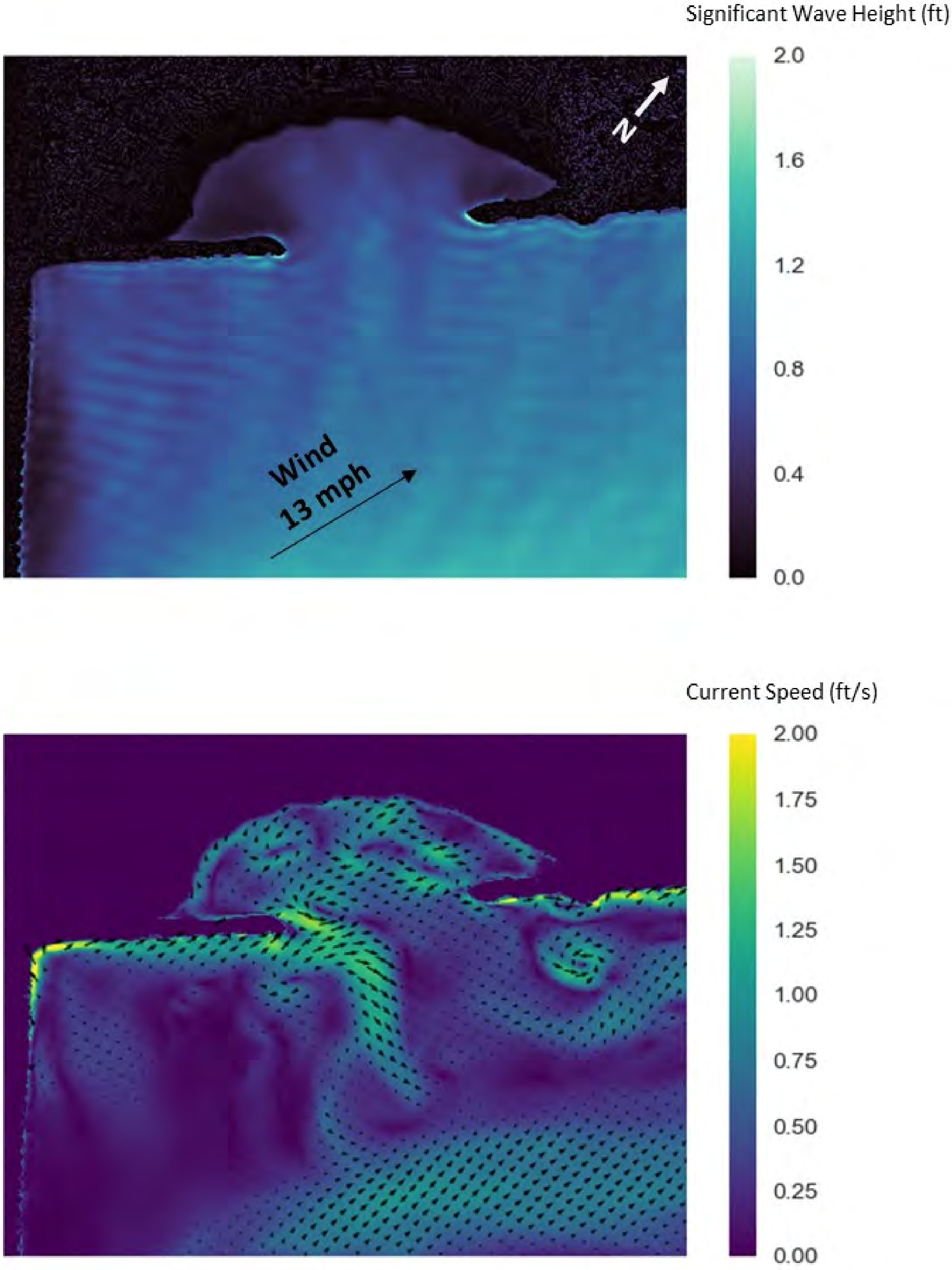


Figure 6: Simulated Wave Heights and Current Speeds, 2-foot Waves, 190-deg direction (out of south) as indicated by the black arrow. Proxy for the June 3 event.

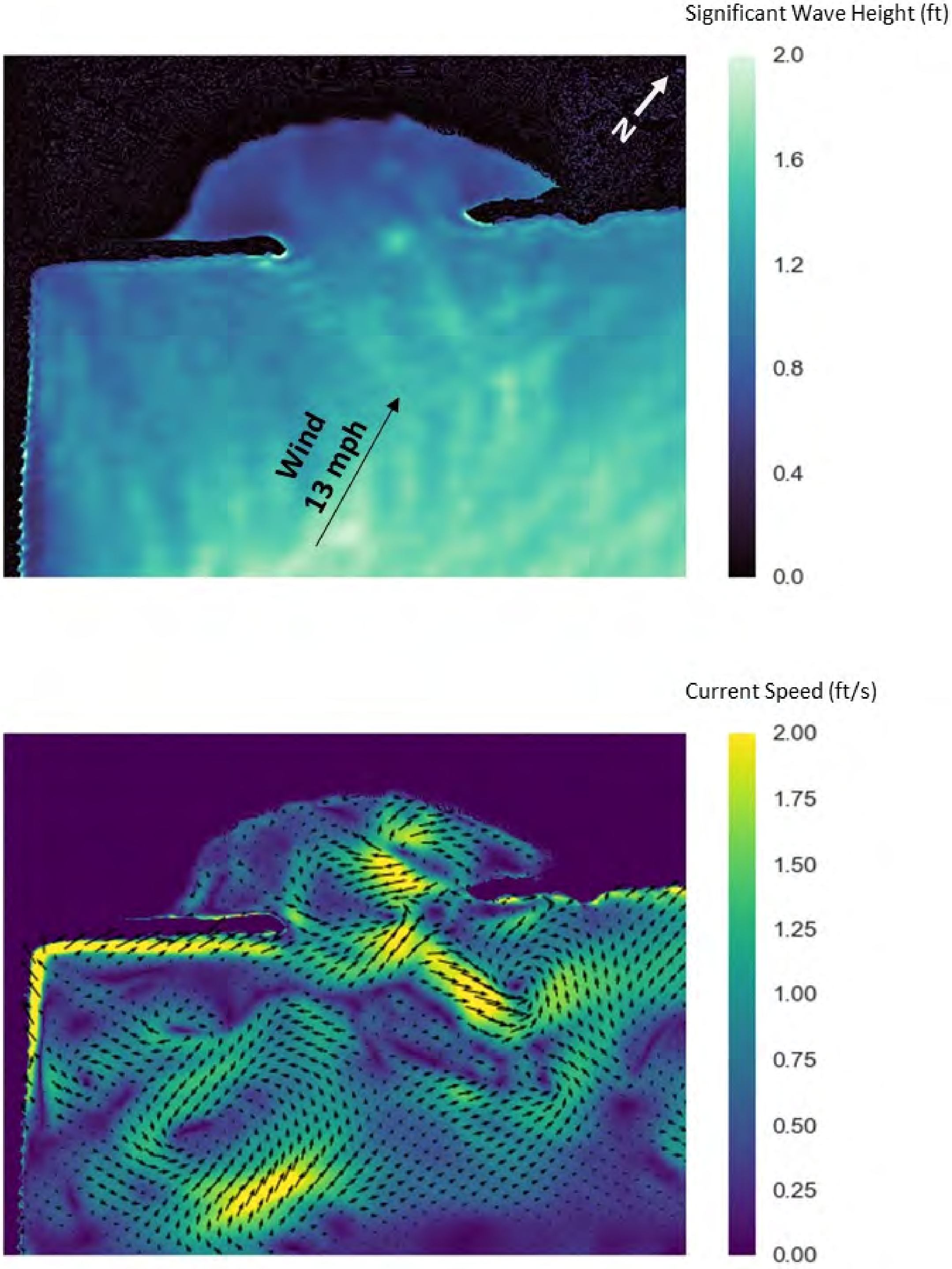


Figure 7: Simulated Wave Heights and Current Speeds, 2-foot Waves, 160-deg direction (out of south-southeast) as indicated by the black arrow. Proxy for the July 18 and August 18 events.

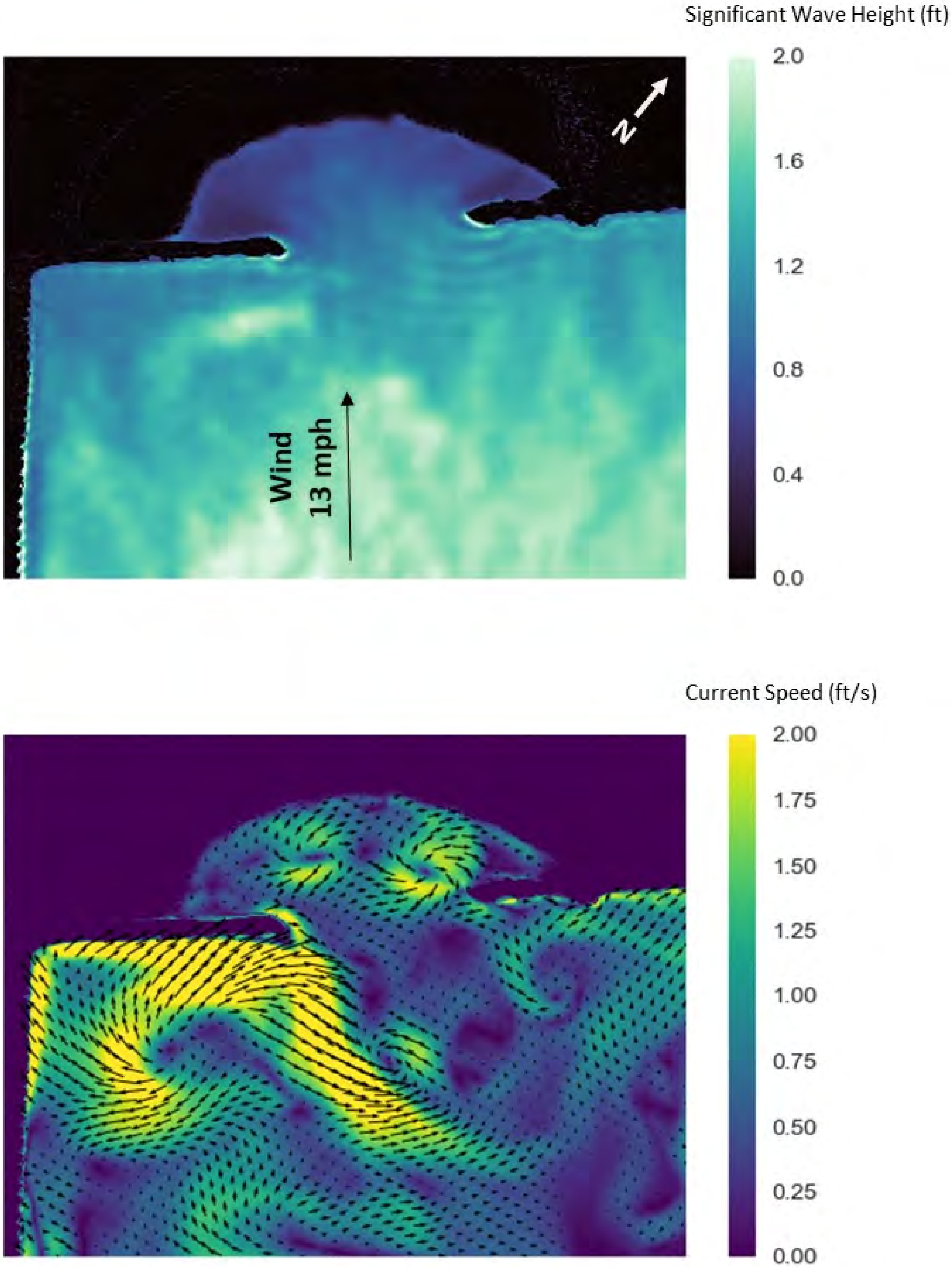


Figure 8: Simulated Wave Heights and Current Speeds, 2-foot Waves, 130-deg direction (out of southeast) as indicated by the black arrow.

