Revised Concept Design Report for Replacement of Port Orchard Marina North and East Breakwaters

Produced By:

ART ANDERSON

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The engineering material and data contained in this report were prepared under the supervision and direction of the undersigned, whose seals as registered professional engineers are affixed below.

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Executive Summary

In 2017, a preliminary concept design of the new breakwaters that will replace the aged north and east breakwaters at the Port Orchard Marina was developed. This preliminary concept design of the new breakwaters was based on the preferred alternative selected in the Value Engineering (VE) study performed from July 24 to July 27, 2017. Valuable elements of the design are the float section and mooring system. Heavy-duty 12' wide concrete float sections could have a service life of more than 50 years in the marine environment with minimum maintenance. A new mooring line system or guide pile system would replace the aged mooring line and anchor pile system. The summary report in Reference A was revised in 2019 to include a new Appendix C.

In 2019, the Port commission decided that it was desirable to reconsider replacing the Port Orchard Marina Breakwater with one like that which was installed in 2008 at the Bremerton Marina – a 25 ft wide breakwater. This would allow for greater usage of the breakwater as an amenity for the community and community events. In this revised report, the 5 alternatives were revisited in the context of using interstitial guide piles for alternatives 3 and 4, and updated cost estimates for revised alternatives 0, 1 and 2. Four additional alternatives, 5 to 8 were added and analyzed for a 20' wide pontoon concept and a 25' wide pontoon concept, using both interstitial guide piles and cable mooring systems. Table 1 is a matrix summarizing all considered breakwater alternatives

Table 1: Alternatives Comparison Matrix

	Float Width	Float Depth	Mooring System	Wall Thickness	Notes
Alt 0	12'	5.75'	Cable mooring with stake piles	4" top deck, 3" sides and bottom	Replace floats and mooring to meet current codes.
Alt 1	12'	5.75'	Cable mooring with stake piles	4" top deck, 3" sides and bottom	Replace floats to meet current codes, replace 25% of failing stake piles. No longer a viable option.
Alt 2	12'	5.75'	Cable mooring with stake piles	5" top deck, 4" sides and bottom	Replace floats and stake piles with upgraded, higher capacity versions.
Alt 3	12'	5.75'	30"x1" guide piles	5" top deck, 4" sides and bottom	Upgraded floats. Interstitial guide piles on inside, external pile hoops on outside.
Alt 4	12'	5.75'	30"x1" guide piles	4" top deck, 3" sides and bottom	Replace floats to meet current codes. Interstitial guide piles on inside, external pile hoops on outside.
Alt 5	25'	5.25'	30"x1" guide piles	5" top deck, 4" sides and bottom	Upgraded, wider floats. Interstitial pile guide piles on both sides.

	Float Width	Float Depth	Mooring System	Wall Thickness	Notes
Alt 6	25’	5.25’	Cable mooring with stake piles	5” top deck, 4” sides and bottom	Upgraded, wider floats. Use cable mooring with stake piles.
Alt 7	20’	5.75’	30”x1” guide piles	5” top deck, 4” sides and bottom	Upgraded, wider floats. Interstitial guide piles on both sides.
Alt 8	20’	5.75’	Cable mooring with stake piles	5” top deck, 4” sides and bottom	Upgraded, wider floats. Use cable mooring with stake piles.

A second Concept design review meeting, which included some Value Engineering effort, was held on 22 October 2019. The focus of this meeting was to get the design team all up to speed on the revised and new options considered, provide comments on these alternatives and the construction cost estimates, and the ultimate trade off analysis conducted in the draft report. Based on the results of the meeting, summarized in Appendix B, Alternative 2 was recommended for execution. Alternative 2 uses 12’ wide floats with thicker walls for increased live load capacity and longevity, a deeper section for greater wave attenuation, and cable mooring with stake pile anchors.

In Appendix D, three alternatives were developed for consideration as a separate project to address the current ADA access deficiencies to the East and North Breakwater. Based on the lowest cost, the recommendation is to implement Option #3 as soon as funding can be made available and design completed.

Background

The existing north and east breakwaters have protected vessels moored at the Port Orchard Marina for more than 46 years and now have damage to the concrete floats. The damage includes delamination, cracks, and spalls, which have resulted in saturation of the styrene foam inside the floats, lowering the freeboard. Therefore, the breakwater floats have been repaired by mortar patching and the addition of bladder units. These types of repairs are only temporarily effective in maintaining the desired freeboard and keeping the breakwaters functional, and it will not extend the service life of the breakwater. Furthermore, addition of bladder units to raise the float freeboard may subject mooring lines and stake piles to higher marine environmental loads than the design maximum. The effectiveness of thin concrete wall patch repair (especially underwater) and addition of bladder units is quite limited for a damaged and saturated float. Considering the typical 25-year service life of a marine structure, including light-duty breakwaters similar to the Port Orchard Breakwaters, the existing north and east breakwaters are overaged and have no effective long-term repair solutions. Therefore, it is necessary to plan for the replacement of the breakwaters to continue to protect the marina and provide waterfront access to the public. Figure 1 in Reference A shows a historical plan for installations and modifications of various Port Orchard Marina facility components including the breakwaters.

A value engineering study to evaluate five alternatives to replace the existing breakwaters was performed from July 24 to July 27, 2017. Three of the alternatives involved different mooring system options (reuse existing mooring lines and stake piles, new mooring lines and stake piles, and heavier float with new stake piles), and two of the alternatives involved concrete float options using a guide pile mooring system The preferred alternative consists of a new heavy-duty concrete float, with an expected service life of 50 years, and an upgraded cable mooring system. A preliminary concept design of the breakwaters based on the selected preferred alternative was developed to meet the main design criteria, which are to maintain the same footprint as the existing, to have a 50-year service life, and to have a minimum 18-inch freeboard under dead load. This effort was documented in reference A, originally in 2017, but then amended to include appendix C in June of 2019.

In 2019, the Port Commission decided that there was a desire to explore the possibility of replacing the Port Orchard Marina Breakwater with a wider float system, thus allowing for greater potential use of the Port Orchard Marina as a park amenity for the City, much like the Bremerton Marina Breakwater serves the City of Bremerton since it was built in 2008. The new breakwater should also be capable of handling temporary mooring of the cruise ships as is currently being carried out at the Bremerton Breakwater.

It was decided that two new float sections, 25’ and 20’ wide floats, would be designed to the concept level, and that both sections would be designed/analyzed for both a new interstitial guide pile system and a cable mooring system. In addition, Alternatives 3 and 4 in reference A would be revised to include interstitial guide piles, and the cost estimates for alternatives 0, 1 and 2 would be updated. Concept designs of all the nine resulting alternatives were developed with supporting concept level calculations and construction cost estimates, and the below report summarizing the results of the analysis was prepared for another Concept Design Review meeting conducted on October 22, 2019. Minutes of that meeting are included in Appendix A.

