MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Grand Marais
Municipal Campground Water Access Project

Addendum to the Wave Numerical Model Study

Prepared For:

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Minnesota
DEPARTMENT OF NATURAL RESOURCES

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Executive Summary

The boat launch at Grand Marais currently experiences agitation levels in excess of comfortable launching/retrieval operations. Due to the unpredictable nature of Lake Superior, concerns exist over the safety of the boat launch during storm events. As the upland area adjacent to the launch is slated for redevelopment, it is the interest of Minnesota Department of Natural Resources to explore alternatives for decreasing the agitation within the area of the boat launch.

The objective of this addendum was to further the previously developed alternatives which would provide sheltering from waves entering the boat launch area. Specifically, the study reviews the possibilities of launching 35/38-ft and 50-ft length vessels from trailers at the launch, and adds pedestrian access along the top of the proposed breakwater structure.

SmithGroupJJR used the previously developed local wave hindcast and advanced numerical models to determine the wave environment at the project site for a given return period event. These models were supplemented with data derived from the new breakwater alternatives.

While there are no standards or guidelines for agitation at boat launches (as the risk of use is generally left to the discretion of the owner or user), it can be surmised that due to the size of vessels which utilize the boat launch at Grand Marais and resonance amplification that can cause excessive heave in small vessels, the limit of safe use of the boat launch is an agitation of 0.5 feet. Using this threshold, four design condition events related to the 1 month, 6 month, 1 year, and 20 year storm events were modelled. Typical boater practice would suggest that waves greater than 4 feet at the mouth of Grand Marais Bay would essentially eliminate the use of the boat launch.

Three additional alternative breakwater designs were reviewed. Using the 0.5 feet agitation limit, the required length of breakwater to reducing incoming wave agitation could be defined based upon the geometry requirements of launching the proposed boat lengths. Based on the resulting agitation and the quantity of rubble required to construct the breakwaters, a modification the original preferred breakwater and two new breakwater layouts were chosen. These alternatives continued to extend the existing rubble breakwater to wrap around the boat launch creating a sheltered bay at different depths and distances. Conceptual plans and cross sections of these breakwaters were developed based on land construction practices and is presented herein. The pedestrian access along the crest of the breakwaters were included on a linear foot cost to allow the overall program to be modified based upon funding availability.

In addition to the wave agitation study for the breakwater alternatives, we were asked to consider the use of a floating wave attenuator at the launch to meet the agitation levels described above. Due to the long period of waves entering the launch area, it was determined that the use of an attenuator would be functionality, cost, size/scale, and permit prohibitive.

The purpose of this addendum is to summarize the technical methods used to develop and test the two new breakwater alternatives that were developed in this study along with updated cost opinions.

Introduction

This report documents the alternative study of the additional breakwater sections for launching 35/38-foot and 50-foot boats in Grand Marais Harbor. This work consisted of reviewing and analyzing the existing local and regional environmental conditions that impact the Grand Marais harbor and water access at the site. Using the determined harbor agitation and recommended levels for safe operation, new conceptual alternative designs for extending the existing breakwater for launching the larger boats were developed and modelled to determine the effects on the agitation at the existing boat launch.

Water Levels

Water level variation can have an important influence on the operations of the boat launch. Low water levels may cause operational issues due to lack of keel clearance and high water levels can cause upland flooding. Because MnDNR has asked for exploration for boat sizes that are not typically considered trailer-able, this can be an important factor to consider.

Wave Conditions

1.1.-Yearly Average Wave Conditions

1.1.1.- Wave Height

The exceedance wave height probability for both boating and non-boating seasons per the direction of largest wave heights, the east, was developed. Table 1 shows the return period wave heights for each season which corresponds to the results shown in Figure 1. It is clear that during the non-boating season more energetic wave conditions are present.

Table 1 Wave Height Seasonal Exceedance

	Exceeded Hmo (feet)	
Return Period Event	Boating	Non-Boating
	E	E
1 Month	3.87	6.20
6 Months	4.80	6.95
1 Year	5.74	8.15
20 Years	8.07	13.02

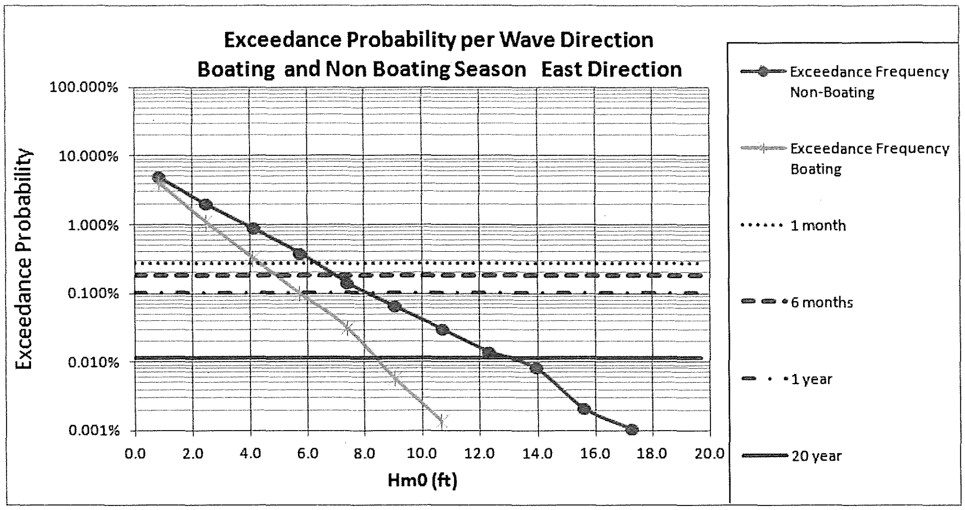


Figure 1 Relationship of Wave Heights from the East Direction for Boating and Non-Boating Seasons

1.1.2.- Wave Period

Wave transformation, refraction, shoaling, reflection, and diffraction are highly affected by the wave period. Waves with larger wave periods will tend to refract and diffract more than shorter period waves. The largest wave periods provided by the WIS hindcast are on the order of 10 s. However, wave periods of this length are not common.

Using the tables for the closest wave station, ST 95300, in WIS Report 23 "Hindcast Wave Studies for the Great Lakes: Lake Superior" (1979-2012), the most predominant wave period associated with the selected representative wave heights was used within the numerical modelling. The table for waves from the east is shown below in Figure 2.