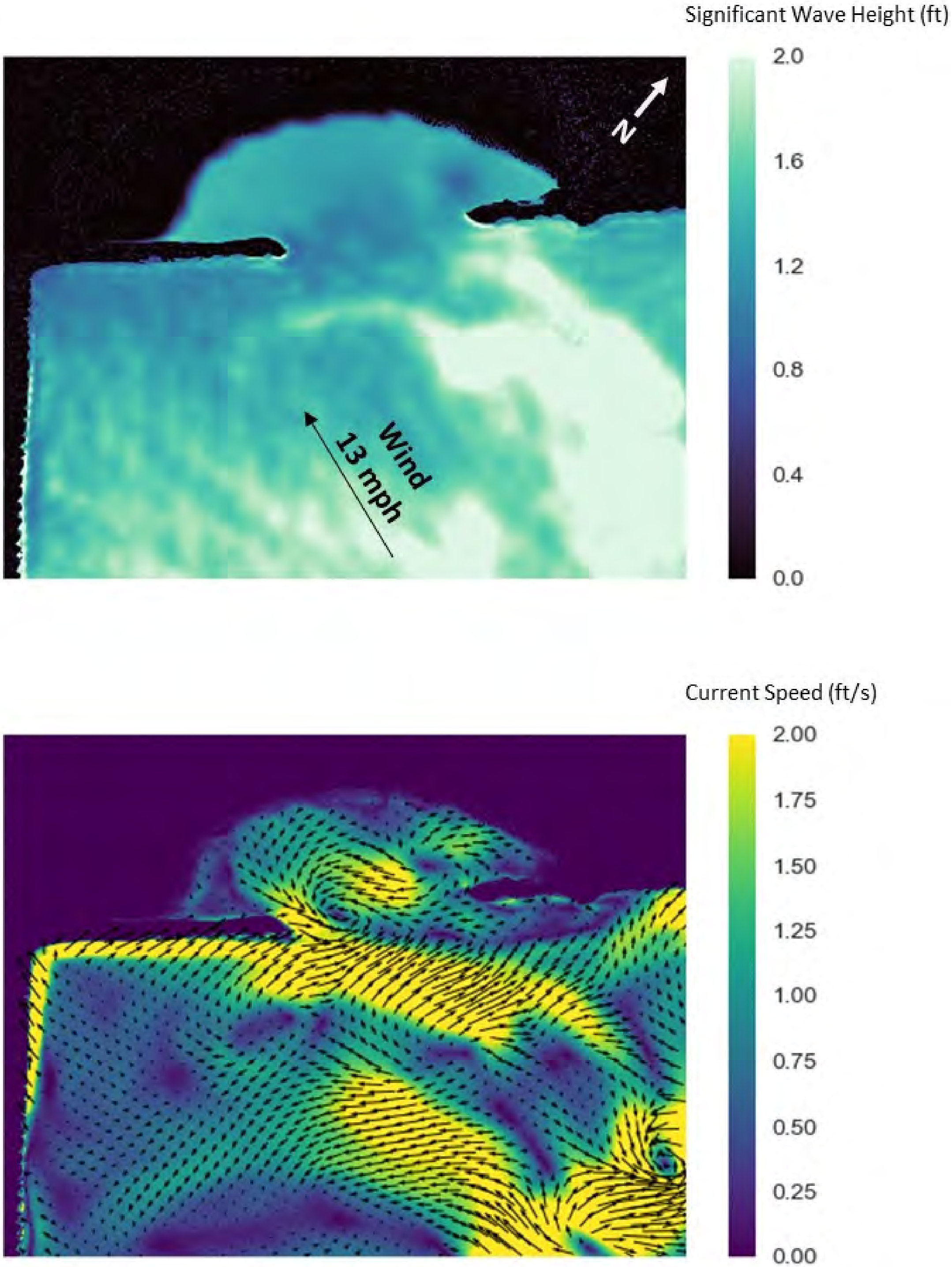


Figure 9: Simulated Wave Heights and Current Speeds, 2-foot Waves, 100-deg direction (out of east-southeast) as indicated by the black arrow

Some additional test simulations were conducted to better understand the factors contributing to rip currents at McKinley Beach. These tests help address the following questions:

1. To what extent does the seawall to the west of McKinley Beach reflect waves and contribute to rip currents at McKinley Beach?
2. Are currents at McKinley Beach less hazardous during lower water conditions?

A test simulation indicates that wave reflection off the seawall west of McKinley Beach is a moderately significant factor contributing to rip currents in the swim area. In the existing conditions wave model, waves reflect off the seawall which begins about 300 feet from shore and extends farther lakeward (closer to shore is a rock revetment which is much less reflective). A test simulation was conducted which absorbs wave energy at the seawall rather than reflecting wave energy. This simulation is useful for evaluating the degree to which wave reflection off the seawall effects currents at McKinley Beach. The simulation showed some reduction in current speeds in the McKinley Beach swim area relative to the more realistic reflective condition, but the effect was only moderately significant. Predicted current speeds with and without wave reflection off the west seawall are illustrated in Figure 10.

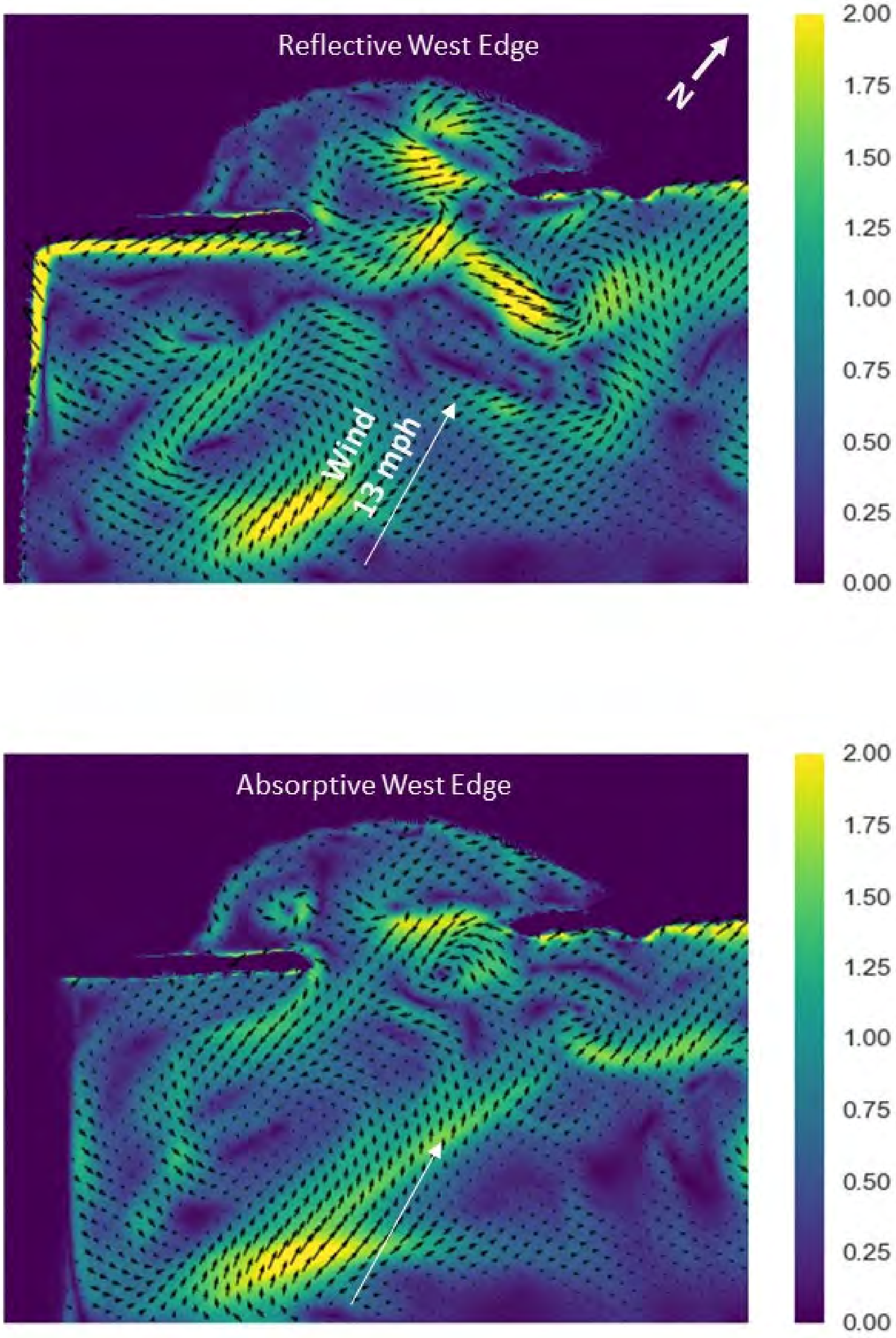


Figure 10: Comparison of Current Speeds (feet/second) with (top) and without (bottom) wave reflection at the western edge of the model area

Another test simulation indicates that recent high water contributed significantly to the presence of rip currents at McKinley Beach. For this simulation, modeled water levels were reduced from 582.5 feet (high water level conditions during summer 2020) 579.2 feet (a moderate lake level). Predicted swim area currents for the moderate lake level condition are appreciably lower and are illustrated in Figure 11 below. During lower lake level conditions, wave energy dissipates farther offshore than during high water conditions. This helps explain the large difference in current speeds within the swim area for the two simulated lake level conditions.

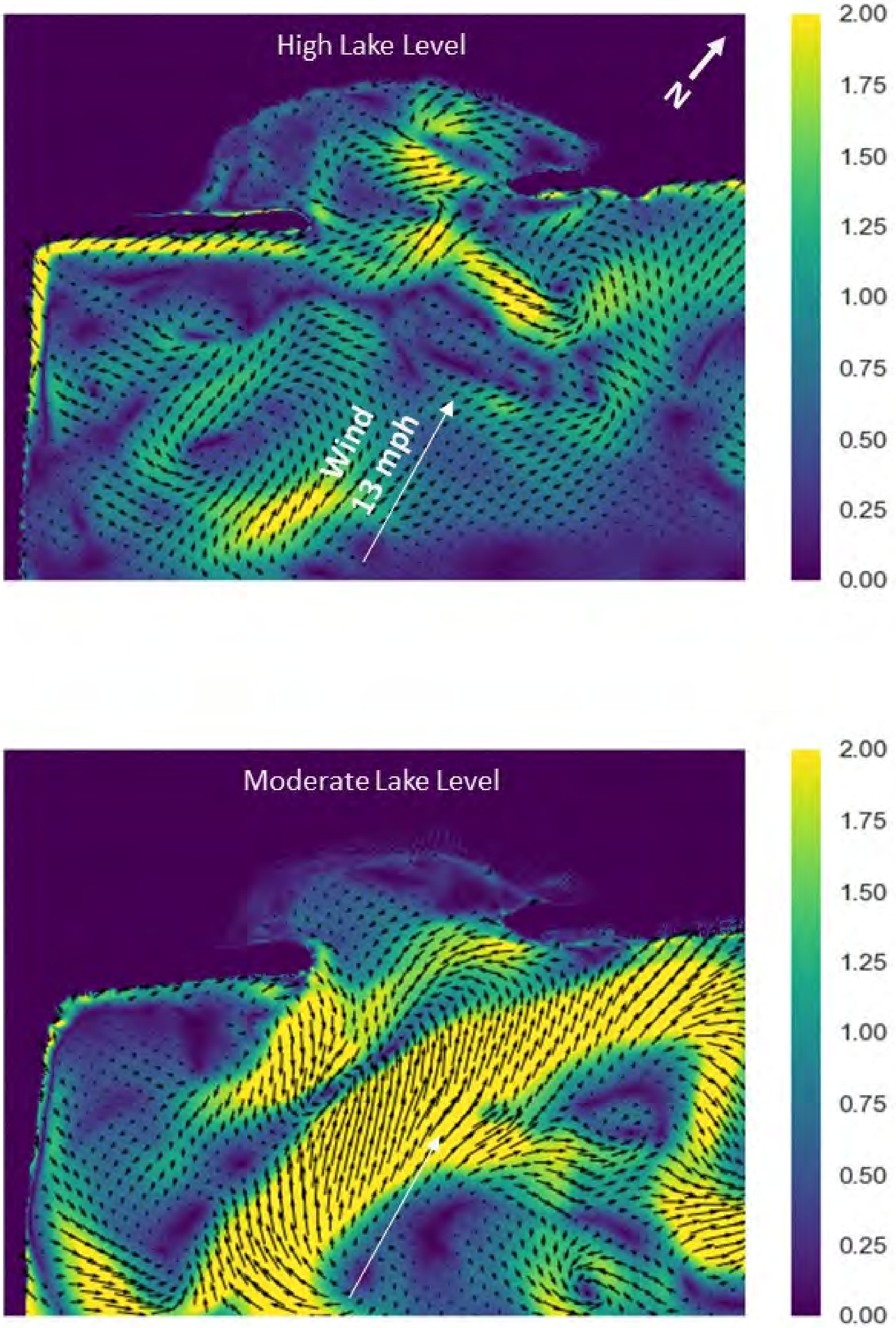


Figure 11: Comparison of Current Speeds (feet/second) during summer 2020 high water conditions (top) and moderate lake level conditions (bottom)

It is also notable that the lake bottom elevations change with time and are another factor contributing to varying rip currents at McKinley Beach. Future design evaluations should consider the effects of both changing lake levels and changing lake bottom elevations. Figure 12 below illustrates the change in lake bottom elevation from a pre-high water survey to a post-high water survey (i.e., late 2021). The lake bottom apparently rose in elevation due to coastal erosion and sediment movement from the northeast toward McKinley Beach.