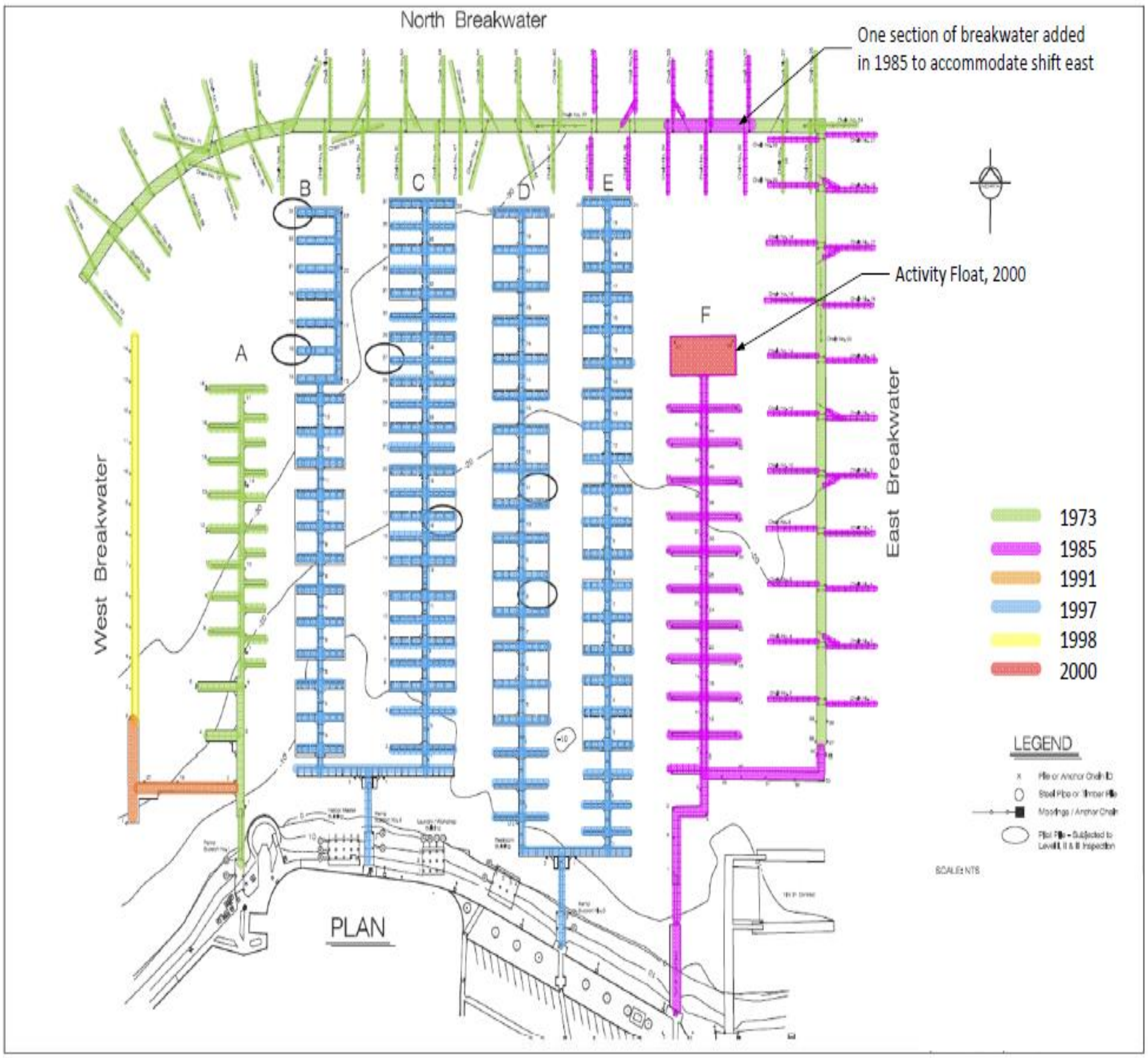


Figure 1 - Port Orchard Marina Historical Plan

Basis of Design

Concept Design Summary

Preliminary conceptual design for replacement of the North and East Breakwaters at Port Orchard Marina mainly includes design of typical section of the breakwater and guide piling system for the breakwater floats.

Codes and References

- 2016 Sea Level Rise and Coastal Flood Risk Summary for Kitsap County, Climate & Central
- 2012 and 2015 International Building Code
- 2010 Department of Justice ADA Standards for Accessible Design
- 2012 AASHTO LRFD Bridge Design Specifications
- ACI 318-11 Building Code Requirements for Structural Concrete
- AISC 325-11 Steel Construction Manual, 14th Edition (2011)
- ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures
- AWS D1.1-2010 Structural Welding Code – Steel
- Shore Protection Manual, SPM 2002, U.S. Army Coastal Engineering Research
- UFC 4-152-01 – Unified Facilities Criteria – Design: Piers and Wharves
- UFC 4-152-07N – DOD Design: Small Craft Berthing Facilities
- UFC 4-159-03 – DOD Design: Moorings
- Bremerton Marina Expansion, Breakwater Fabrication Package, Port of Bremerton, 2006
- Study for Bremerton Marina, Pacific International Engineering, 2003
- Marine Structures Engineering Specialized Applications, G. P. Tsinker, 1995

Datum

Vertical: MLLW

Water Levels

Tide	Elevation (ft, MLLW)
Highest Estimated Tide (HET)	+15.20
Mean Higher High Water (MHHW)	+ 11.74
Mean High Water (MHW)	+10.87
Mean Low Water (MLW)	+2.83
Mean Lower Low Water (MLLW)	0.00
Lowest Estimated Tide (LET)	-5.00

Service Life

50 years

Material Properties

Structural Steel

Wide Flanges	ASTM A992, Grade 50
Plates	ASTM A572, Grade 50
Angles and Channels	ASTM A36
Rods	ASTM A36
Pipe Pile	ASTM A252, Grade 3 Mod, F_y=60 ksi
	API 5L-X60, F_y=60 ksi
Tubes	ASTM A500, Grade B, f_y = 46 ksi
Bolts	ASTM A325 {ASTM A490}, A307, F593, A193
Welding Electrodes	E70XX

Aluminum

Aluminum gangway, guardrail, and transition plate shall be alloy 6061-T6 or 6063-T5.

Concrete

Normal-weight concrete (average 150 pcf)
Minimum compressive strength: 6,000 psi
Maximum water/cement (binder) ratio: 0.4

Foundations and Soils

Piles

Float Guide Pile: 30" diameter x 1" wall thickness steel pipe piling

Loads

Live Loads

Breakwater Float	60 psf uniform or 400 pound concentrated
Transition Plate	100 psf uniform or 400 pound concentrated

Wind Loads

Basic Wind Speed for Moorage Condition	98 mph
Exposure Category	C

Wind Generated Wave

Significant wave height, H_s 3.1 ft
Wave Period, T 3.5 sec

Vessel Wake

Wake (Ferry): height, H_w 2.0 ft

Wake Period, T 3.7 sec

Tidal Current

Current Speed: 0.1 knot

Sea Level Rise

Sea Level Rise: 4 ft. above MHHW (EL=+11.74) = +15.74

Design Vessel (Temporary Berth – Cruise Ship)

Vessel Length (LOA): 268 ft
Vessel Length (waterline): 246 ft
Vessel Beam: 55 ft
Vessel Displacement: 1217 net tons
Profile Height: 65 ft
Design Draft: 9 ft
Superstructure Wind Area: 6,923 SF
Hull Wind Area: 3,743 SF
Number of Vessels along the Breakwaters: One at a time
Length of stay: 1 Night
Berthing Speed (Normal to Berth): 1 fps

Design Vessel (Permanent Berths)

Vessel Length: 100 ft
Vessel Beam: 33 ft
Vessel Displacement: 720 long ton
Profile Height: 20 ft
Number of Vessels along the Breakwaters: Continuous
Berthing Speed (Normal to Berth): 1 fps

New Breakwater Float Section

Width: 12 ft (same footprint as existing),
25 ft. (same width as that of existing Bremerton Breakwater),

20 ft. (same width as that of previous (pre-2008) Bremerton Breakwater)

Minimum Length of Individual Float: 100 ft. long for 12 ft. wide breakwater and 50 ft. long for 25 ft. or 20 ft. wide breakwater. Individual float pontoons shall be rigidly connected by post-tensioning strands or rods.

Freeboard (under dead load): minimum 18 inches

Freeboard (under full live load): minimum 10 inches

Filled Material for Buoyancy: Coated EPS (Expanded Poly-Styrene) Foam

Port Orchard Marina Breakwater Concept Design Alternatives

Alternative concept designs considered in the Design Review Meeting and developed in this report include:

Alternative #0

Replace floats (12' wide, 5.75' deep) and stake piles to meet current codes. Concrete float with 4" top deck and 3" concrete walls on sides and bottom.

Alternative #1

Replace floats to meet current codes (12' wide, 5.75' deep) and only replace 25% stake piles (failing). Concrete float with 4" top deck and 3" concrete walls on sides and bottom. It was determined in the calculations included in appendix A that this alternative is no longer viable as the existing stake piles will not be able to withstand the forces absorbed by the deeper floats. This alternative was retained in the spreadsheets but evaluated with a Life cycle of zero to indicate it non-viability.