LAKE SUPERIOR WAVE HINDCAST :ST95300
ALL MONTHS FOR YEARS PROCESSED : 1979 - 2012
STATION LOCATION : (-90.32 W / 47.68 N)
DEPTH : 164.0 m

PERCENT OCCURRENCE (X1000) OF HEIGHT AND PERIOD
FOR ALL DIRECTIONS

NO. CASES : 298054
NO. ICED : 15336
NO. CALMS : 31015

HEIGHT PARABOLIC FIT OF PEAK SPECTRAL WAVE PERIOD (IN SECONDS)

IN	<3.0	-4	-5	-6	-7	-8	-9	-10	-12	-14	TOTAL
METERS		4.9	5.9	6.9	7.9	8.9	9.9	10.9	12.9	LONGER	
0.00-0.10	.	.	.	.	.	.	.	.	.	.	10405
0.10-0.49	31557	13578	5108	3070	1595	412	72	6	.	.	55398
0.50-0.99	1461	8696	7136	2265	1456	689	279	48	.	.	22030
1.00-1.49	.	272	1499	2020	670	297	214	68	.	.	5040
1.50-1.99	.	.	40	480	453	182	113	62	.	.	1330
2.00-2.49	.	.	.	19	190	130	75	24	.	.	438
2.50-2.99	.	.	.	.	16	48	37	16	.	.	117
3.00-3.49	.	.	.	.	.	12	19	9	.	.	40
3.50-3.99	.	.	.	.	.	5	12	5	.	.	22
4.00-4.49	.	.	.	.	.	.	3	3	.	.	6
4.50-4.99	.	.	.	.	.	.	4	2	.	.	6
5.00-5.99	.	.	.	.	.	.	1	.	.	.	1
5.00+	.	.	.	.	.	.	1	.	.	.	1
TOTAL	33018	22546	13783	7854	4380	1775	829	243	0	0	

Figure 2 Hindcast Wave Information for Lake Superior, (USACE, WIS - http://wis.usace.army.mil/hindcasts.shtml?dmn=lakesWIS)

Operation and Modelling Criteria

There are no set standards for operations of a boat launch. Guidelines for agitation do not specifically cover wave heights at the boat launch though it is universally agreed that boat launches should be located well inside a sheltered basin. Due to resonance amplification, small waves can cause a small boat to have excessive heave, pitch, and roll. Therefore, for safe egress and for the purposes of this study, it is recommended that the wave height at the boat launch be less than 0.5 feet.

Understanding the response of users will help set the design criteria for the boat launch. Lake Superior is known to have sudden storms which rapidly change the marine environment. While local boats may be more accustomed to rough waters, it has been considered, for the purposes of this study, that deepwater wave heights greater than 3.5 feet will effectively stop users from launching vessels at the boat launch. It is assumed that for the majority of boaters already on the water, deepwater waves greater than 4 feet will drive them back to the boat launch. Based on the hindcast analysis presented above, this event has a return period of approximately 1 month during the boating season.

More experienced boaters may choose to be on the lake at greater agitation levels, or less experienced boaters may get caught unaware in a storm. For this reason, the yearly and twenty year events during the boating season were also reviewed. This can be considered a value engineering approach as the conceptual designs presented will attempt only to limit agitation to 'comfortable' levels.

The hydrodynamic numerical modelling consisted of testing four conditions of various storm intensities. These conditions represent the boating season event occurring once per month, once per six months, once per year, and once per 20 years and are labeled as Conditions 1, 2, 3, & 4 respectively. It can be seen in Table 2 below that Condition 1, the once per month event, is similar in scale to the condition in which boaters will stop utilizing the boat launch.

Table 2 Numerical Modelling Conditions Matrix

Condition	Wave Criteria for Modelling	
	Deepwater Wave Height Hmo	Peak Wave Period Tp
Condition 1 (1 month)	3.87 ft	6.5 s
Condition 2 (6 month)	4.80 ft	7.0 s
Condition 3 (1 year)	5.74 ft	7.5 s
Condition 4 (20 year)	8.07 ft	8.8 s

Wave Agitation Modelling

1.2.-Existing Conditions

1.2.1.- Operational Wave Conditions

The agitation modelling was limited to easterly wave conditions as this was found to be the governing direction for agitation at the boat launch. Using the conditions matrix presented in Table 2, the agitation was determined and shown below.

Table 3 Existing Modelled Wave Agitation at Boat Launch

	Wave Criteria for Modelling	Wave Agitation at the Boat Launch

Condition	Deepwater Wave Height	Peak Wave Period	Local Wave Height
	Hmo	Tp	Hs
Condition 1 (1 month)	3.87 ft	6.5 s	0.44 ft
Condition 2 (6 month)	4.80 ft	7.0 s	0.83 ft
Condition 3 (1 year)	5.74 ft	7.5 s	0.99 ft
Condition 4 (20 year)	8.07 ft	8.8 s	1.65 ft

As shown in Table 3, the wave agitation at the boat launch during the 1 month condition is already below the required 0.5 feet agitation limit. This event has a high probability of occurring once a month during the open water season. We would assume that when storm waves reach the height of Condition 1 outside the basin breakwaters, use of the boat launch for launching will decrease and the facility primarily will be used for boat retrieval.

For less frequent storms, such as Conditions 2 through 4, the agitation at the boat launch is above the 0.5 feet threshold which means use of the boat launch will be hindered and possibly even dangerous.

1.3.-Alternatives to Reduce the Agitation Levels at the Boat Launch Location

In order to reduce the agitation at the boat launch location, the original preferred alternative was modified to allow for the pedestrian access and the two new alternatives which included elongating the existing breakwater were considered in order to allow for the launching of 25/38-ft and 50-ft boats. These alternatives included a pedestrian walkway along the crest of the breakwater. These three new alternatives are shown in Figure 3 thru Figure 5 below.