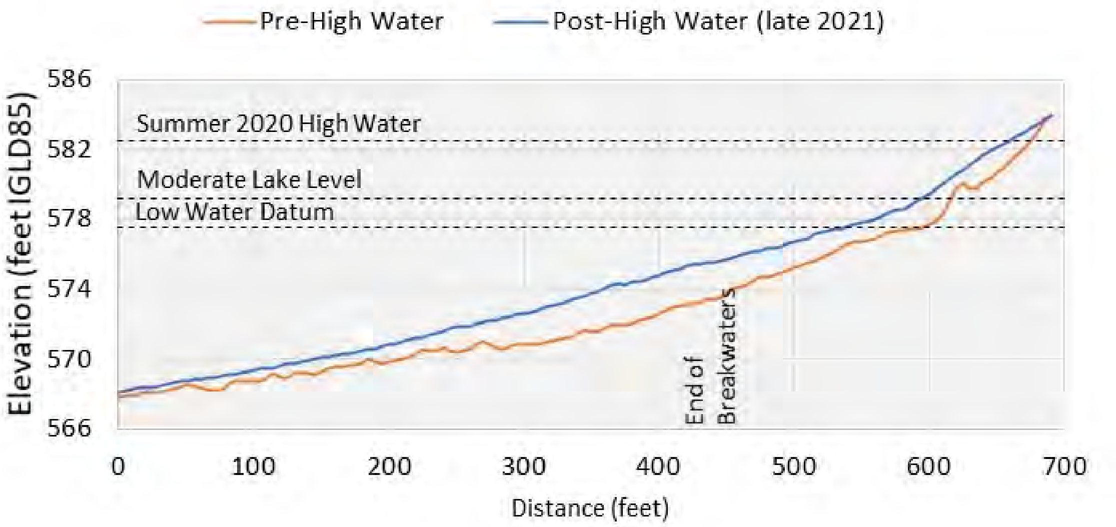


Figure 12: Change in Lake Bottom Profile from Pre- to Post-High Water Conditions

Conceptual Designs Analysis

Four conceptual designs were simulated in the model and compared with existing condition results. These were simulated for each of the four directional conditions described above. Only Concept 2 showed significant reductions in rip current potential, although under some simulated wave directional conditions, this concept also produced rip currents.

The five concepts are summarized as follows:

1. Concept 1: simplification of swim area shape by removal of northern breakwater and construction of marsh area to the north of the northern breakwater (Figure 10).
2. Concept 2: construction of submerged reef offshore of breakwaters to dampen wave energy offshore. This concept also includes extensions of the existing breakwaters.
3. Concept 3 (not simulated): conversion of beach and swim area to naturalized marsh area by connecting the two breakwaters and significantly reducing wave action in the proposed marsh area. This concept was not simulated because the site would no longer be used for swimming under this concept. Instead of simulating Concept 3, an additional concept with potential for enabling safer swimming at McKinley Beach (#5) was simulated.
4. Concept 4: replenishment of the beach and swim area to grades as designed in the 1989 plans for McKinley Beach. This concept would require 1 to 2 feet of sand replenishment on average.

5. Concept 5: construction of a curved breakwater that would protect the beach from waves approaching from the southeast. This concept would also tend to capture sands as they naturally move from northeast to the southwest.

Digital elevation models developed for these concepts are included in Figure 10.

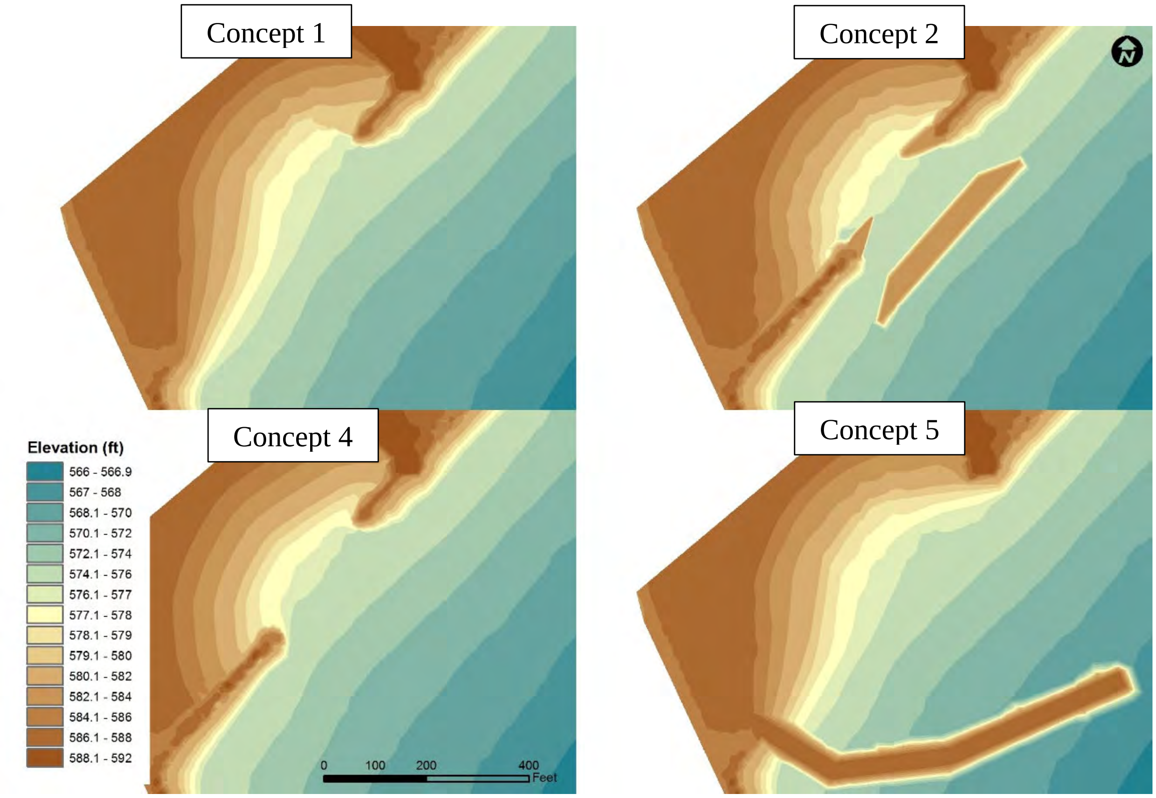


Figure 10: Elevation Conditions Representing Concepts 1, 2, 4, and 5

Following this section is one describing uncertainty and recommendations for future data collection and modeling analysis to evaluate and improve the accuracy of model results and build confidence in the effectiveness of potential mitigation measures.

Average currents for the four simulated concepts and four simulated directional conditions are included in Figures 11 through 14.