Alternative #2

Replace floats and stake piles with upgraded versions (12' wide, 5.75' deep) –Concrete float with 5" top deck and 4" concrete walls on sides and bottom and higher capacity stake piles.

Alternative #3

Replace floats with upgraded versions (12' wide, 5.75' deep) and replace stake piles with interstitial guide pile systems. Concrete float with 5" top deck and 4" concrete walls on sides and bottom and 30" diameter, 1" wall steel guide piles with interstitial pile hoops on one side only.

Alternative #4

Replace floats to meet current codes (12' wide, 5.75' deep) and replace stake piles with interstitial guide pile systems. Concrete float with 4" top deck and 3" concrete wall on sides and bottom and 30" diameter, 1" wall steel guide piles with interstitial pile hoops on one-side only.

Alternative #5

Replace floats with wider, upgraded versions (25' wide, 5.25' deep) and replace stake piles with interstitial guide pile systems on both sides of each float. Concrete float with 5" top deck and 4" concrete walls on sides and bottom and 30" diameter, 1" wall steel guide piles with interstitial pile hoops on each side.

Alternative #6

Replace floats with wider, upgraded versions (25’ wide, 5.25’ deep) and replace stake piles upgraded stake pile system. Concrete float with 5” top deck and 4” concrete walls on sides and bottom and upgraded stake piles and cable mooring system.

Alternative #7

Replace floats with wider, upgraded versions (20’ wide, 5.75’ deep) and replace stake piles with interstitial guide pile systems on both sides of each float. Concrete float with 5” top deck and 4”concrete walls on sides and bottom and 30” diameter, 1” wall steel guide piles with interstitial pile hoops on each side.

Alternative #8

Replace floats with wider, upgraded versions (20’ wide, 5.75’ deep) and replace stake piles upgraded stake pile system. Concrete float with 5” top deck and 4” concrete walls on sides and bottom and upgraded stake piles and cable mooring system.

12’ Wide Cable Moored Breakwater Alternatives – Mooring Installation Plans/Float Cross-Section

Alternatives #0 through #4 all use 12’ wide sections like the existing floats at the Port Orchard Marina breakwater, except that the pontoons to be built in these new alternative designs are completely enclosed concrete boxes. Alternatives #0, #1 and #2, all utilize cable/chain mooring systems. Typical section of breakwater and installation of breakwater plan are shown in Figures 2 and 3. Approximately 60 cable moorings are required for each of these designs. Note that concrete thickness of the walls is decreased for Alternatives #0 and #1, and the cable mooring system is upgraded on Alternative #2.

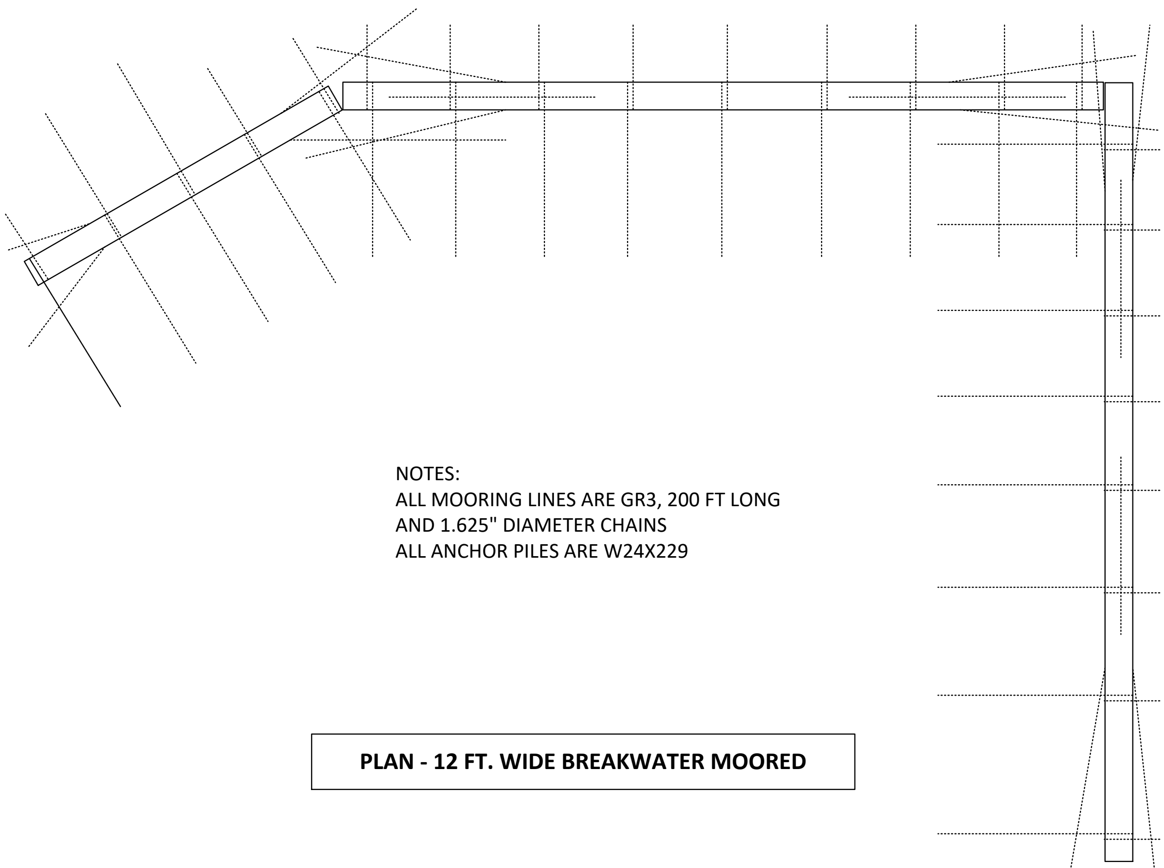


Figure 2 - Typical Cable Mooring System Installation Plan for 12' Wide Floats (60 Cables)

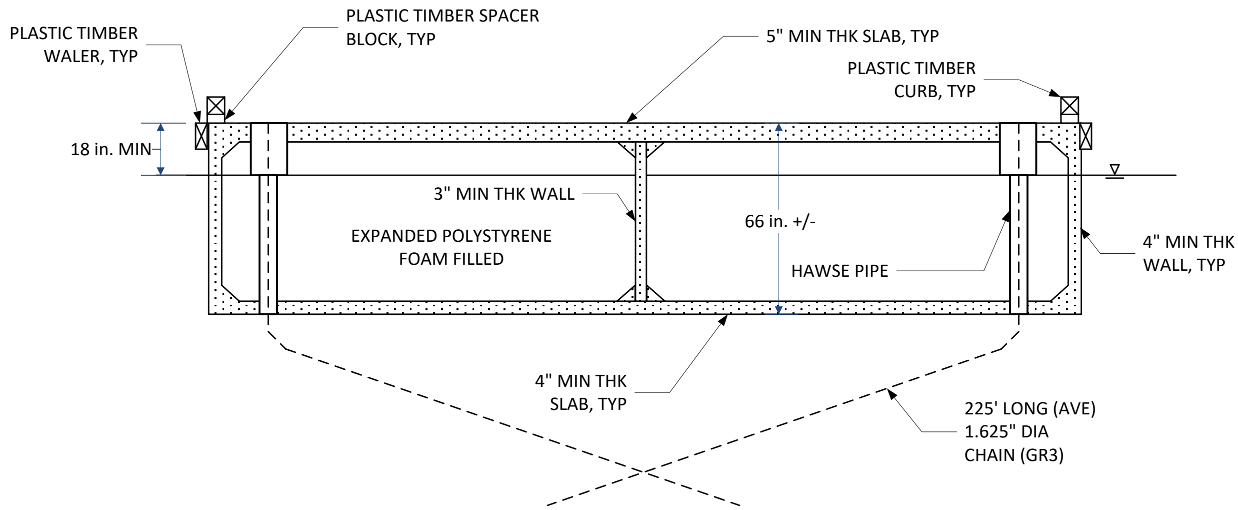


Figure 3 - Typical Cable Moored Float Cross Section for 12', 20', and 25' Wide Floats

12’ Wide Breakwater Interstitial Pile Moored Alternatives – Mooring Installation Plans/Float Cross-Section

Alternatives #3 and #4 use 12’ wide sections, like the existing floats at the Port Orchard Marina Breakwater, except that the pontoons to be built in these new alternative designs are completely enclosed concrete boxes. Alternatives #3 and #4 both utilize Interstitial Guide Pile mooring systems, however because of the 12’ width of the floats, interstitial piles can only be used on one side of the breakwater. On the other side of the breakwater, the guide piles must be employed with normal pile hoops. Typical section of breakwater and installation of breakwater plan are shown in Figures 4 and 5. Approximately 34 - 30” diameter 1” thick wall steel guide piles are required for each of these designs. Note that concrete thickness of the walls is decreased for Alternative #4.