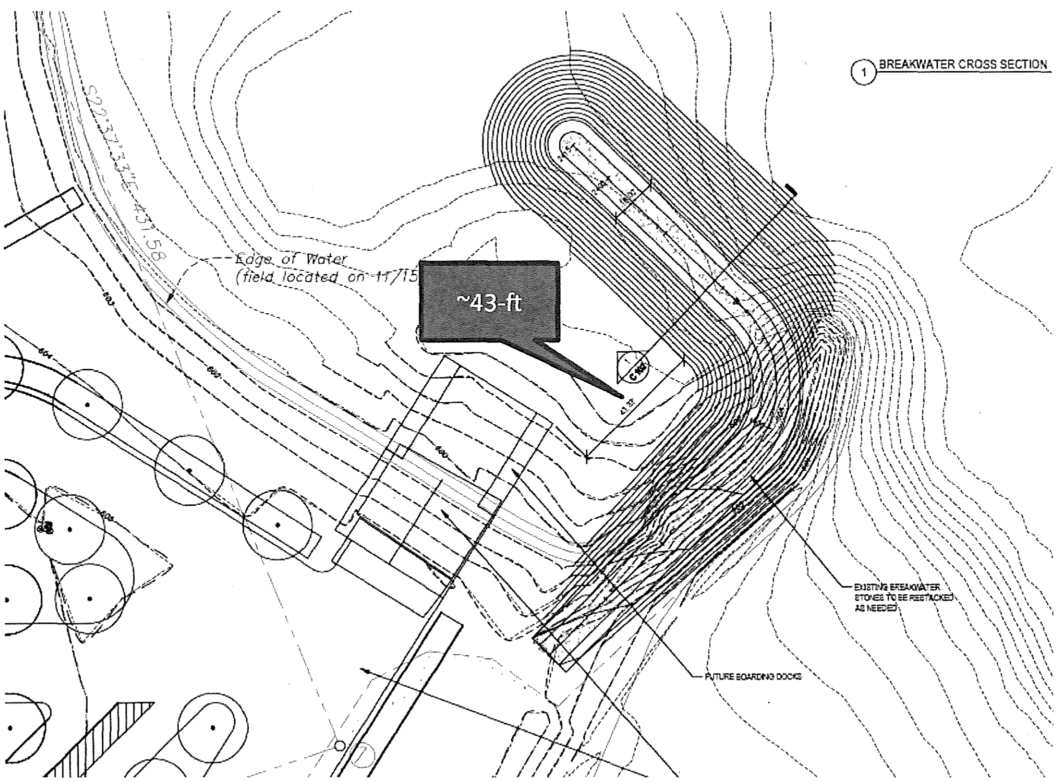


Figure 3 **Alternative 1: Updated alternative with pedestrian access**

The breakwater alternatives proposed, Alternatives 1, 2 & 3, are all connected to the existing breakwater groin and would be constructed of local stone similar to that of the existing structure. This would create a visually continuous breakwater. By extending the existing breakwater structure around the boat launch, an enclosed, sheltered basin is created. The location of the breakwater extension was specifically chosen to limit construction away from the deeper lakebed contours while creating an adequate basin size beyond the toe of the boat launch for boater staging. Options two and three extended the breakwater further into deep water due to the launching geometry required for the requested larger boats.