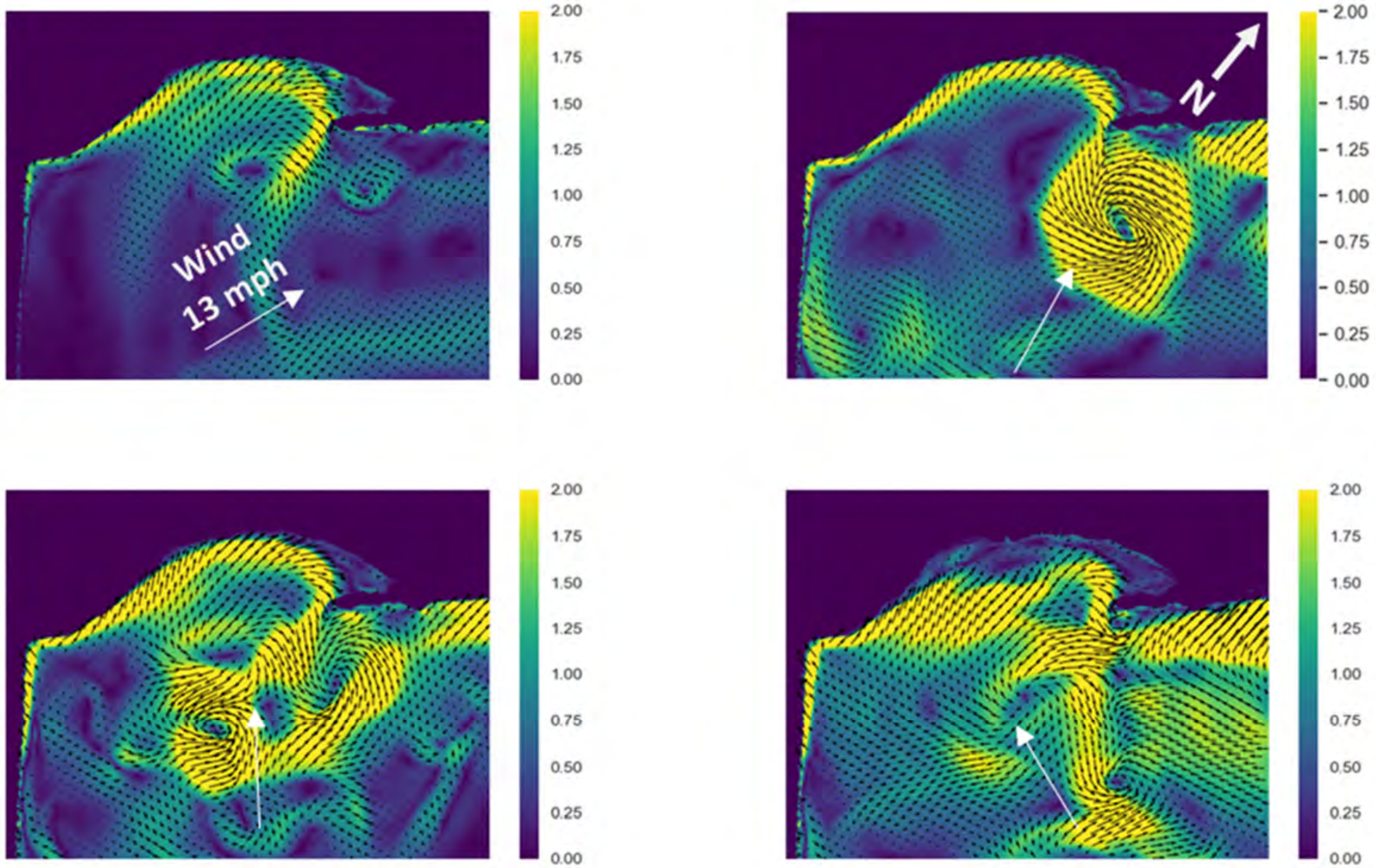


Figure 11: Concept 1, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

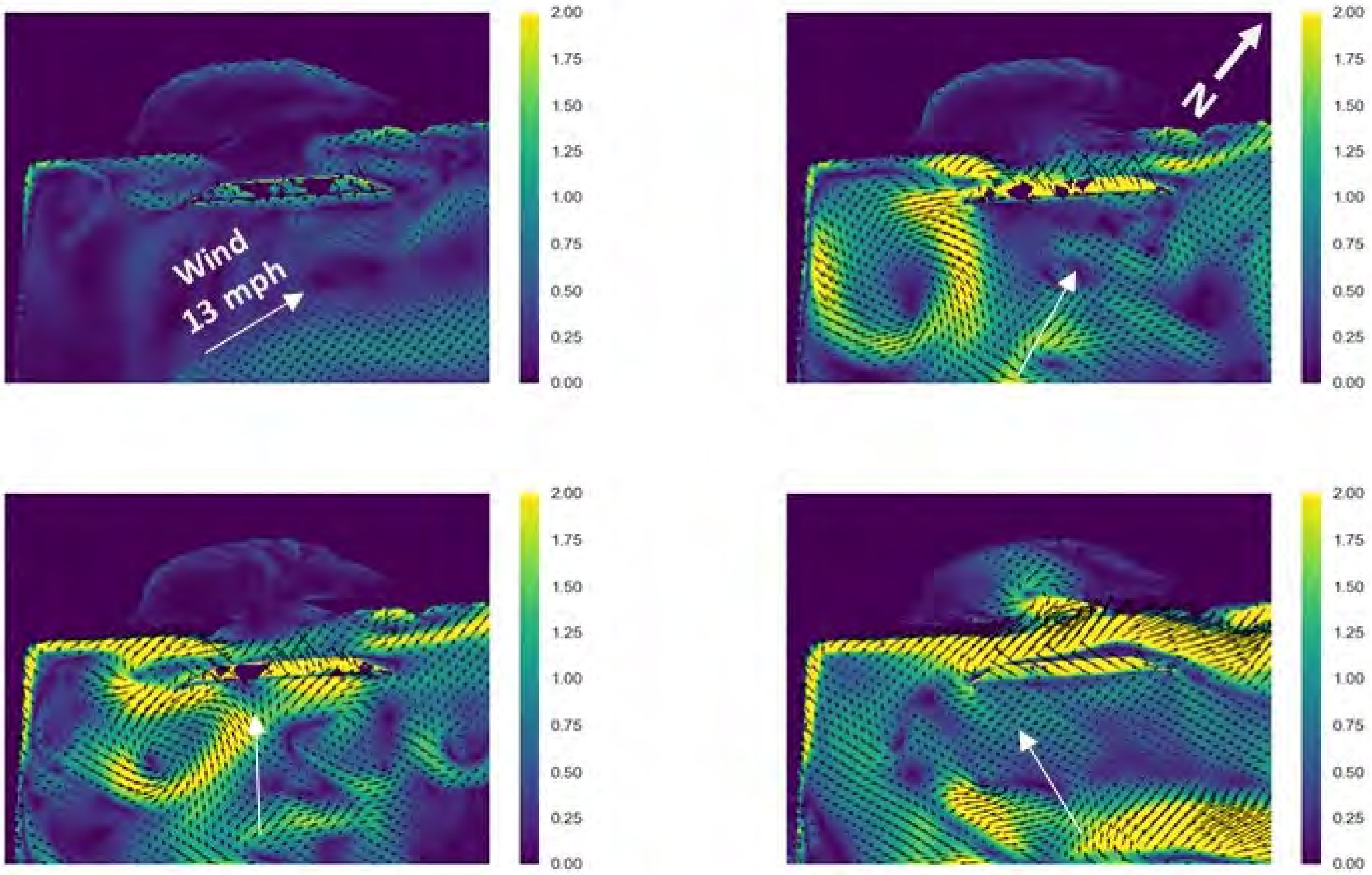


Figure 12: Concept 2, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

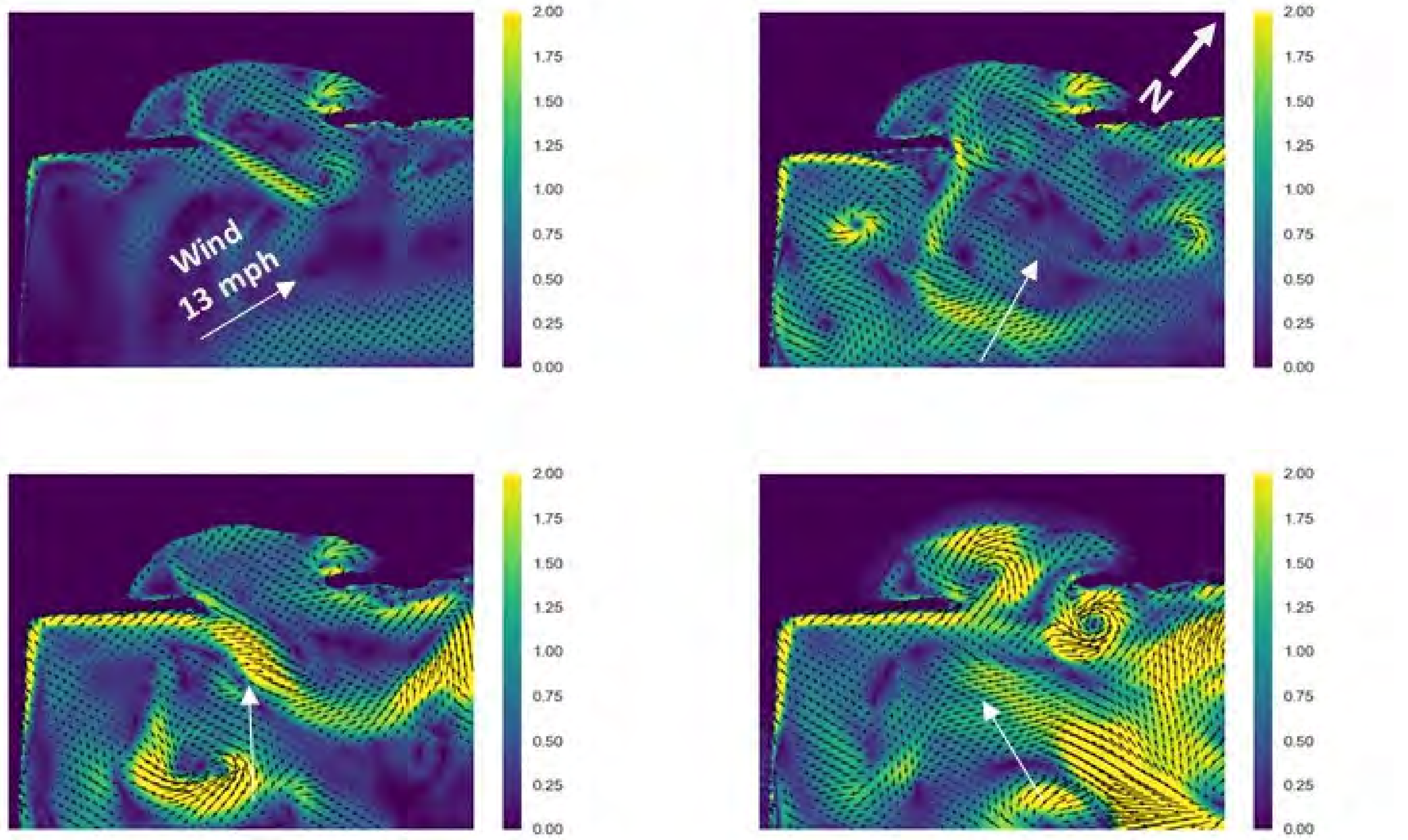


Figure 13: Concept 4, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

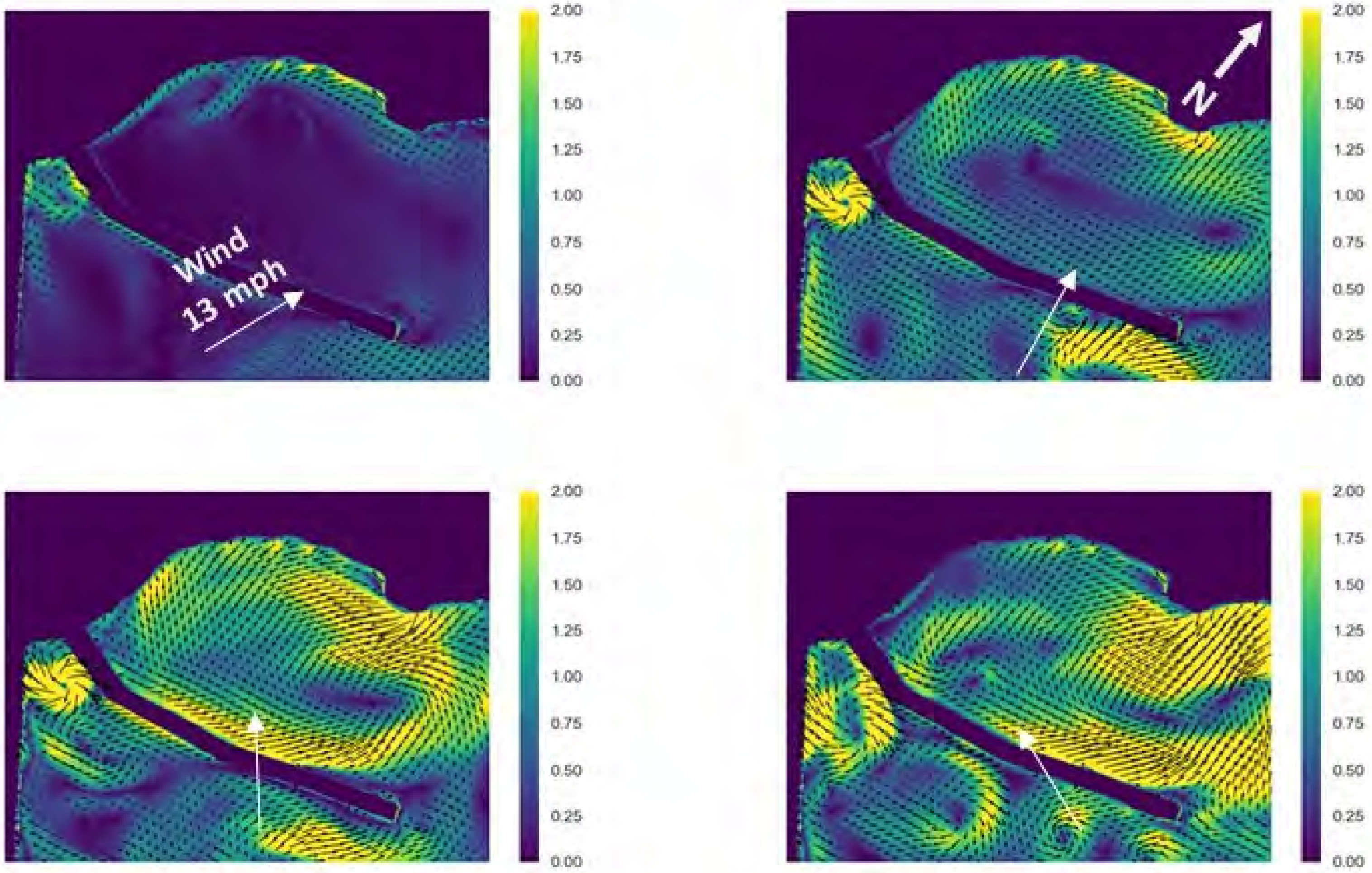


Figure 14: Concept 5, Simulated Current Speeds (feet/second), 2-foot Waves, Four Directional Conditions

Caveats and Recommendations for Future Analysis

There are two key caveats to these results: 1) the model's extent was set to the extent of the detailed and current bathymetric data which may limit the accuracy of results for some wind directional conditions, and 2) a comparison of modeled currents with observed current data would strengthen the confidence in the results. We recommend the following future work to address these two items: 1) For detailed design, confirm the necessary spatial extent by testing two additional, larger model extents and evaluating whether a larger extent is necessary and 2) monitor currents during summertime using a horizontal ADCP (acoustic doppler current profiler) mounted near the south breakwater. This second recommendation is considered especially critical because of the surprising and varied nature of apparent rip currents at the beach.

Related to caveat 1: the best practice for establishing wind-wave model extents is to test multiple, successively larger extents and evaluate results. Typically, current velocities predicted by wave models are less reliable right at the boundary, and more reliable far from the boundary. By doing these tests, the modeler confirms that the area of interest is sufficiently far from the boundary so that results are not affected by boundary location. So as these tests are conducted, if the model result in the area of interest shows little change as the model extent is increased, it indicates that the extent is large enough. One such test was conducted during this short-duration project, and results did change appreciably between the smaller-extent test and the larger-extent test, indicating the need for an additional test with a larger extent.

Related to caveat 2: the best practice for relying on model simulations to inform detailed design on projects with significant construction costs is to confirm the accuracy of model results by comparing these results with data. This comparison allows the modeler to evaluate whether model parameters or other settings should be adjusted to better represent site conditions. For this application, the following model parameters and settings could be adjusted based on data to increase agreement between the model and data and lend greater confidence to the model results for use in design:

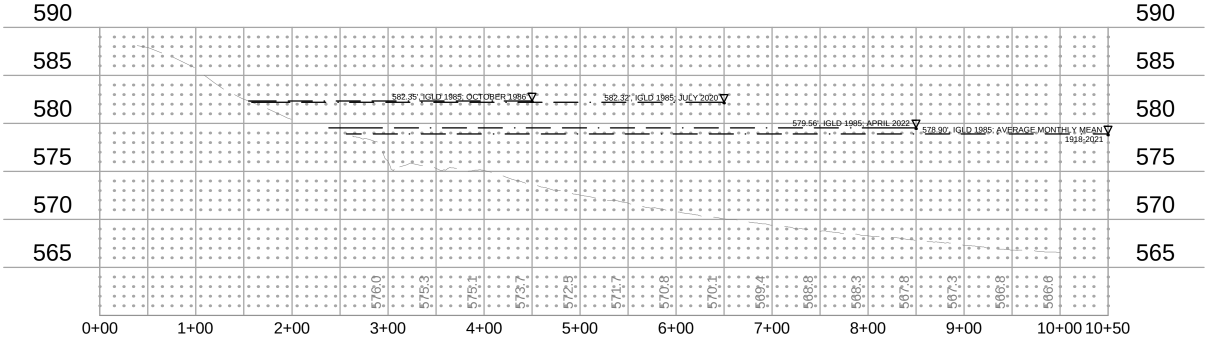
- Material roughness (lake bottom, breakwaters, and revetments)
- Horizontal momentum viscosity (controls the rate of turbulent mixing)
- Model extent
- Model numerical scheme used to approximate changes in wave conditions with depth

For each of these settings, default parameters and guidance from the user manual were relied on to develop inputs for the model. Comparison with site data would help refine or confirm these settings and improve confidence that mitigation measures will be effective.