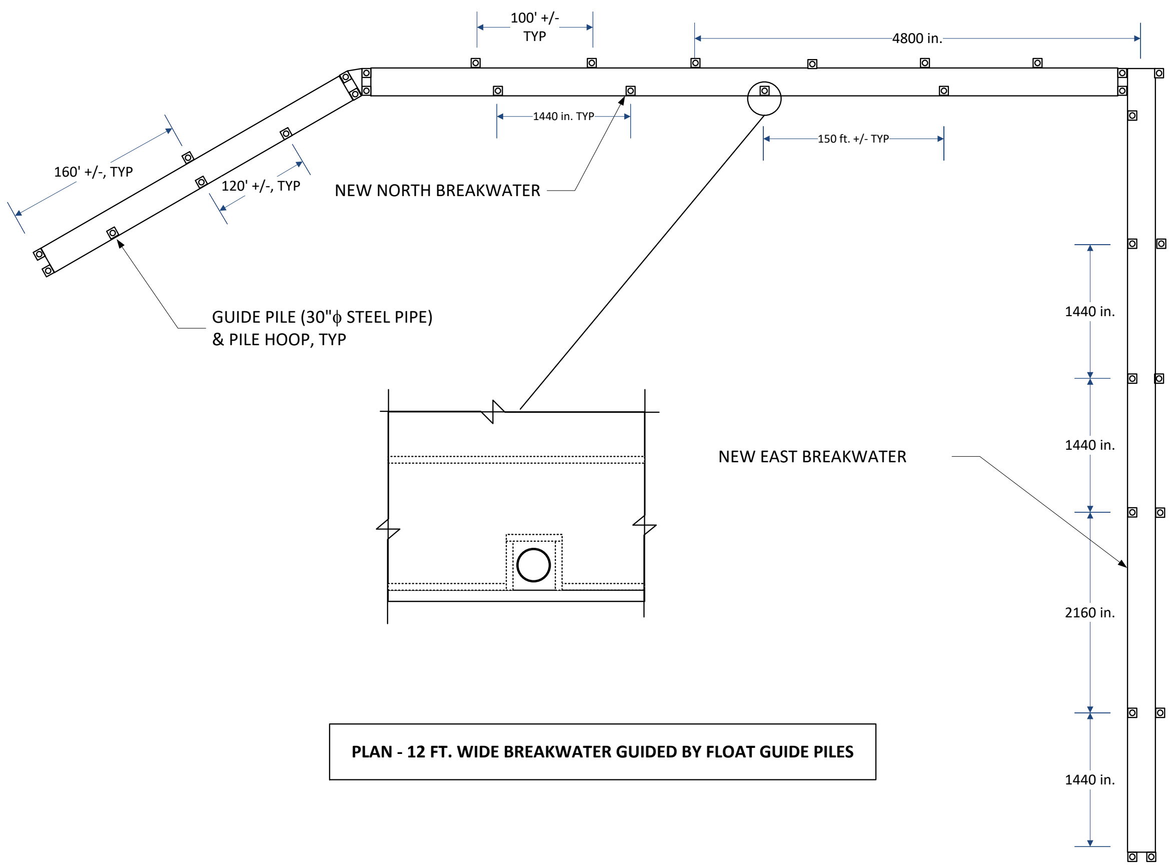


Figure 4 - Typical Interstitial Guide Pile Mooring System Installation Plan for 12’ Wide Floats (34 Piles)

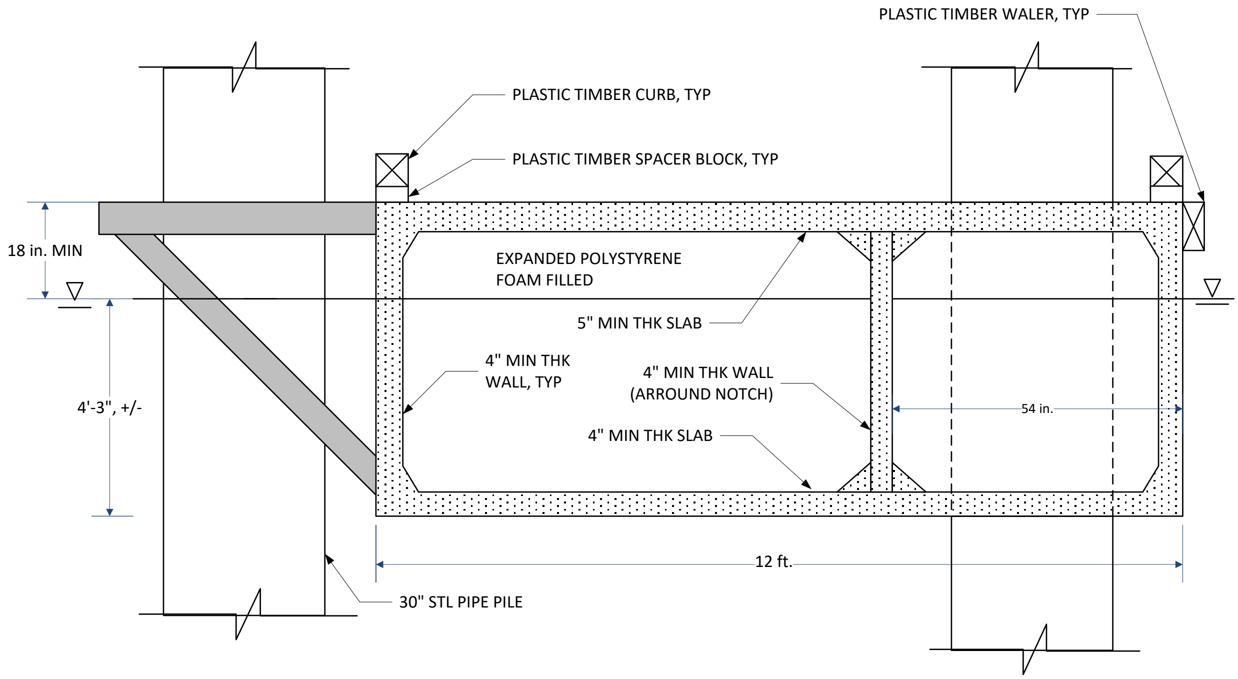


Figure 5 - Typical Interstitial Guide Pile Moored Float Cross-Section for 12' Wide Floats

25' & 20' Wide Floats Interstitial Pile Moored Alternatives – Mooring Installation Plans/Float Cross-Section

The installation plans and cross-sections for the interstitial guide pile moored breakwater versions using the 25' wide float (Alternative #5) and 20' wide float (Alternative #7) are similar. This installation plan is shown in Figure 6 and a typical cross-section is shown in Figure 7.