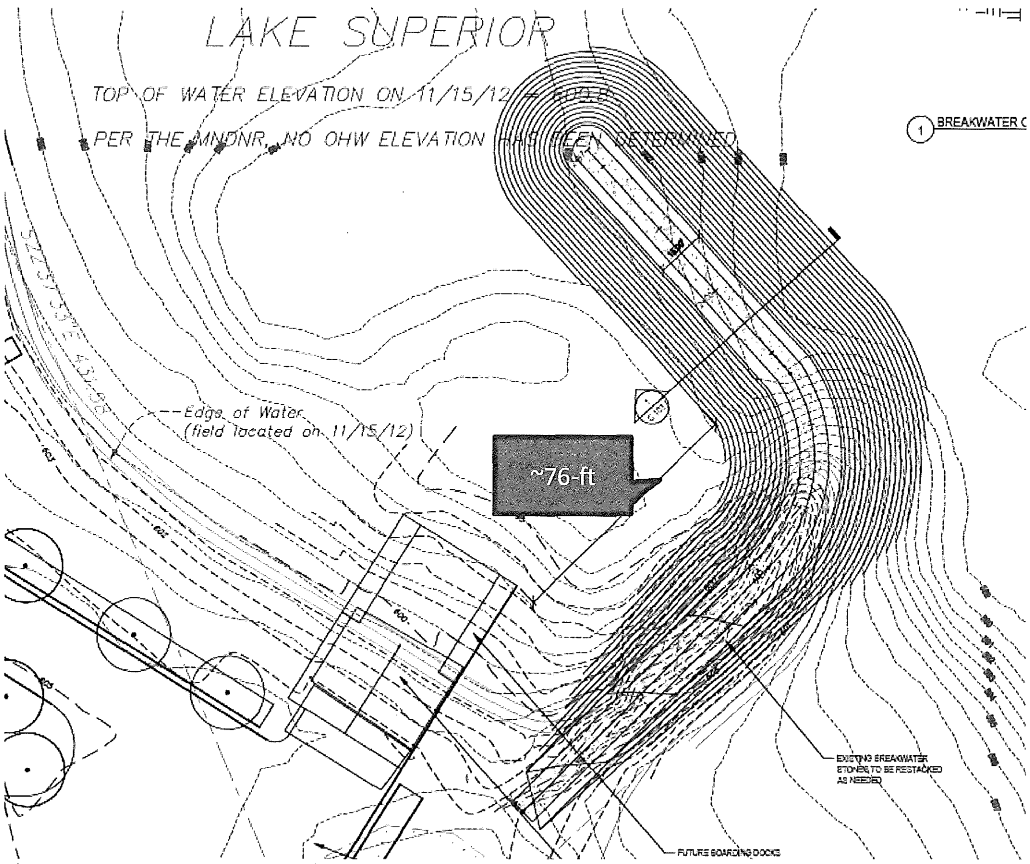


Figure 4 **Alternative 2: 35/38-ft vessels**

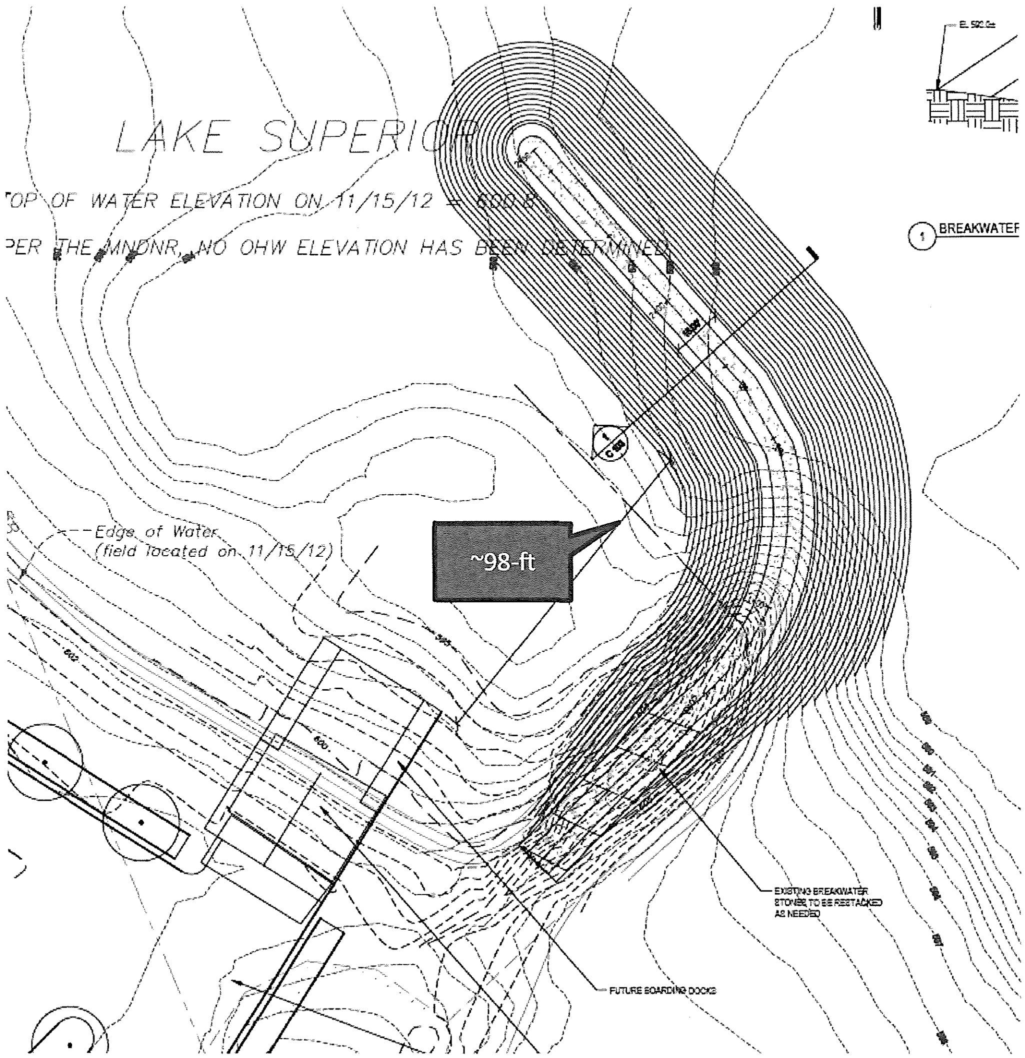


Figure 5 **Alternative 2: 50-ft vessels**

1.4.-Reduction in Agitation

Each of the breakwater alternatives were modelled with the operational conditions listed in Table 2 to determine the reduction in agitation at the boat launch using the average of the two identified output points. The modelled agitation at the boat launch for each condition for the existing layout was given in Table 3. The goal in each modelling case was to reduce the wave agitation to an acceptable 0.5 feet wave height during the event. Since Condition 1, the 1 Month event, already produced agitation below 0.5 feet, this condition was not further analyzed. The results for the remaining conditions per alternative are shown in Table 4.

Table 4 **Resulting Reduction in Agitation due to Breakwater Modifications**

Alternative	6mth Event: Hmo=4.92ft Tp=7.0s		1yr Event: Hmo=5.7ft Tp=7.5s		20yr Event: Hmo=8.0ft Tp=8.8s	
	Hmo (ft.)	Relative Improvement	Hmo (ft)	Relative Improvement	Hmo (ft)	Relative Improvement
Existing condition	0.83	0.00%	0.99	0.00%	1.65	0.00%
Original design (Alt 1)			0.46	53.67%	1.27	23.30%
Alternative 35/38 ft Launch (Alt 2)	0.32	60.85%	0.43	56.92%	1.36	17.74%
Alternative 50ft Launch (Alt 3)	0.36	56.89%	0.52	47.04%	1.48	10.38%

As shown, the 20 year event, was not reduced to the desired 0.5 feet agitation at the boat launch. As within the original modeling report, it was determined that the required breakwater length would be prohibitive and that during an event of 8 foot waves in deepwater, the launch would not be utilized. As storms generally build over time, it is theorized that educated boaters will exit the water prior to the peak of such an event. Therefore, it is recommended that the 1 year event be considered the "design event."

In addition to the numerical modelling of waves generated outside of Grand Marais Bay, locally generated waves created within the bay were also examined. These waves would not be impeded before entering the boat launch basin as it currently exists. Due to the restricted fetch within the basin, the locally generated waves, such as from the northeast, would not grow larger than 0.7 feet. Once a breakwater is constructed, this energy will be damped below the desired 0.5 feet and is therefore not further considered.

Recommended Layout and Cross Section

To allow land based construction, modifications will be required to the existing breakwater. This will require removal of the larger armor stone material and placement of a bed of coarse stone which will act as a roadway for the construction equipment. It is recommended that the 'roadway' be a minimum of 12 feet wide to accommodate smaller construction equipment. Following construction, armor stone will be replaced on top of the existing jetty to cover the newly placed coarse stone which will act as a filter. This may, depending on the cross section of the existing breakwater, widen the structure. It is recommended that the changes to this breakwater be engineered in tandem with the new breakwater extension.

As discussed previously, the new breakwater extension will be designed to survive a more severe event than those analyzed in this study. The service life of a structure is typically less than the design event it is engineered for. This is due to the probability of a design event happening within a projects service life. The service life is defined as the amount of time a project is expected to function with only a low level of maintenance. Projects will generally continue to function well past their service life though it is advisable that they be thoroughly inspected and updated as needed.

In order to construct the breakwater from the land, an adequate 'roadway' constructed of core material is required. This suggests that the core material have a width of at least 12 feet above the waterline. For the purposes of a conceptual design, the crest of this roadway was placed 1 foot above the current waterline. This may be adjusted later depending on actual construction equipment used and its associated weights.

Proposed cross sections used for the layout and modeling of the breakwaters are shown below in Figure 6 and Figure 7. Pedestrian access along the crest of the breakwater required the slight increase in width of the crest from 14.5-feet to 15-feet minimum, and final width will be determined based upon final armor stone dimensions. The pedestrian access requires a concrete wall and footer to properly contain and separate the core stone from the filter and armor layers. The inclusion of this wall/footer combination is used to prevent uplift forces from the waves breaking against the voids and armor layers and causing damage to the walking surface.