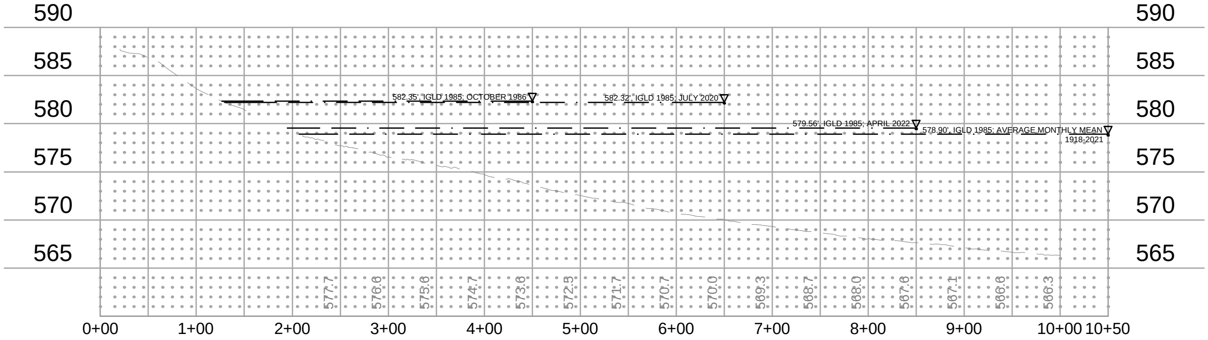
Appendix F

Conceptual Solutions

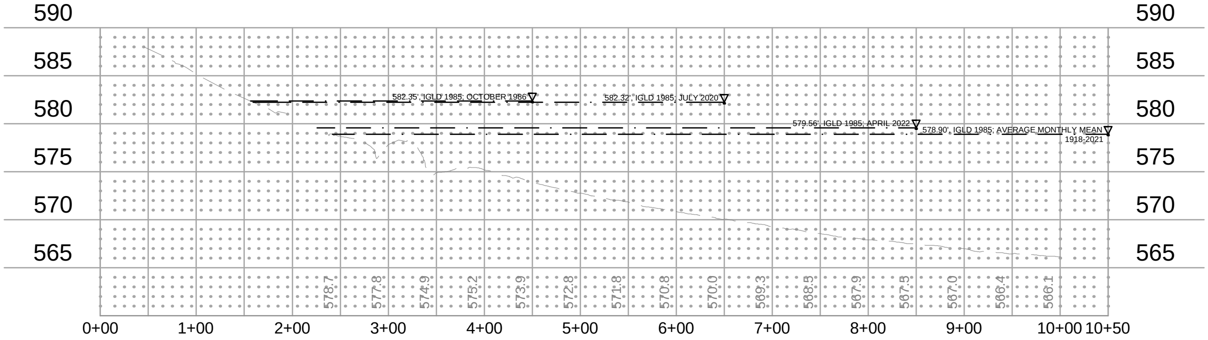
A-A



B-B



C-C



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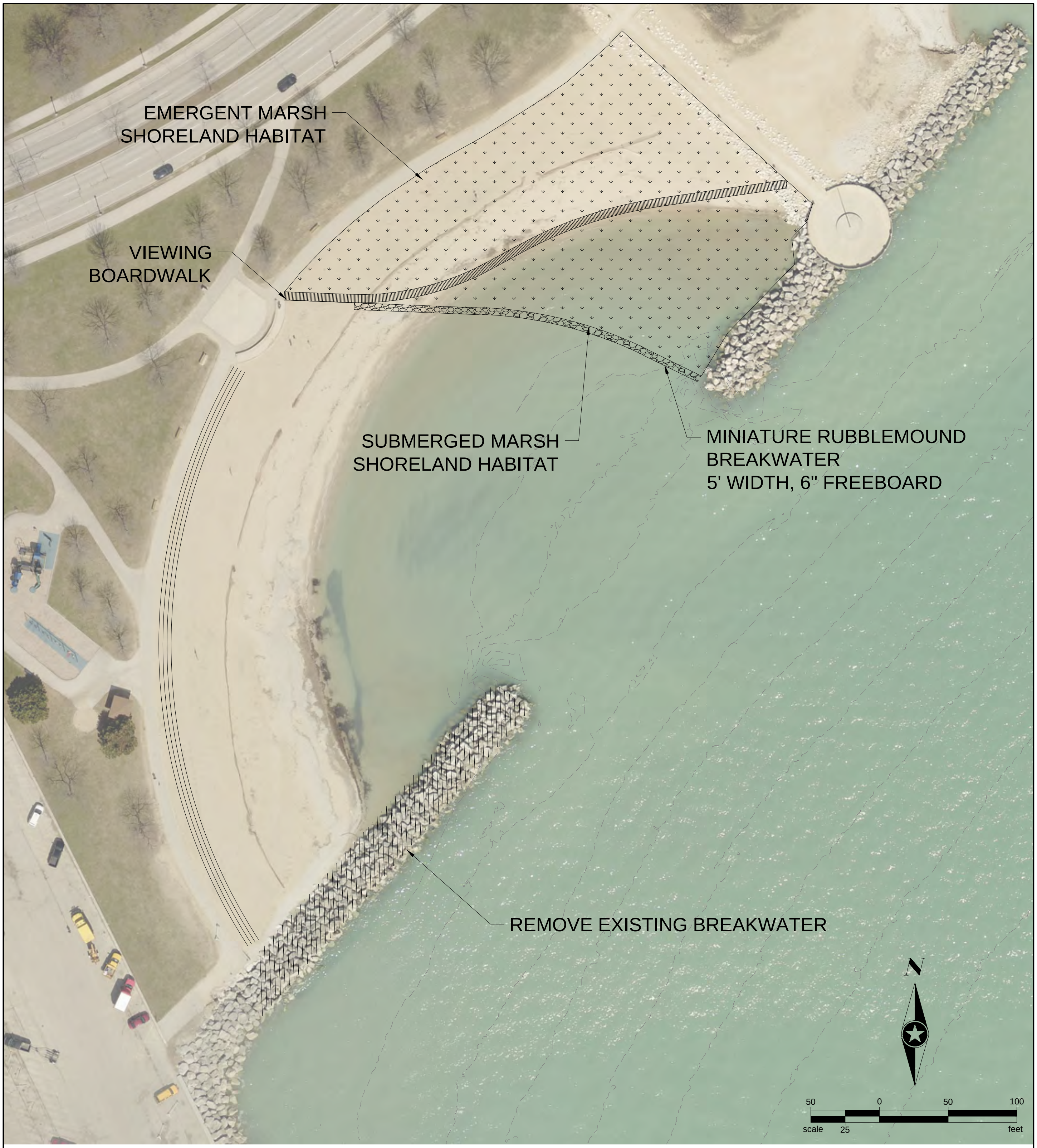
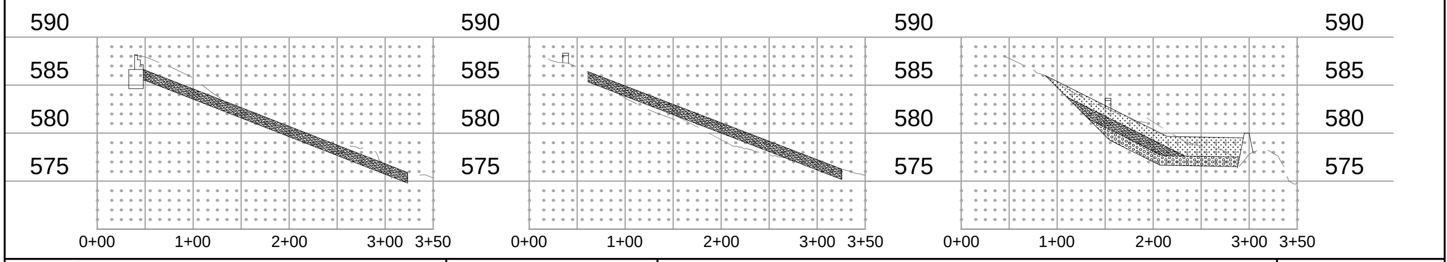
Existing Conditions
McKinley Beach - Lake Michigan
Milwaukee County, Wisconsin

Exhibit
1





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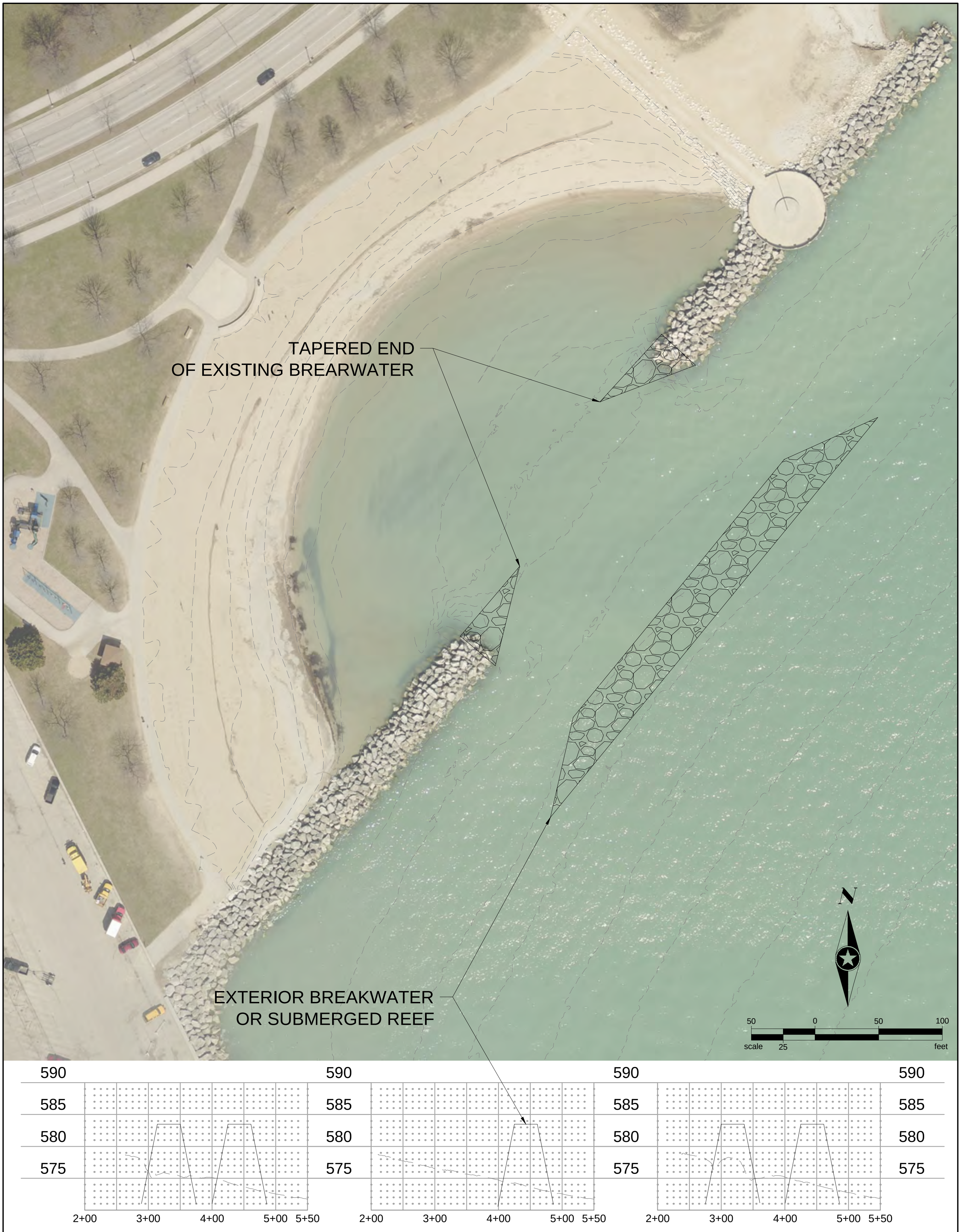
Conceptual Solution #1
McKinley Beach Lake Michigan
Milwaukee County, Wisconsin