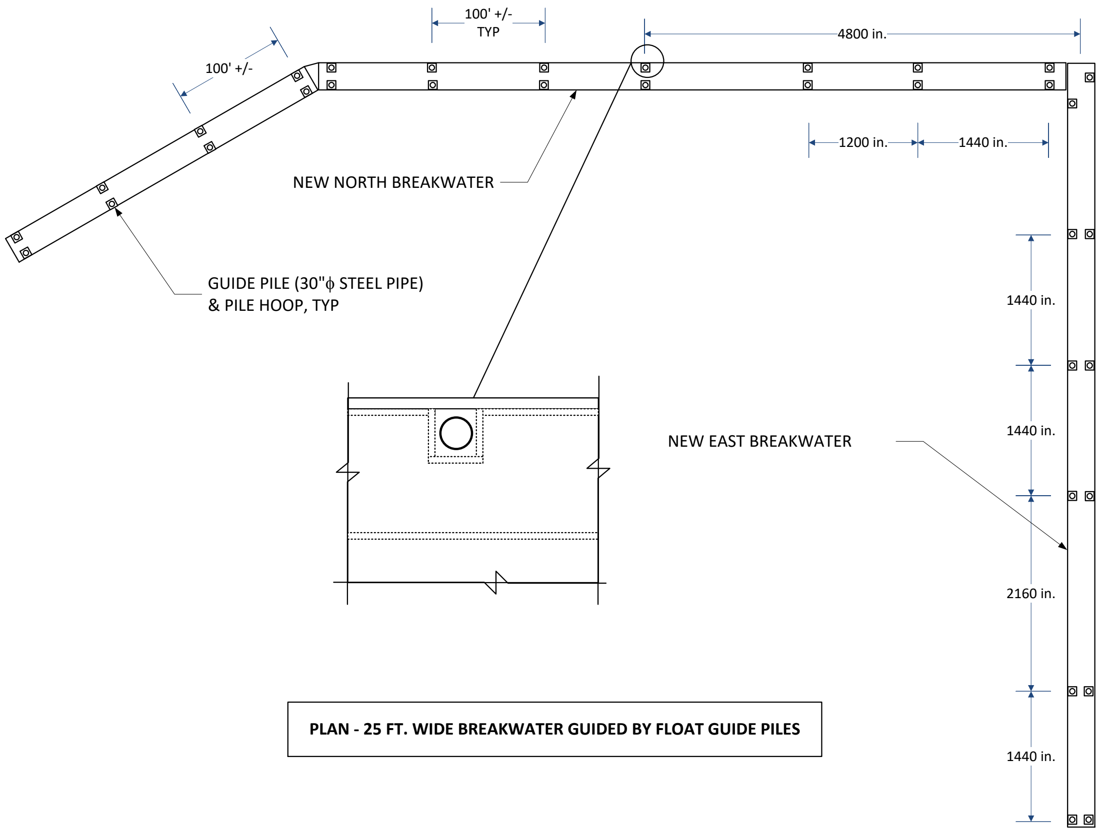


Figure 6 - Typical Interstitial Guide Pile Mooring System Installation Plan for 25 and 20' Wide Floats (34 Piles)

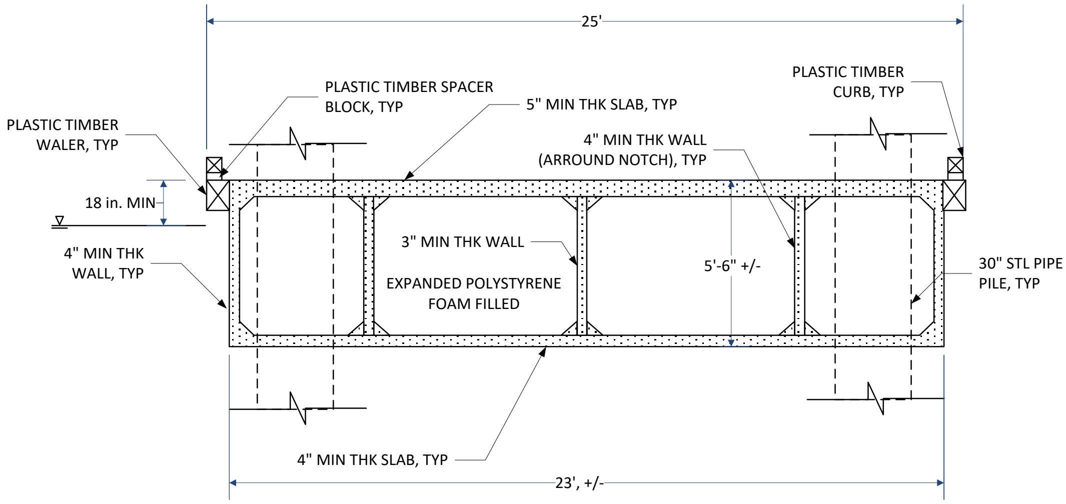


Figure 7 - Typical Interstitial Guide Pile Moored Float Cross-Section for 20 and 25' Wide Floats

25’ &20’ Wide Floats Cable Moored Alternatives – Mooring Installation Plans/Float Cross-Section

The installation plans and cross-sections for cable moored breakwater versions using the 25’ wide float (Alternative #6) and 20’ wide float (Alternative #8) are similar.

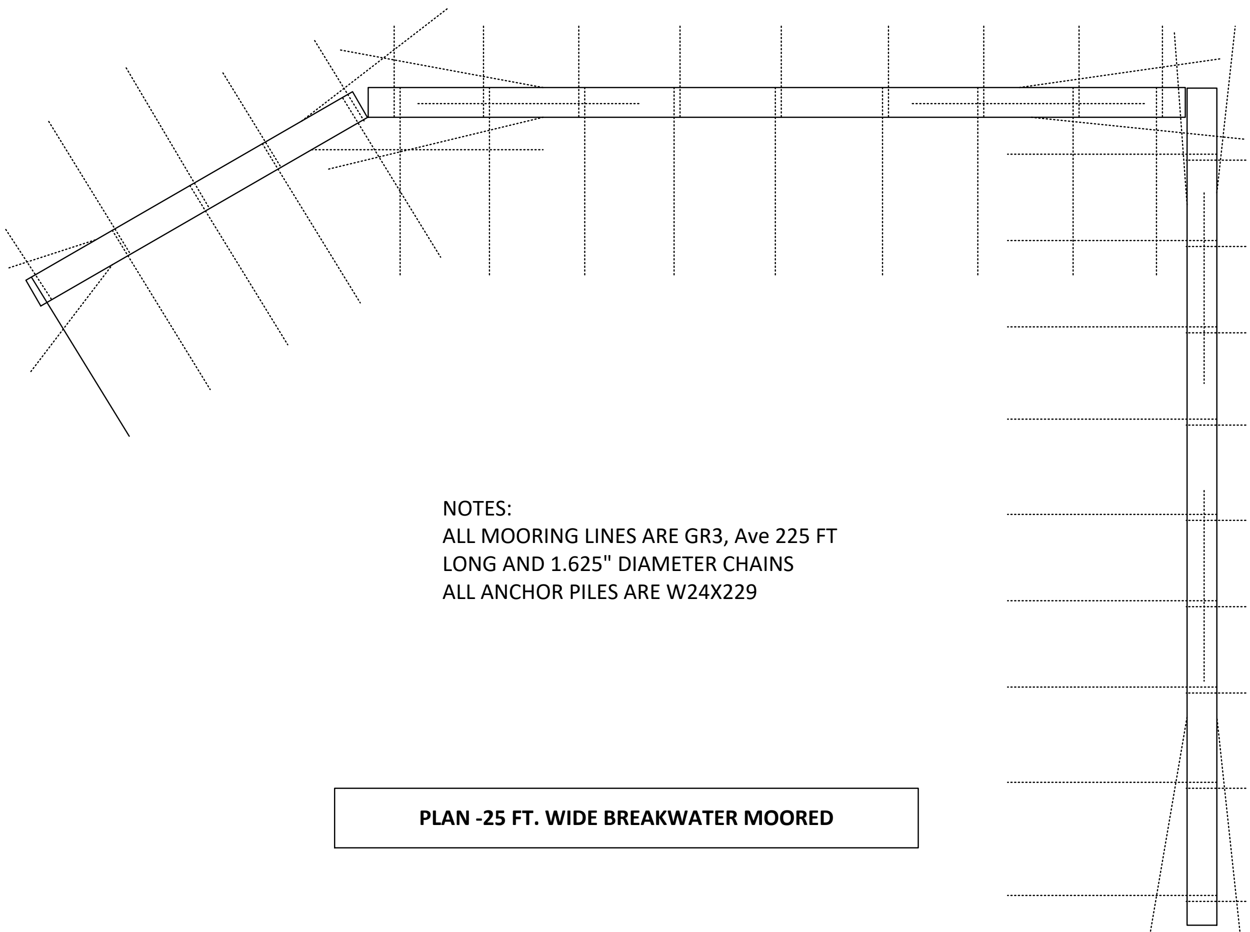


Figure 8 - Typical Cable Moored System Installation Plan for 25 and 20’ Wide Floats (62 Cables)