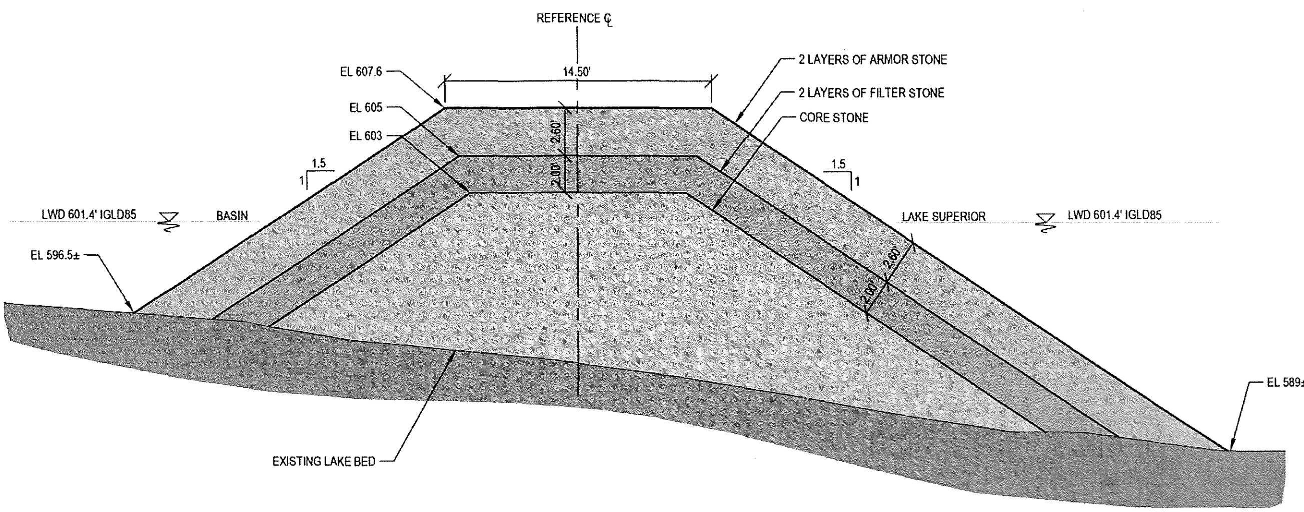


Figure 6 **Standard Breakwater Cross Section**

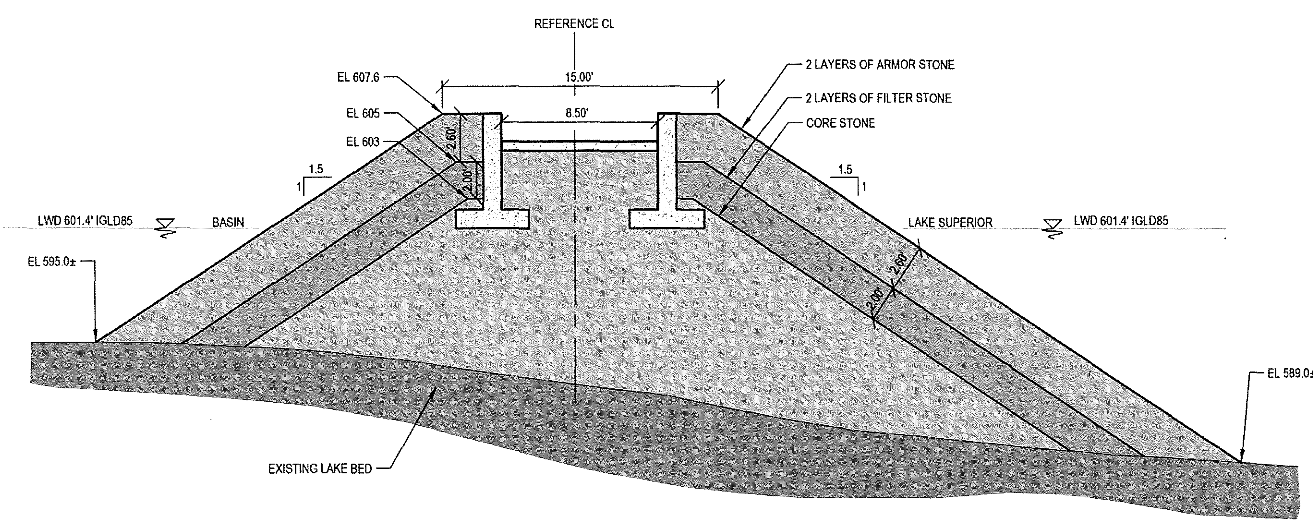


Figure 7 **Breakwater Cross Section with Pedestrian Access**

Floating Wave Attenuator for Wave Protection and Launch Tranquility

A floating wave attenuator was considered for an additional method of wave reduction at the launch area. Table 3 above details the deepwater Wave Heights and Peak Wave Periods associated for different return events modeled. It should be noted that all Peak Wave Periods are greater than 6-seconds. Floating wave attenuators will not function once wave periods exceed 3.5 to 4 seconds. The floating attenuator is not a recommended option for further exploration to protect the launch at the wave periods that occur within the marina basin.

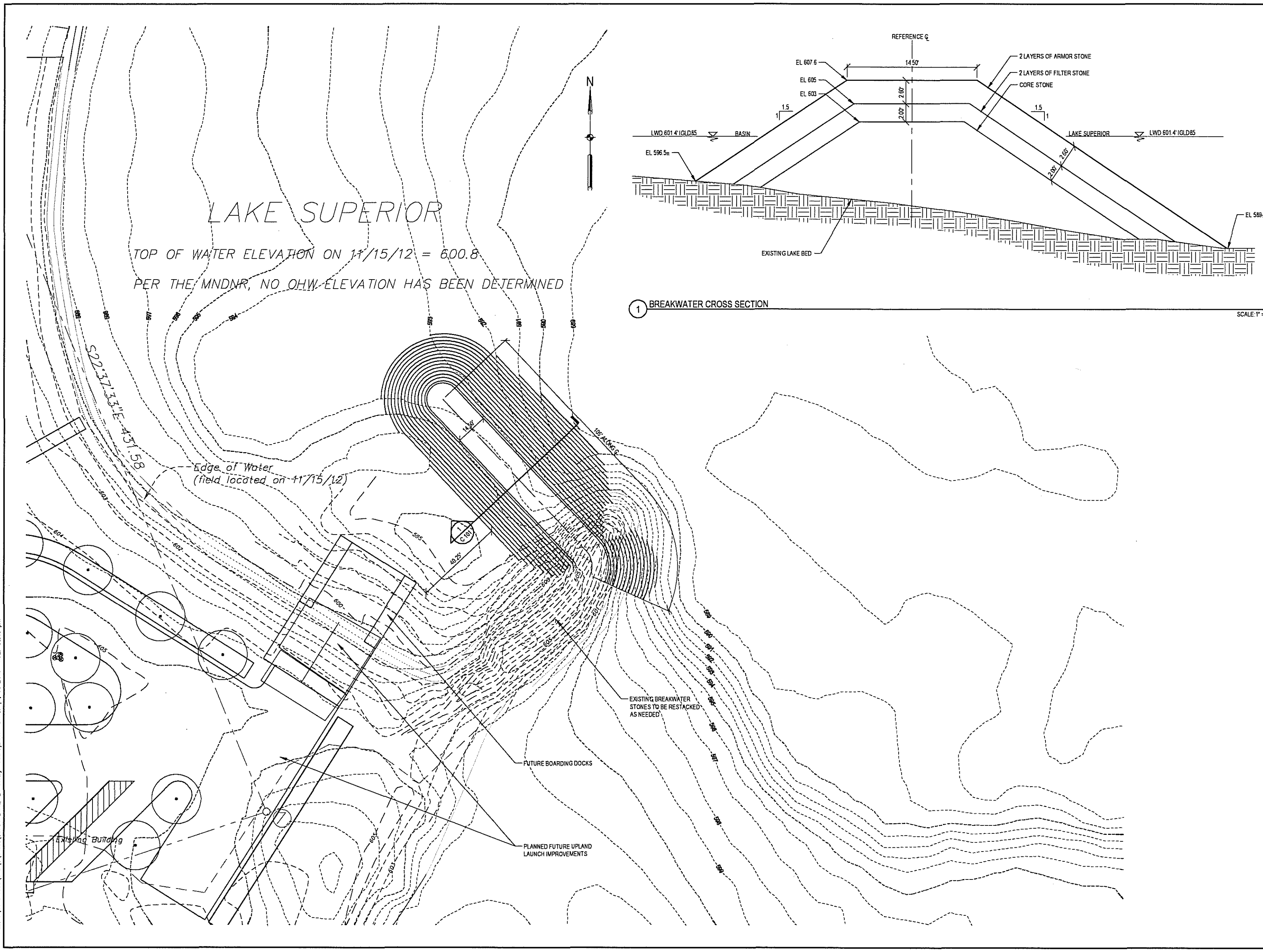
Opinion of Probable Construction Costs for Presented Alternatives

Table 5 Opinion of Probable Construction Costs (2015 Dollars)

Alternative	**6mth Event: Hmo=4.92ft Tp=7.0s**		**1yr Event: Hmo=5.7ft Tp=7.5s**		**20yr Event: Hmo=8.0ft Tp=8.8s**		**Preliminary Cost Opinion**
	Hmo (ft)	Relative Improvement	Hmo (ft)	Relative Improvement	Hmo (ft)	Relative Improvement	
Extended breakwater	0.83	0.00%	0.46	53.67%	1.27	23.30%	**$614,000**
Extended breakwater w/ access			0.46	53.67%	1.27	23.30%	**$741,000**
Alternative 35ft w/ access	0.32	60.85%	0.43	56.92%	1.36	17.74%	**$936,000**
Alternative 50ft w/ access	0.36	56.89%	0.52	47.04%	1.48	10.38%	**$1,186,000**

Please see attached detailed cost opinions for more detailed units and prices used to prepare the opinions. As shown on the drawings of the alternatives above and in the appendices, the pedestrian walkway was extended the full length of the rubble mound. Unit prices per lineal foot have been included for this pathway in order for MnDNR to evaluate an equitable solution and ultimate distance on the pathway.