EXHIBIT
2



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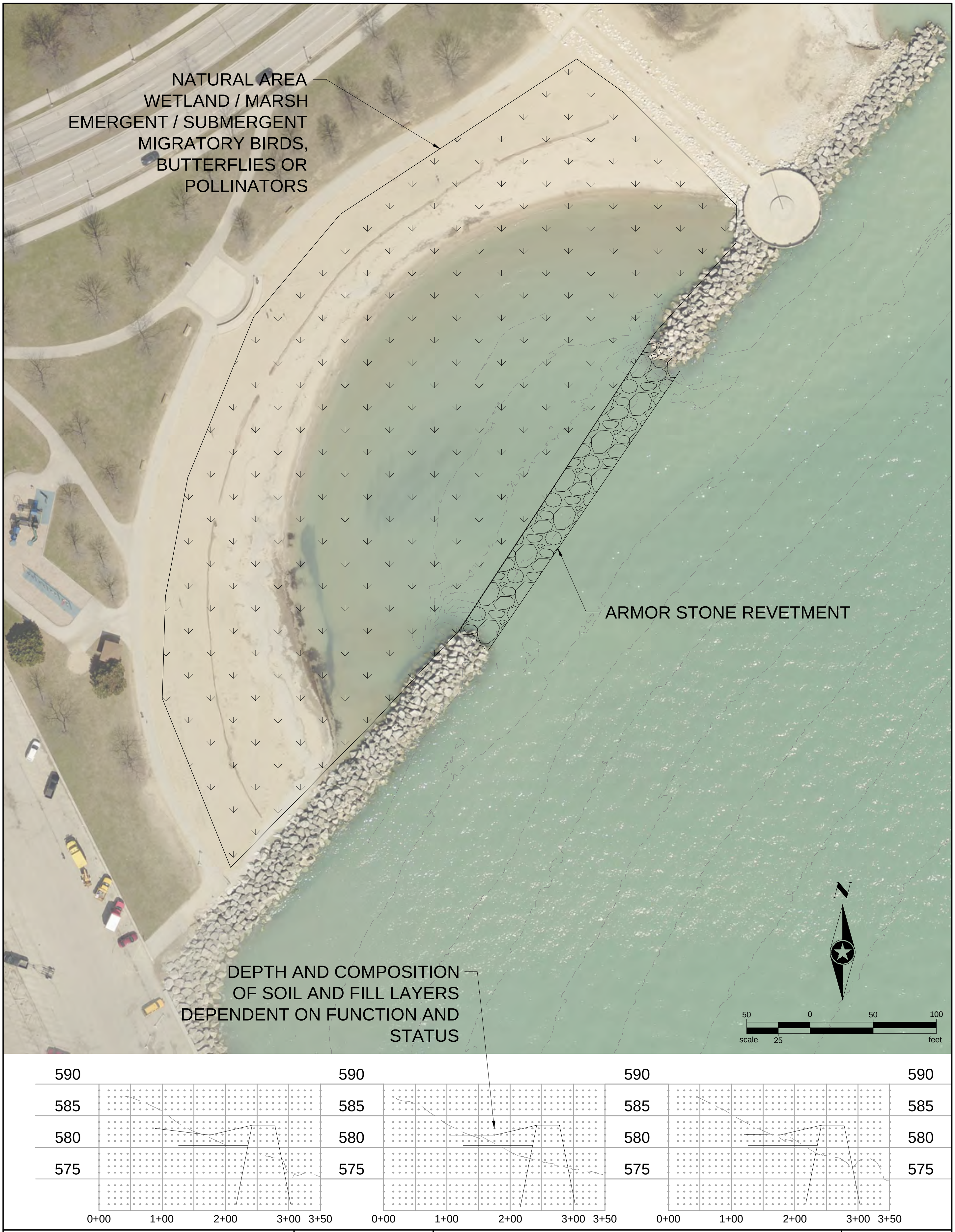
Conceptual Solution #2
McKinley Beach Lake Michigan
Milwaukee County, Wisconsin

EXHIBIT
3



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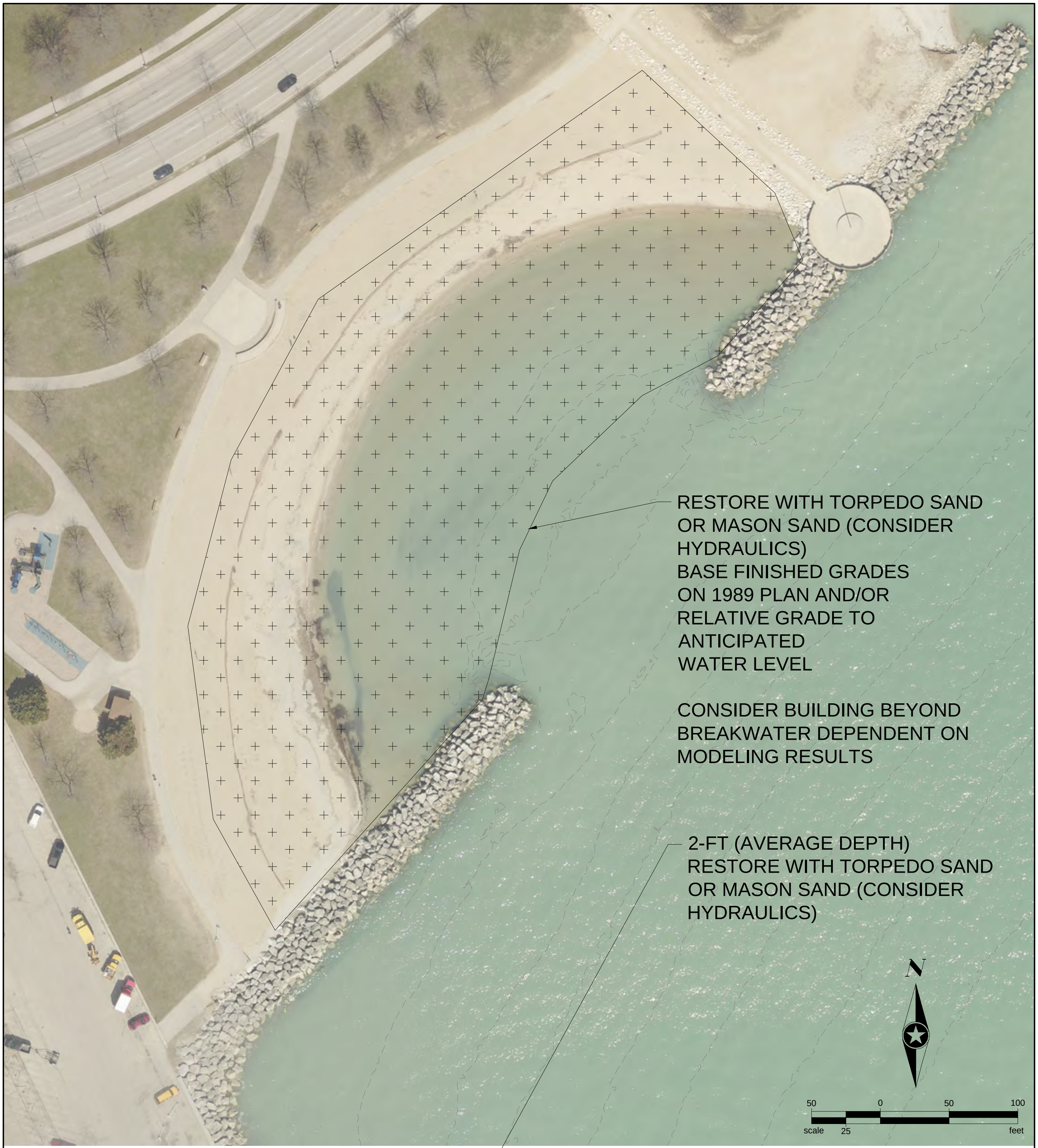
Conceptual Solution #3
McKinley Beach Lake Michigan
Milwaukee County, Wisconsin

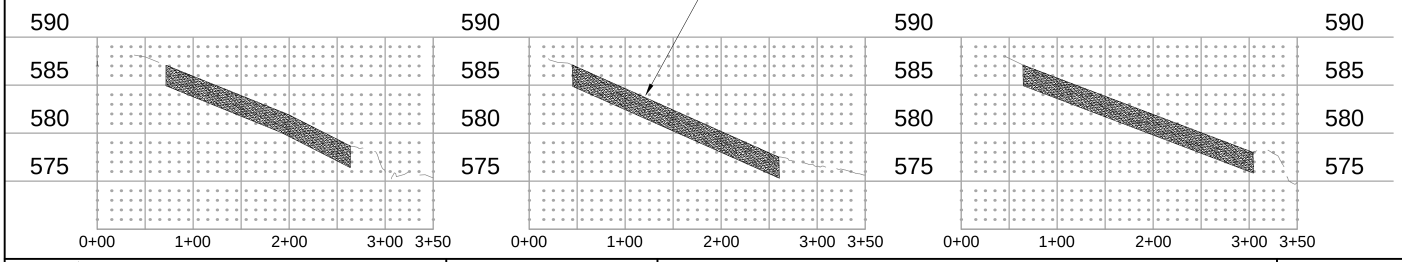
EXHIBIT
4



RESTORE WITH TORPEDO SAND
OR MASON SAND (CONSIDER
HYDRAULICS)
BASE FINISHED GRADES
ON 1989 PLAN AND/OR
RELATIVE GRADE TO
ANTICIPATED
WATER LEVEL

CONSIDER BUILDING BEYOND
BREAKWATER DEPENDENT ON
MODELING RESULTS

2-FT (AVERAGE DEPTH)
RESTORE WITH TORPEDO SAND
OR MASON SAND (CONSIDER
HYDRAULICS)