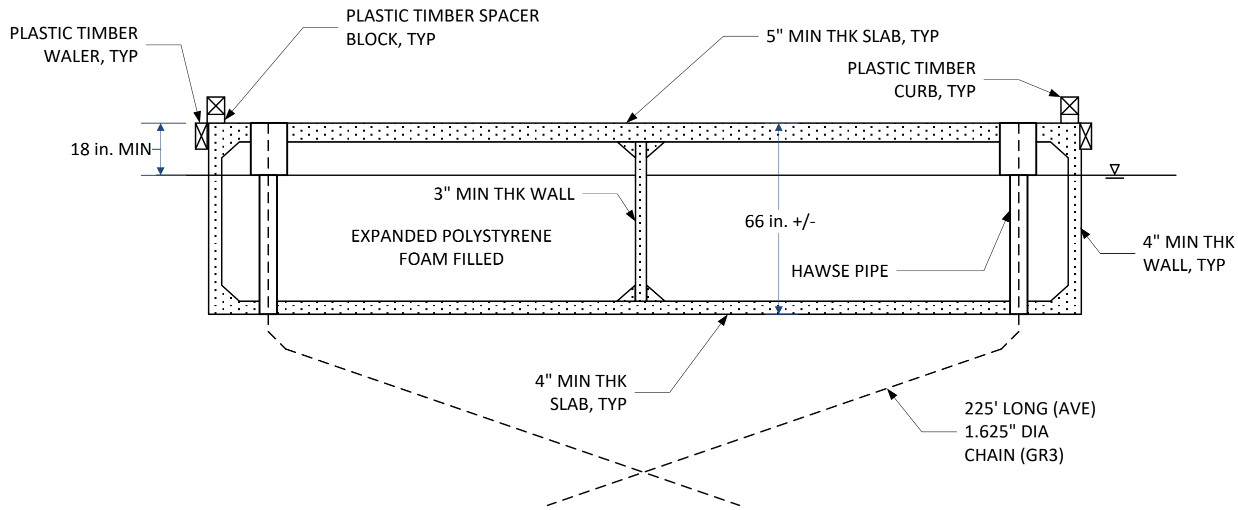


Figure 9 – Typical Cable Moored Float Cross-Section for 25' and 20' Wide Floats

Opinion of Probable Construction Cost

A Rough Order of Magnitude (ROM) estimate of construction cost for the replacement of north and east breakwaters at Port Orchard Marina was performed and a summary of the cost estimate for the breakwater replacement project for each alternative, including the indirect costs (contingency, contractor's overhead and profit, taxes, permitting and mitigation costs, and design fees) is shown on the table below. A summary of estimated annual cost for maintenance for each alternative also is shown in this table at the very bottom of the spreadsheet.

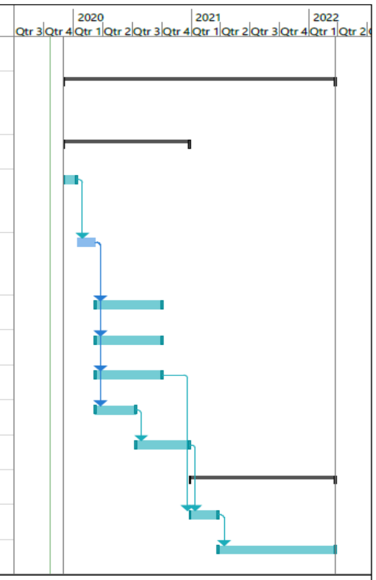
ROM COST ESTIMATE WORKSHEET
ART ANDERSON ASSOCIATES

ITEMS	QUANTITY			FIRST COST OF CONSTRUCTION								
DESCRIPTION OF WORK	#	UNIT	Unit $	Alt #0	Alt #1	Alt #2	Alt #3	Alt #4	Alt #5	Alt #6	Alt #7	Alt #8
Mobilization	1	LS	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Remove exst floats	19,700	SF	$15	$295,500	$295,500	$295,500	$295,500	$295,500	$295,500	$295,500	$295,500	$295,500
Demo all exst float chains/cables	70	EA	$400	$28,000		$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000
Demo 25% exst float chains/Cables (alt 1)	17	EA	$400		$6,800							
Demo all exst stake piles	70	EA	$3,000	$210,000		$210,000	$210,000	$210,000	$210,000	$210,000	$210,000	$210,000
Demo 25% exst stake piles (alt 1)	17	EA	$3,000		$51,000							
New 12'W x 5.75'H floats (4" top/3" sides+btm)	19,700	SF	$200	$3,940,000	$3,940,000			$4,137,000				
New 12'W x 5.75'H floats (5" top/4" sides+btm)	19,700	SF	$220			$4,334,000	$4,550,700					
New 20'W x 5.75'H floats (5" top/4" sides+btm)	33,000	SF	$260								$8,580,000	$8,580,000
New 25'W x 5.25'H floats (5" top/4" sides+btm)	41,000	SF	$270						$11,070,000	$11,070,000		
New Interstitial GuidePiles (30" diameter, 1" wall)	34	EA	$17,000				$481,667	$481,667	$578,000		$578,000	
New stake piles (W24 x 229)	62	EA	$8,000	$496,000		$644,800				$744,000		$744,000
25% New stake piles (W24 x 229) Alt 1	17	EA	$8,000		$136,000							
New mooring lines (200'L with 1-5/8' chain)	62	EA	$1,500	$93,000		$120,900				$139,500		$139,500
25% New mooring lines (200'L with 1-5/8' chain) Alt 1	17	EA	$1,500		$25,500							
Wet + drystandpipe fire suppression/Potable Water	19,700	SF	$25	$492,500	$492,500	$492,500	$492,500	$492,500	$640,250	$640,250	$640,250	$640,250
Electrical power/distribution/Lighting	19,700	SF	$45	$886,500	$886,500	$886,500	$886,500	$886,500	$1,152,450	$1,152,450	$1,152,450	$1,152,450
Mooring/Float Accessories (allow)	1	LS	$15,500	$15,500	$15,500	$15,500	$15,500	$15,500	$15,500	$15,500	$15,500	$15,500
Permits - Same Footprint	1	LS	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000				
Permits - Larger Floats	1	LS	$100,000						$100,000	$100,000	$100,000	$100,000
Mitigation - Larger Floats	1	LS	$250,000						$250,000	$250,000	$250,000	$250,000
Demobilization	1	LS	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
DIRECT LABOR/MATERIAL ITEM SUBTOTAL				**$6,627,000**	**$6,019,300**	**$7,197,700**	**$7,130,367**	**$6,716,667**	**$14,489,700**	**$14,795,200**	**$11,999,700**	**$12,305,200**
GENERAL CONDITIONS ITEMS	QUANTITY											
Description of Item	#	UNIT	UNIT($)									
Project Manager/Field Supervision Cost	10%	LS		$662,700	$601,930	$719,770	$713,037	$671,667	$1,448,970	$1,479,520	$1,199,970	$1,230,520
SUBTOTAL				**$662,700**	**$601,930**	**$719,770**	**$713,037**	**$671,667**	**$1,448,970**	**$1,479,520**	**$1,199,970**	**$1,230,520**
CONTRACTOR'S OVERHEAD	15%			$1,093,455	$993,185	$1,187,621	$1,176,511	$1,108,250	$2,390,801	$2,441,208	$1,979,951	$2,030,358
CONTRACTOR'S PROFIT	10%			$728,970	$662,123	$791,747	$784,340	$738,833	$1,593,867	$1,627,472	$1,319,967	$1,353,572
BONDS/INSURANCE	3%			$218,691	$198,637	$237,524	$235,302	$221,650	$478,160	$488,242	$395,990	$406,072
SUBTOTAL				**$2,041,116**	**$1,853,944**	**$2,216,892**	**$2,196,153**	**$2,068,733**	**$4,462,828**	**$4,556,922**	**$3,695,908**	**$3,790,002**
BID ADDITIVE ITEMS												
N/A			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
N/A			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
LABOR & MATERIALS SUBTOTAL				**$9,330,816**	**$8,475,174**	**$10,134,362**	**$10,039,556**	**$9,457,067**	**$20,401,498**	**$20,831,642**	**$16,895,578**	**$17,325,722**
BREMERTON SALES TAX	9%			$839,773.44	$762,765.70	$912,092.54	$903,560.06	$851,136.00	$1,836,134.78	$1,874,847.74	$1,520,601.98	$1,559,314.94
DESIGN/ENGINEERING FEE*	15%			$1,399,622	$1,271,276	$1,520,154	$1,505,933	$1,418,560	$3,060,225	$3,124,746	$2,534,337	$2,598,858
DESIGN CONTINGENCY	10%			$933,081.60	$847,517.44	$1,013,436.16	$1,003,955.63	$945,706.67	$2,040,149.76	$2,083,164.16	$1,689,557.76	$1,732,572.16
CONSTRUCTION EST CONTINGENCY	15%			$1,399,622.40	$1,271,276.16	$1,520,154.24	$1,505,933.44	$1,418,560.00	$3,060,224.64	$3,124,746.24	$2,534,336.64	$2,598,858.24
ESCALATION TO 2021	6%			$559,849	$508,510	$608,062	$602,373	$567,424	$1,224,090	$1,249,898	$1,013,735	$1,039,543
SUBTOTAL				**$5,131,949**	**$4,661,346**	**$5,573,899**	**$5,521,756**	**$5,201,387**	**$11,220,824**	**$11,457,403**	**$9,292,568**	**$9,529,147**
* Note: permitting costs are not included in this design fee estimate												
GRAND TOTAL				**$14,460,000**	**$13,140,000**	**$15,710,000**	**$15,560,000**	**$14,660,000**	**$31,620,000**	**$32,290,000**	**$26,190,000**	**$26,850,000**
~~**Annual Operations & Maintenance Costs**~~				**$584,000**	**$527,000**	**$636,000**	**$622,000**	**$586,000**	**$1,265,000**	**$1,300,000**	**$1,048,000**	**$1,083,000**