Appendix A: Rubble Mound Breakwater Concept Drawings



GRAND MARAIS WATER ACCESS

114 SOUTH 8TH AVENUE WEST
GRAND MARAIS, MN 55604

Owner:

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

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ISSUED FOR	REV	DATE
REPORT ADDENDUM		4/10/2015

SEALS AND SIGNATURES

NOT FOR CONSTRUCTION

KEY PLAN

DRAWING TITLE

Breakwater Concept Grading Plan

SCALE

SCALE

50704.000

PROJECT NUMBER

C 101

DRAWING NUMBER

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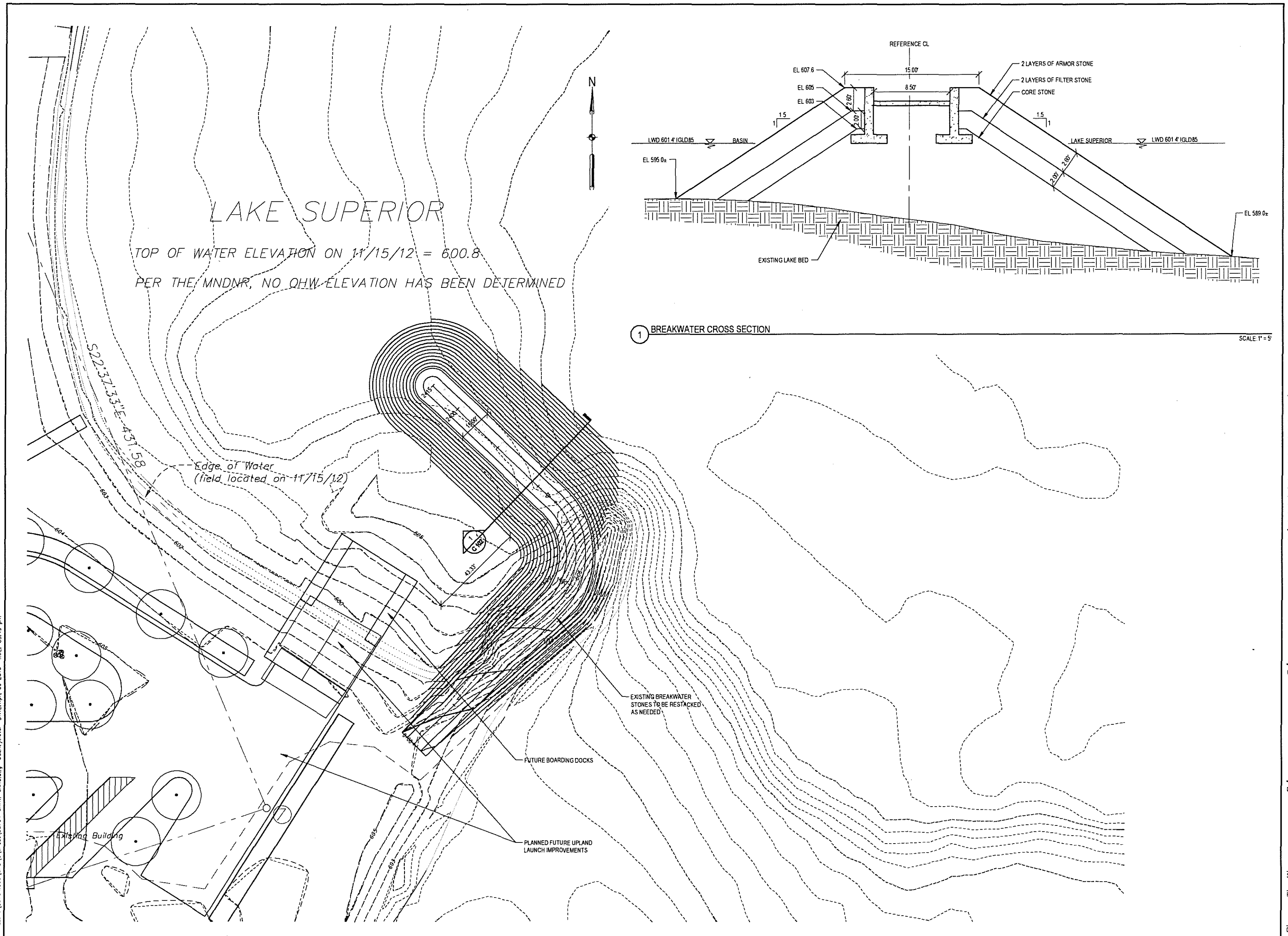