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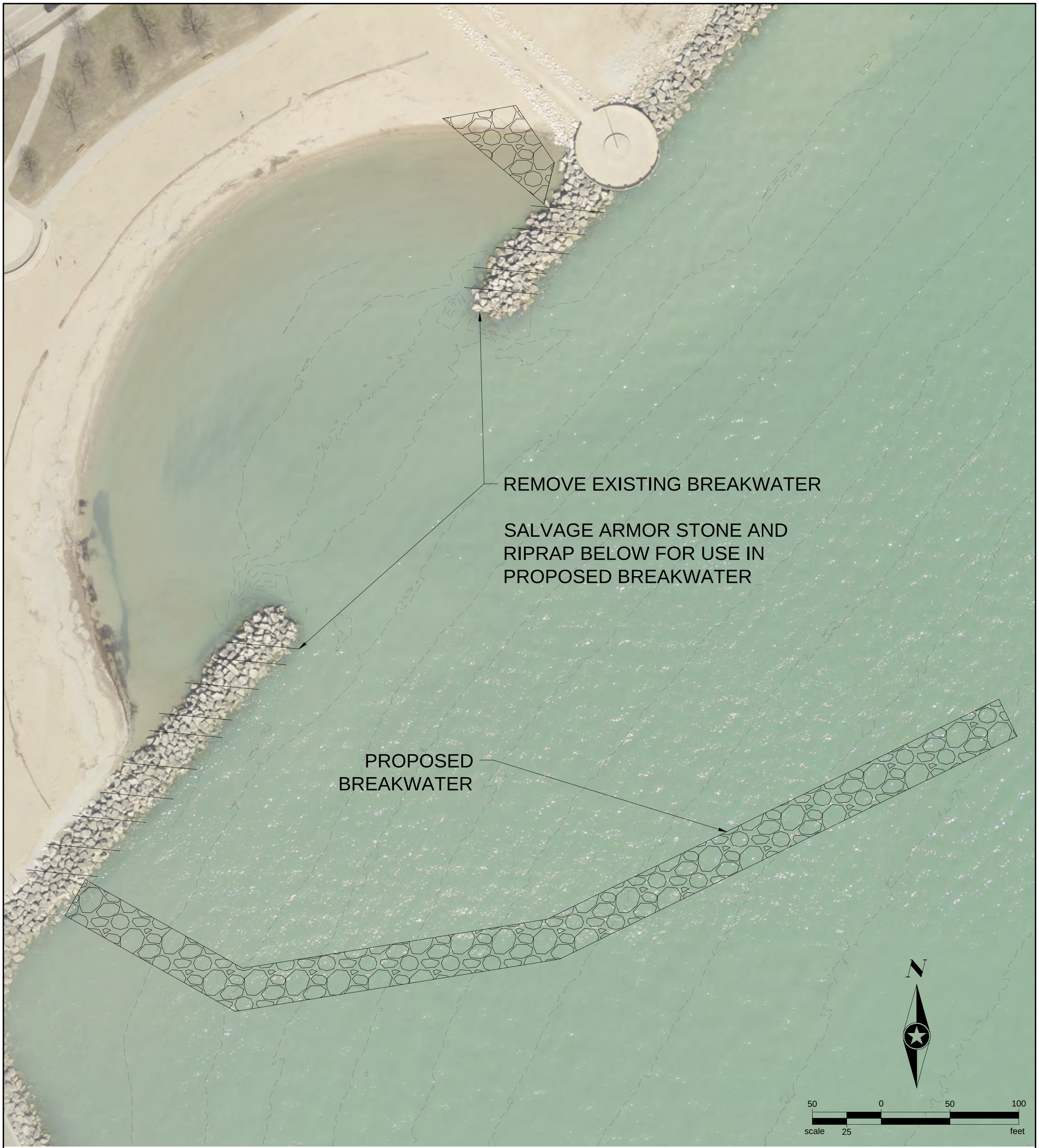
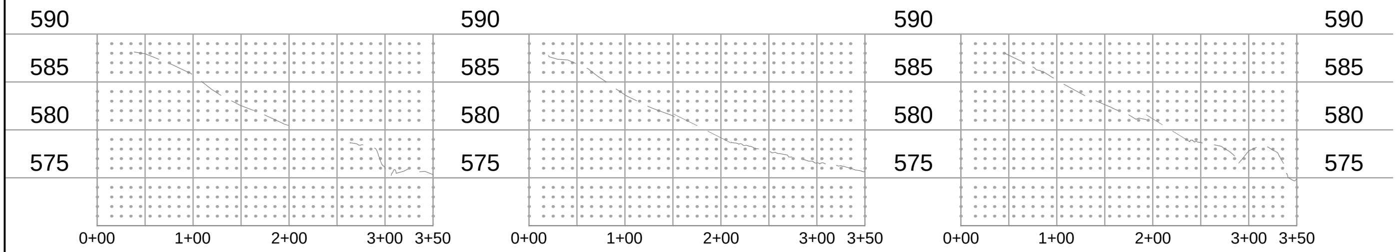
Conceptual Solution #4
McKinley Beach Lake Michigan
Milwaukee County, Wisconsin

EXHIBIT
5


REMOVE EXISTING BREAKWATER

SALVAGE ARMOR STONE AND
RIPRAP BELOW FOR USE IN
PROPOSED BREAKWATER

PROPOSED
BREAKWATER



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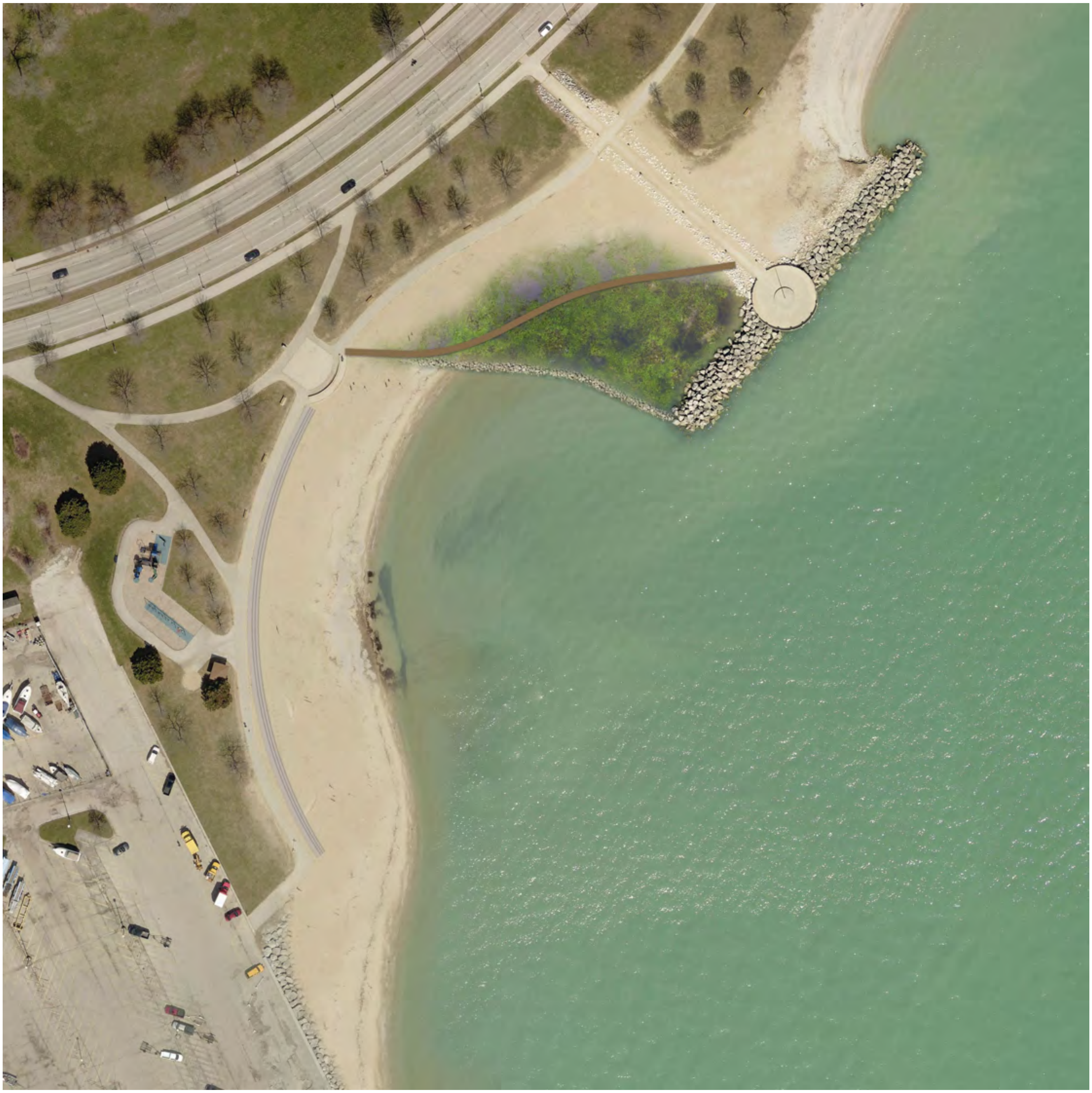
Conceptual Solution #5
McKinley Beach Lake Michigan
Milwaukee County, Wisconsin

EXHIBIT
6



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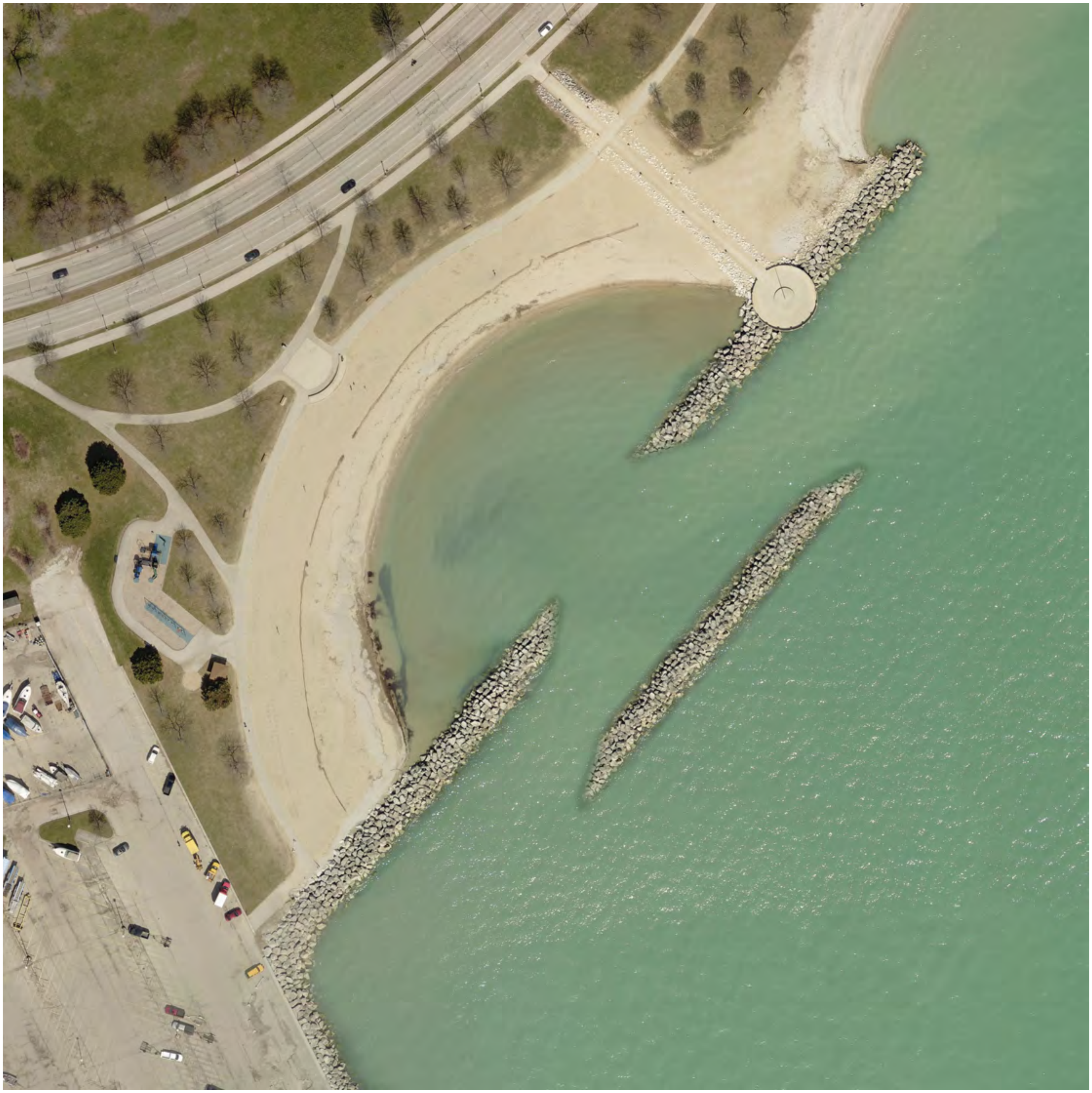
FILE NO.	Conceptual Solution #1	Exhibit 7
-		
DATE:	Enhanced Schematic Design	
2/2/2022		