Project Schedule

There are two potential schedules for all 12' wide Alternatives driven by the design process and the 20-25' alternatives driven by the permitting process.

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1						
2		**Replacement of N & E Breakwaters at Port Orchard Marina - 12' wide**	**604 days**	**Mon 12/2/19**	**Thu 3/24/22**	
3		**Design and permit**	**280 days**	**Mon 12/2/19**	**Fri 12/25/20**	
4		Issue and Award RFQ for design	30 days	Mon 12/2/19	Fri 1/10/20	
5		35% Design For Permit Application	40 days	Mon 1/13/20	Fri 3/6/20	4
6		NWP-3 (USACE) Permit Effort	150 days	Mon 3/9/20	Fri 10/2/20	5
7		HPA/Shoreline Permit Effort	150 days	Mon 3/9/20	Fri 10/2/20	5
8		Mitigation Effort	150 days	Mon 3/9/20	Fri 10/2/20	5
9		Design Develelopment	90 days	Mon 3/9/20	Fri 7/10/20	5
10		Final Design	120 days	Mon 7/13/20	Fri 12/25/20	9
11		**Bid & Construction**	**324 days**	**Mon 12/28/20**	**Thu 3/24/22**	
12		Bid - Advertise & Award	64 days	Mon 12/28/20	Thu 3/25/21	10,8
13		Construction	260 days	Fri 3/26/21	Thu 3/24/22	12



Project: PO Breakwater Replace
Date: Mon 10/21/19

Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress

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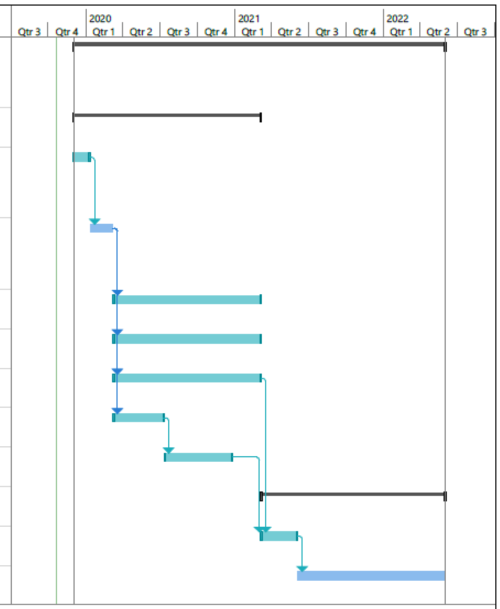
Figure 10 - 12' Wide Alternative

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Replacement of N & E Breakwaters at Port Orchard Marina - 20-25' wide**	**654 days**	**Mon 12/2/19**	**Thu 6/2/22**	
2		**Design and permit**	**330 days**	**Mon 12/2/19**	**Fri 3/5/21**	
3		Issue and Award RFQ for design	30 days	Mon 12/2/19	Fri 1/10/20	
4		35% Design For Permit Application	40 days	Mon 1/13/20	Fri 3/6/20	3
5		Individual Permit (USACE) Effort	260 days	Mon 3/9/20	Fri 3/5/21	4
6		HPA/Shoreline Permit Effort	260 days	Mon 3/9/20	Fri 3/5/21	4
7		Mitigation Effort	260 days	Mon 3/9/20	Fri 3/5/21	4
8		Design Develelopment	90 days	Mon 3/9/20	Fri 7/10/20	4
9		Final Design	120 days	Mon 7/13/20	Fri 12/25/20	8
10		**Bid & Construction**	**324 days**	**Mon 3/8/21**	**Thu 6/2/22**	
11		Bid - Advertise & Award	64 days	Mon 3/8/21	Thu 6/3/21	7,9
12		Construction	260 days	Fri 6/4/21	Thu 6/2/22	11



Project: PO Breakwater Replace
Date: Mon 10/21/19

Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress

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Figure 11 - 20-25' Wide Alternative

Trade-Off Analysis of Alternatives

Trade-Off Analysis Criteria

The critical issues to consider in this analysis are those issues that will most greatly influence the decision to be made by the Port Commissioners. These are:

First Cost impacts

1. Estimated Construction Cost – represented as a cost value from the estimated cost spreadsheet.

2. Constructability – This is a measure of the likelihood of getting competitive bids. Complexity of construction, length of float modules, etc., can significantly influence the number of bidders and ultimate first cost.

Lifecycle impacts

1. Estimated Annual Maintenance Cost – represented as a cost value from the estimated cost spreadsheet

2. Impacts on Port Maintenance Staff – Time/resource impacts requiring greater than normal attention from Port Maintenance Staff will reduce this grade.

3. Estimated Lifecycle – all alternative using new materials will be designed to 50-year life cycle. Re-use of components lowers the expected lifecycle of the overall system.

Permitting/Mitigation Impacts

1. Permitting Impacts on Schedule – Larger floats will cause the need for an Individual Permit and longer approval times. This delays execution which will increase costs due to inflation in labor and material and delays beneficial use.

2. Permitting and Mitigation Costs – represented as a cost value from the estimated cost spreadsheet

Functionality

Note that all alternatives provide adequate protection to the Marina.

1. Flexibility in providing Permanent Berthing Spaces on the inside of the Breakwater – Guide piles, whether interstitial or not, impact the ability for flexible spacing of permanent mooring positions.

2. Ease of ability to provide a suitable temporary berth for the Cruise Vessel, close to shore access points, if possible.

3. Ability of the breakwater to serve as a community amenity (park). Available clear space on the deck of the breakwater to allow public waterfront access for community activities conforming to ADA requirements and other beneficial use as a Park Amenity.