GRAND MARAIS WATER ACCESS

114 SOUTH 8TH AVENUE WEST
GRAND MARAIS, MN 55604

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REPORT ADDENDUM		4/10/2015

SEALS AND SIGNATURES

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KEY PLAN

DRAWING TITLE

Breakwater Concept Grading Plan with Original Walkway

0 10' 20' 40'
SCALE

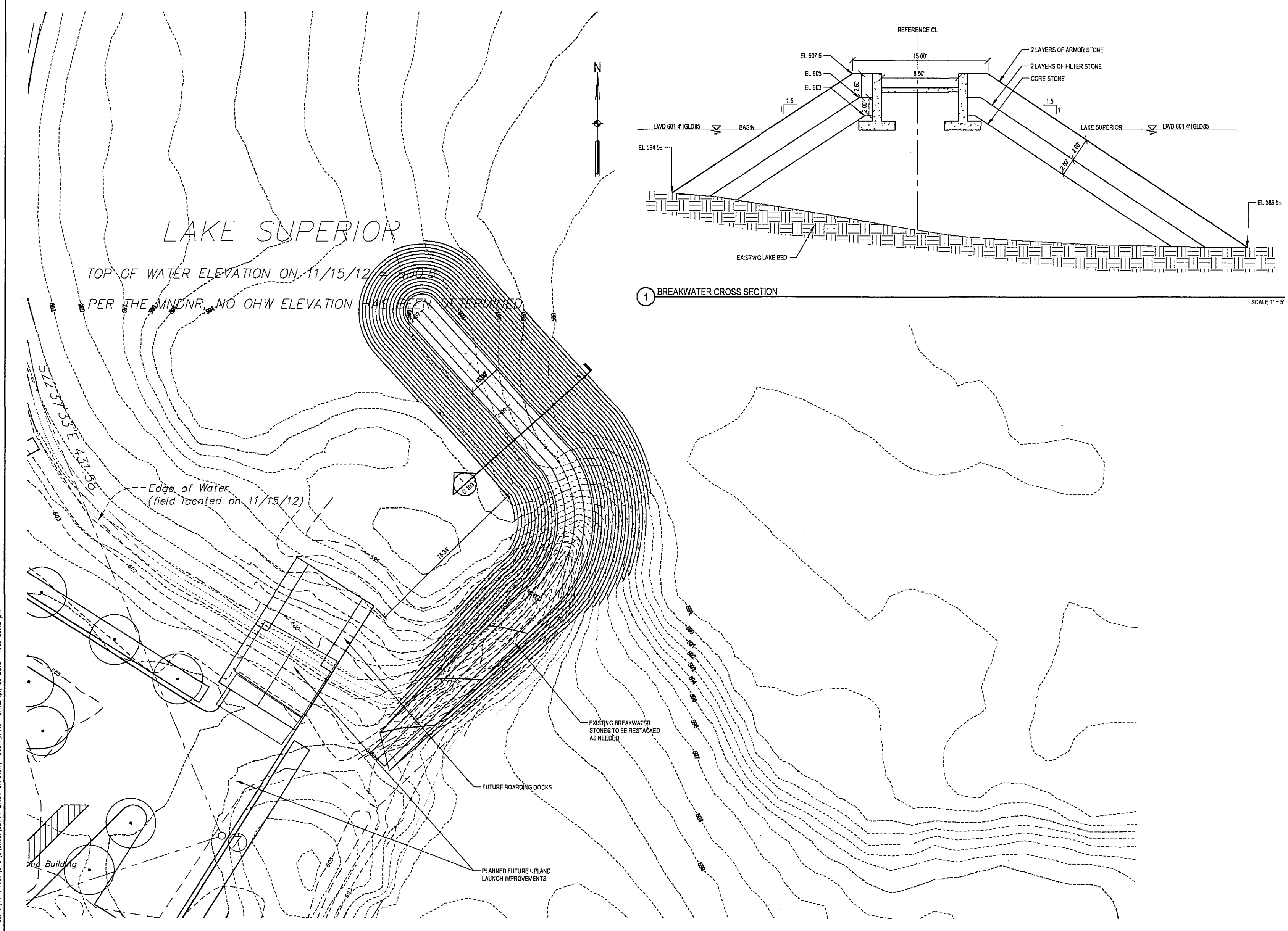
SCALE

50704.000

PROJECT NUMBER

C 102

DRAWING NUMBER



GRAND MARAIS WATER ACCESS
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ISSUED FOR	REV	DATE
REPORT ADDENDUM		4/10/2015

SEALS AND SIGNATURES

NOT FOR CONSTRUCTION

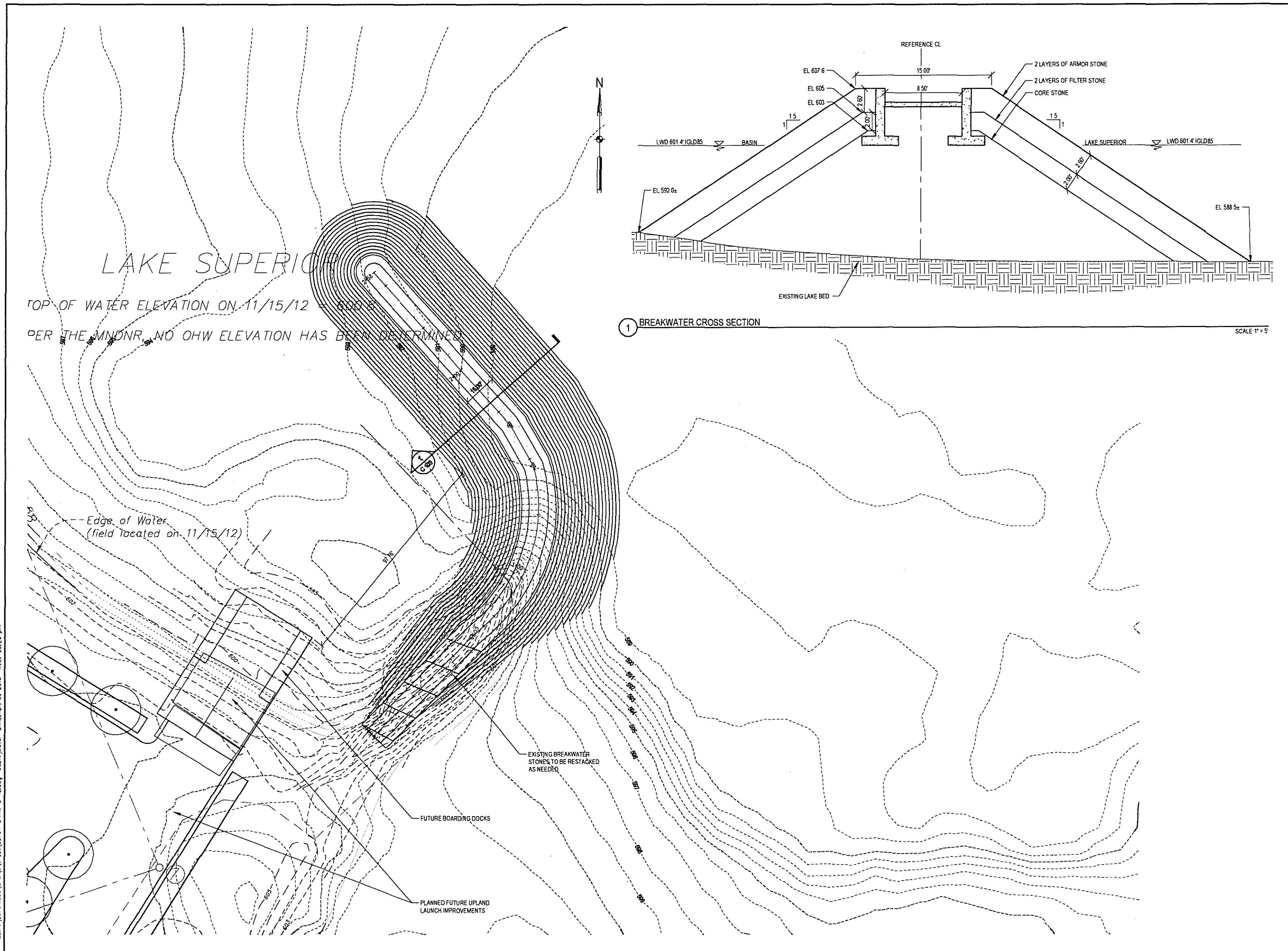
KEY PLAN

DRAWING TITLE
Breakwater Concept
Grading Plan - 35-ft Boat Launch with Walkway

SCALE

SCALE
50704.000
PROJECT NUMBER

C 103
DRAWING NUMBER



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GRAND MARAIS, MN 55604

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REPORT ADDENDUM		4/10/2015

SEALS AND SIGNATURES

NOT FOR CONSTRUCTION

KEY PLAN

DRAWING TITLE

Breakwater Concept Grading Plan - 50-ft Boat Launch with Walkway

SCALE

PROJECT NUMBER: 50704.000

DRAWING NUMBER: C.104

Appendix B: Opinions of Probable Construction Costs

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Date **4/12/2015**
Project **Grand Marais Water Access Project**
Client **Minnesota Department of Natural Resources**
Job # **50704.001**