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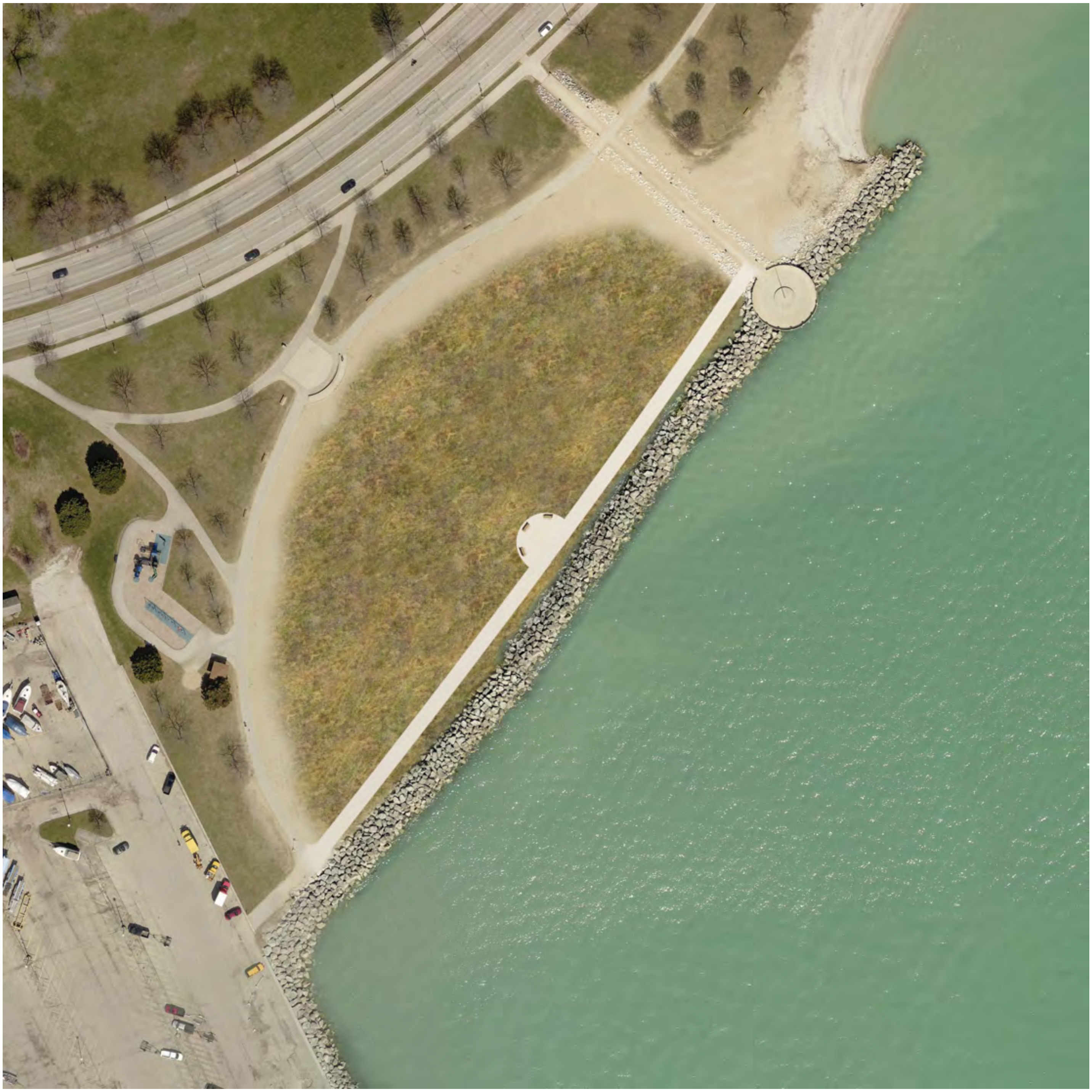
FILE NO.	Conceptual Solution #2	Exhibit 8
-		
DATE:	**Enhanced Schematic Design**	
2/2/2022		



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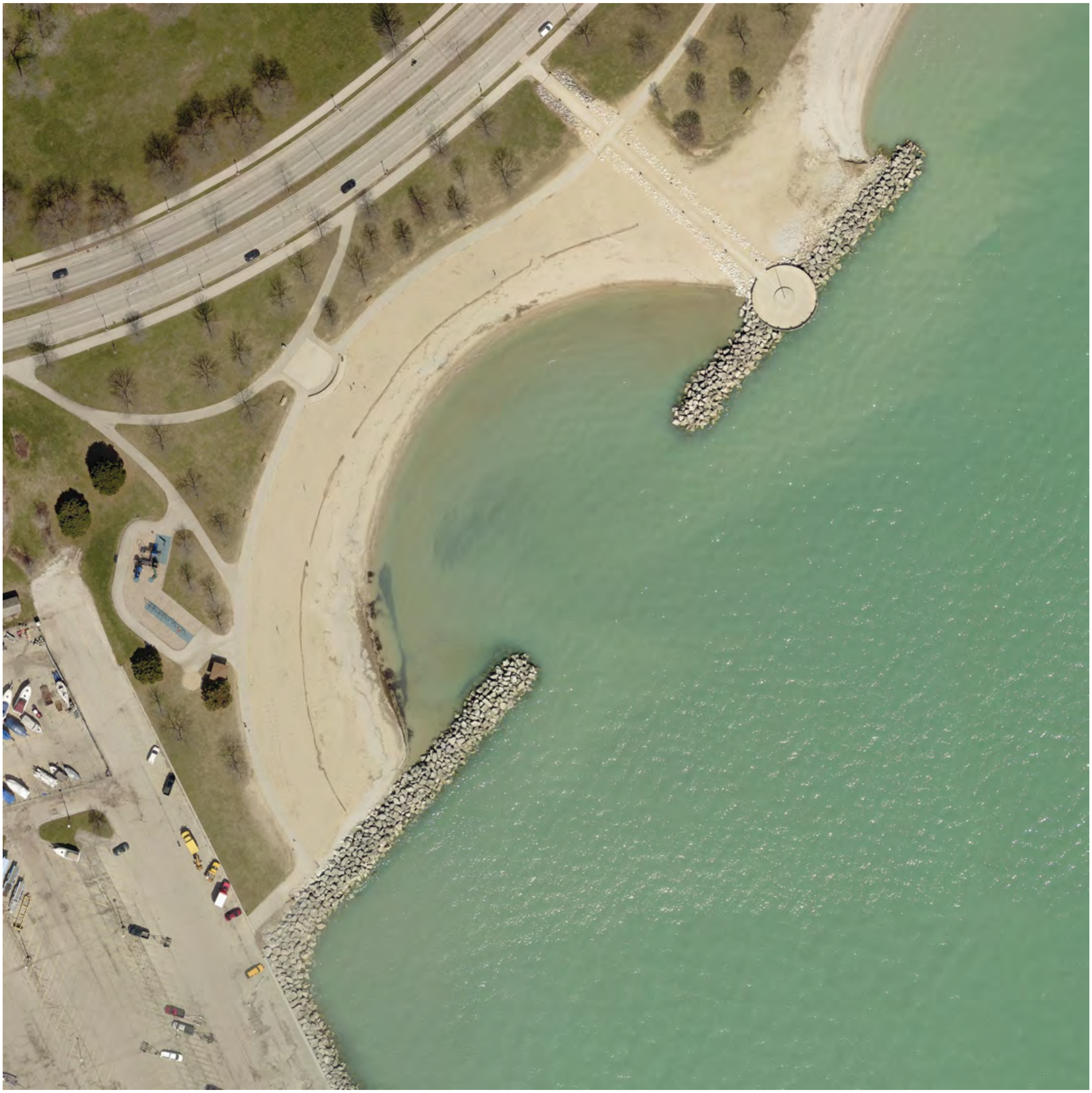
Conceptual Solution #3

Enhanced Schematic Design

Exhibit
9



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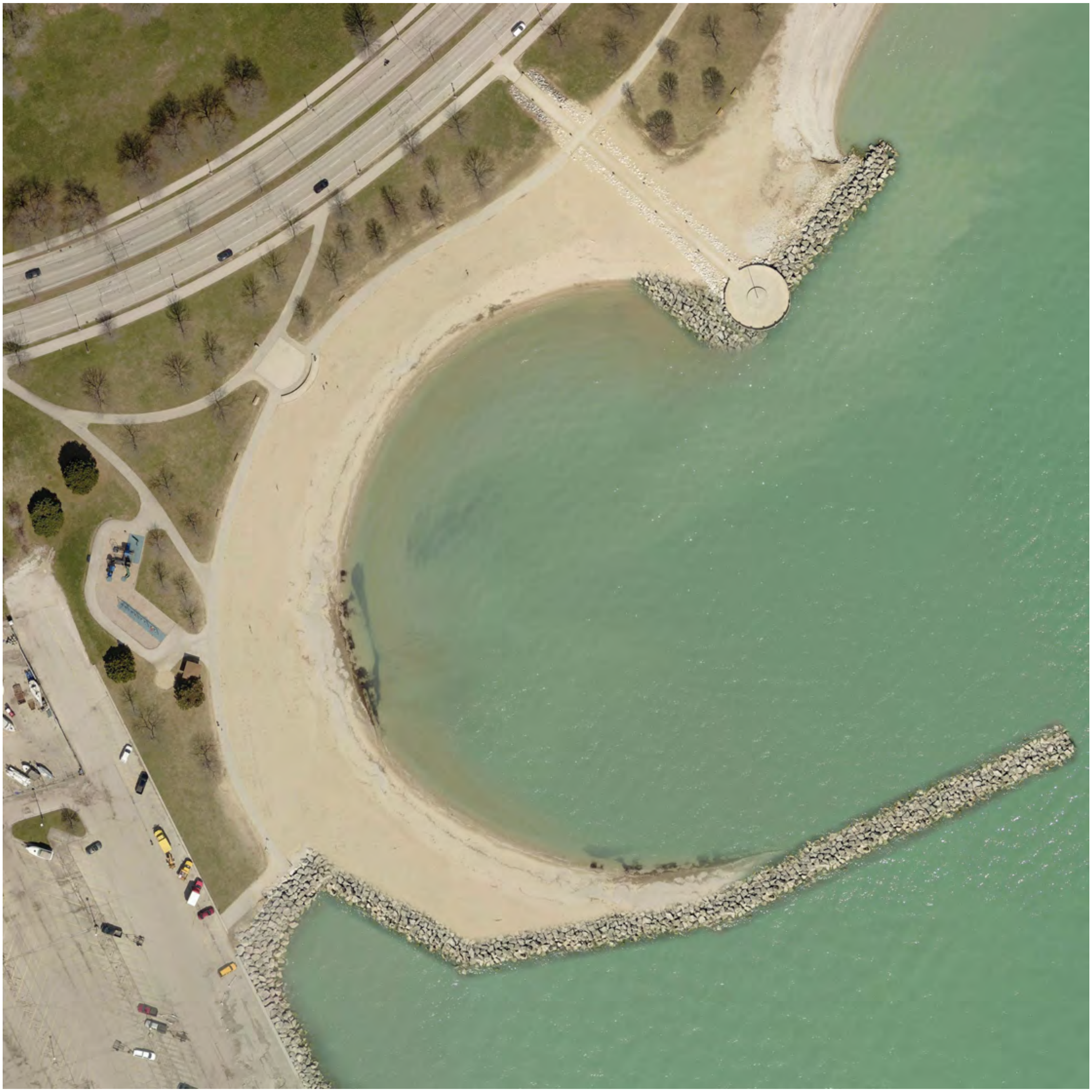
FILE NO.	Conceptual Solution #4	Exhibit 10
-		
DATE:	Enhanced Schematic Design	
2/2/2022		



	FILE NO.		
PHONE: 414.465.1200 316 NORTH MILWAUKEE STREET SUITE 302 MILWAUKEE, WI 53202-5888 www.sehinc.com	FILE NO. -	**Conceptual Solution #5**	Exhibit 11
	DATE: 2/2/2022	**Enhanced Schematic Design**	

Appendix G

Cost-Benefit Matrix

Cost-Benefit Matrix	**Swim Safety**		**Beach Sustainability**		**Water Quality**		**Recreation**		**Level Of Maintenance**	**Cost**	**Total Points**	**$ / Point**
Alternative	*Rip Currents*	*Swim Area Water Depth*	*Erodibility*	*Wave Energy*	*Reduce E.coli*	*Water Circulation/Stagnancy*	*Friendly to All Abilities*	*Level of Service*	*Activities*	*$*		
Concept 1 - Nature-Based Design / Hard Infrastructure Hybrid	7	0	4	6	3	8	8	7	3	$1,513,800	46	$32,909
Concept 2 - Offshore Breakwater & Modifications to Existing	0	0	3	9	5	2	7	4	8	$4,292,000	38	$112,947
Concept 3 – Connected Breakwater and Natural Restoration	8	N/A	8	9	8	5	5	5	6	$2,679,600	54	$49,622
Concept 4 – Beach Restoration to Intended Design	7	10	6	5	5	6	9	8	6	$290,000	62	$4,677
Concept 5 - Offshore Breakwater, Reconfigured	3	4	3	7	5	10	6	6	6	$5,684,000	50	$113,680
	0 - 10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0 - 10			
	0 -Increases Rip Currents	0 - Has No Effect on Water Depth	0 - Currents > 1 ft/s Present Along Structures or Shore	0 - Configuration Does Not Inhibit Incoming Wave Energy	0 - Encourages Avian Wildlife, Moreso than Sand Beach	0 -Water Circulation Absent in Many Locations	0 - Swim Area Appears Challenging to Novice Swimmers	0 - Level of Service Decreases	0 - Intra-Season Maintenance Activities Required			
	10 - Mitigates All Rip Currents	10 - Restores Water Depth Within Swim Area to 2.5' or Less	10 - Currents > 1 ft/s Not Present Along Structures or Shore	10 - Configuration Inhibits Incoming Wave Energy	10 - Does Not Encourage Avian Wildlife, Moreso than Sand Beach	10 -Water Circulation Present in Most Locations	10 - Swim Area Appears Welcoming to All Abilities	10 - Level of Service Increases	10 - Seasonal/Annual Maintenance Activities Required			