Opinion of Probable Construction Cost **Option 1 - Pedestrian Access on Original Concept**

	Item	Quantity	Unit	Unit Cost	Item Total	Subtotal	Remarks
A	**General**						
	1. Mobilization	1	LS	$ 150,000	$ 150,000		
	2. Erosion Control	1	LS	$ 8,000	$ 8,000		
	3. General Conditions	1	LS	$ 4,000	$ 4,000		
	Subtotal					**$ 162,000**	
B	**Site Preparation / Demolition / Erosion Control**						
	4. Rework of Existing Breakwater	100	LF	$ 1,000	$ 100,000		Restack stones for reuse while allowing the existing breakwater to be used for construction staging
	5. Armor Stone	685	Ton	$ 112	$ 76,720		Assumed 2-feet diameter maximum stone size
	6. Filter Stone	400	Ton	$ 95	$ 38,000		Assumed 9-inch diameter maximum stone size
	7. Core Material	700	Ton	$ 80	$ 56,000		Assumed 2-inch diameter average stone size
	8. Restoration	1	LS	$ 20,000	$ 20,000		General site restoration from disturbance of upland area from construction staging
	Subtotal					**$ 290,720**	
C	**Pedestrian Access**						
	9. Concrete Footing	450	LF	$ 89	$ 40,000		
	10. Concrete Wall	450	LF	$ 71	$ 32,000		
	11. Concrete Walkway	1,858	SF	$ 13	$ 24,154		
	Subtotal					**$ 96,154**	
	Project Subtotal					**$ 548,874**	
D	**Contingency**						
	Contingency			20%	$ 110,000		
	Geotechnical Investigation/ Final Design/CA			15%	$ 82,000		
	Subtotal					**$ 192,000**	
	Project Total (excluding design, engineering and permitting)					**$ 740,874**	

Note:

1 Breakwater assumed to be constructed from land without a barge due to water depths and heights of the breakwater
2 Design life of project and extreme event wave analysis has not been completed and is required during final design to determine final breakwater cross-section
3 Does not include reconstruction and lengthening of ramp or boarding docks

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Date **4/12/2015**
Project **Grand Marais Water Access Project**
Client **Minnesota Department of Natural Resources**
Job # **50704.001**

Opinion of Probable Construction Cost **Option 2 - Launch capable of 35-ft boat length with Pedestrian Access**

	Item	Quantity	Unit	Unit Cost	Item Total	Subtotal	Remarks
A	General						
	1. Mobilization	1	LS	$ 150,000	$ 150,000		
	2. Erosion Control	1	LS	$ 8,000	$ 8,000		
	3. General Conditions	1	LS	$ 4,000	$ 4,000		
	Subtotal					**$ 162,000**	
B	Site Preparation / Demolition / Erosion Control						
	4. Rework of Existing Breakwater	150	LF	$ 1,000	$ 150,000		Restack stones for reuse while allowing the existing breakwater to be used for construction staging
	5. Armor Stone	900	Ton	$ 112	$ 100,800		Assumed 2-feet diameter maximum stone size
	6. Filter Stone	550	Ton	$ 95	$ 52,250		Assumed 9-inch diameter maximum stone size
	7. Core Material	1,175	Ton	$ 80	$ 94,000		Assumed 2-inch diameter average stone size
	8. Restoration	1	LS	$ 20,000	$ 20,000		General site restoration from disturbance of upland area from construction staging
	Subtotal					**$ 417,050**	
C	Pedestrian Access						
	9. Concrete Footing	530	LF	$ 89	$ 47,111		
	10. Concrete Wall	530	LF	$ 71	$ 37,689		
	11. Concrete Walkway	2,211	SF	$ 13	$ 28,743		
	Subtotal					**$ 113,543**	
	Project Subtotal					**$ 692,593**	
D	Contingency						
	Contingency			20%	$ 139,000		
	Geotechnical Investigation/ Final Design/CA			15%	$ 104,000		
	Subtotal					**$ 243,000**	
	Project Total (excluding design, engineering and permitting)					**$ 935,593**	

Note:

1 Breakwater assumed to be constructed from land without a barge due to water depths and heights of the breakwater
2 Design life of project and extreme event wave analysis has not been completed and is required during final design to determine final breakwater cross-section
3 Does not include reconstruction and lengthening of ramp or boarding docks

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Project **Grand Marais Water Access Project**
Client **Minnesota Department of Natural Resources**
Job # **50704.001**

Opinion of Probable Construction Cost **Option 3 - Launch capable of 50-ft boat length with Pedestrian Access**

	Item	Quantity	Unit	Unit Cost	Item Total	Subtotal	Remarks
A	**General**						
	1. Mobilization	1	LS	$ 150,000	$ 150,000		
	2. Erosion Control	1	LS	$ 8,000	$ 8,000		
	3. General Conditions	1	LS	$ 4,000	$ 4,000		
	Subtotal					**$ 162,000**	
B	**Site Preparation / Demolition / Erosion Control**						
	4. Rework of Existing Breakwater	200	LF	$ 1,100	$ 220,000		Restack stones for reuse while allowing the existing breakwater to be used for construction staging
	5. Armor Stone	1,275	Ton	$ 112	$ 142,800		Assumed 2-feet diameter maximum stone size
	6. Filter Stone	750	Ton	$ 95	$ 71,250		Assumed 9-inch diameter maximum stone size
	7. Core Material	1,850	Ton	$ 80	$ 148,000		Assumed 2-inch diameter average stone size
	8. Restoration	1	LS	$ 20,000	$ 20,000		General site restoration from disturbance of upland area from construction staging
	Subtotal					**$ 602,050**	
C	**Pedestrian Access**						
	9. Concrete Footing	530	LF	$ 89	$ 47,111		
	10. Concrete Wall	530	LF	$ 71	$ 37,689		
	11. Concrete Walkway	2,220	SF	$ 13	$ 28,860		
	Subtotal					**$ 113,660**	
	Project Subtotal					**$ 877,710**	
D	**Contingency**						
	Contingency			20%	$ 176,000		
	Geotechnical Investigation/ Final Design/CA			15%	$ 132,000		
	Subtotal					**$ 308,000**	
	Project Total (excluding design, engineering and permitting)					**$ 1,185,710**	

Note:

1 Breakwater assumed to be constructed from land without a barge due to water depths and heights of the breakwater
2 Design life of project and extreme event wave analysis has not been completed and is required during final design to determine final breakwater cross-section
3 Does not include reconstruction and lengthening of ramp or boarding docks

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