For the initial analysis, First Cost was given a weight of 3, Annual Maintenance Cost was given a weight of 2, Lifecycle was given a weight of 2, and the remaining criteria were weighted at 1. If a change to the weighting of the factors is desired, this can be corrected during the review process.

Another important consideration is availability and capability of local float manufacturers. Below is a table of local vendors and their capabilities. These factors will be important criteria to be considered during the design phase. Concept design assumes that sections will be designed and built to maximize competition during bidding, and that the resulting sections will be rigidly connected for each straight section via post-tensioning cables – similar to what was done for the Bremerton breakwater in 2007.

Table 2 - Summary Maximum Sizes (Approx.) of Individual Pontoons

Manufacturers	Facility and/or Equipment for Launching and Lifting	Max. Effective Lifting Capacities (kip)	Max. Effective Length for 25 ft. Wide Float (ft.)	Max. Effective Length for 12 ft. Wide Float (ft.)
Concrete Tech	Graving Dock	Unlimited	200	200
Concrete Tech	Precast Plant	120	25	50
Bellingham Marine	150-ton Travel Lift	250	50	100
Bellingham Marine	Precast Plant Crane	120	25	50
Manson Construction	Submersible Ocean Barge	642	160	160

Performance results for various widths of breakwater float are shown below. This table demonstrates that the new 12’ section for the breakwater is nearly as effective as the 20’ section in attenuating waves.

Table 3 - Breakwater Performance for Wave Height 3.1 ft.

Breakwaters	Transmission Coefficient, K_t	Transmitted Wave Height (ft.) inside Marina
Existing – 12’ wide x 3’ deep	0.77	2.4’
New – 12’ wide x 5.75’ deep	0.66	2.0’
New – 20’ wide x 5.75’ deep	0.51	1.6’
New – 25’ wide x 5.5’ deep	0.45	1.4’

Grading Standards for Quantitative Analysis

The below table describes the criteria used for determining the quantitative scores for each option.

Scoring Values/Ranges for Each Criterion						
	Weighting Factor	Low (L)	Medium Low (ML)	Medium (M)	Medium High (MH)	High (H)
Quantitative Score		1	2	3	4	5
First Cost Impacts	-	-	-	-	-	-
Estimated Construction Cost	3	>$30,000,001	$25,000,001-$30,000,000	$20,000,001-$25,000,000	$15,000,000-$20,000,000	<$15,000,000
Constructability	1	L	ML	M	MH	H
Lifecycle Impacts	-	-	-	-	-	-
Estimated Annual Maintenance Cost	2	>$800,000	$600,001-$800,000	$400,001-$600,000	$200,001-$400,000	<$200,000
Impacts on Port Maintenance Staff	1	H	MH	M	ML	L
Estimated Lifecycle (years)	2	0-25	>25 - 30	>30 - 35	>35 - 40	>45
Permitting/Mitigation	-	-	-	-	-	-
Schedule Impacts (Months delay)	1	> 6	5-6	3-4	1-2	0
Permitting/Mitigation Costs	1	>$500,000	$400,001-$500,000	$300,001-$400,000	$200,001-$300,000	< $200,000
Functionality	-	-	-	-	-	-
Permanent Berth Flexibility	1	L	ML	M	MH	H
Suitable Cruise Vessel Berth	1	L	ML	M	MH	H
Community Amenity Value	1	L	ML	M	MH	H

Table 4 - Scoring Values/Ranges for Each Criterion

Evaluation Values for Each Alternative

Inputs for evaluating alternative scores are provided below:

Table 5 - Evaluation Values for Each Criterion

Evaluation Values for Each Criterion

	Weighting Factor	Alt #0	Alt #1	Alt #2	Alt #3	Alt #4	Alt #5	Alt #6	Alt #7	Alt #8
First Cost Impacts	-	-	-	-	-	-	-	-	-	-
Estimated Construction Cost	3	$14,460,000	$13,140,000	$15,710,000	$15,560,000	$14,660,000	$31,620,000	$32,290,000	$26,190,000	$26,850,000
Constructability	1	M	L	MH	MH	MH	MH	MH	MH	MH
Lifecycle Impacts	-	-	-	-	-	-	-	-	-	-
Estimated Annual Maintenance Cost	2	$584,000	$527,000	$636,000	$622,000	$586,000	$1,265,000	$1,300,000	$1,048,000	$1,083,000
Impacts on Port Maintenance Staff	1	M	MH	M	ML	M	ML	M	ML	M
Estimated Lifecycle	2	35	0	50	50	35	50	50	50	50
Permitting/Mitigation	-	-	-	-	-	-	-	-	-	-
Schedule Impacts	1	0	0	0	2	2	6	6	6	6
Permitting/Mitigation Costs	1	$20,000	$20,000	$20,000	$20,000	$20,000	$350,000	$350,000	$350,000	$350,000
Functionality	-	-	-	-	-	-	-	-	-	-
Permanent Berth Flexibility	1	L	L	MH	M	M	MH	H	MH	H
Suitable Cruise Vessel Berth	1	L	L	MH	ML	ML	MH	H	MH	H
Community Amenity Value	1	ML	ML	M	ML	ML	MH	H	MH	H

Quantitative Values for Each Alternative

Quantitative Scores for the Alternatives are shown below: Update the scores for the changes above.

Table 6 - Quantitative Values for Each Criterion

Quantitative Values for Each Criterion

	Weighting Factor	Alt #0	Alt #1	Alt #2	Alt #3	Alt #4	Alt #5	Alt #6	Alt #7	Alt #8
First Cost Impacts	-	-	-	-	-	-	-	-	-	-
Estimated Construction Cost	3	5	5	4	4	5	1	1	2	2
Constructability	1	3	1	4	4	4	4	4	4	4
Lifecycle Impacts	-	-	-	-	-	-	-	-	-	-
Estimated Annual Maintenance Cost	2	3	3	2	2	3	1	1	1	1
Impacts on Port Maintenance Staff	1	3	2	3	4	3	4	3	4	3
Estimated Lifecycle	2	2	1	5	5	2	5	5	5	5
Permitting/Mitigation	-	-	-	-	-	-	-	-	-	-
Schedule Impacts	1	5	5	5	4	4	2	2	2	2
Permitting/Mitigation Costs	1	5	5	5	5	5	3	3	3	3
Functionality	-	-	-	-	-	-	-	-	-	-
Permanent Berth Flexibility	1	1	1	4	3	3	4	5	4	5
Suitable Cruise Vessel Berth	1	1	1	4	2	2	4	5	4	5
Community Amenity Value	1	2	2	3	2	2	4	5	4	5
Sum of Values		30	26	39	35	33	32	34	33	35
Sum of weighted values		45	40	54	50	48	40	42	43	45

Summary and Recommendations

Short-term repairs including mortar patching and the addition of bladder units are no longer effective to extend service lives of the existing overaged north and east breakwaters. It is recommended that replacement of the breakwater floats with new heavier duty units, which last minimum 50 years.

Because of the relatively shallow water in this marina (compared to that of Bremerton) the use of guide piling system is feasible for installation of the new breakwaters because it is competitive in cost with the stake pile/cable moored system. However, there are positive and negative considerations for both methods of mooring the floats:

1. External guide pile hoops complicate temporary berthing space and limit permanent berthing space along the breakwater. This impact is especially significant for the 12' wide floats because guide piles on one side or the other of each 12' wide float will need to be moored with external pile hoops.
2. Interstitial guide piles act as interferences to diminish deck space for use for community events and other uses. This impact is also especially significant for the 12' wide floats.
3. Even Interstitial piles will complicate permanent berthing layouts, as the extending pile presents an obstruction for gangways, maintenance, etc.
4. Guide piles are more accessible than cable mooring systems for maintenance, and thus have a lower annual maintenance cost.
5. The first cost of both mooring systems is about the same.
6. While the annual maintenance cost for a cable moored system is higher than that for a guide pile system, the requirement for annual inspections of the cable moored system tends to ensure that corrosion is managed more diligently, thus extending the lifecycle of a cable moored system over that of a guide pile mooring system.
7. A cable moored system is preferred for a 12'wide float system and graded out highest (alternative #2) with a cumulative weighted sum of 54 in the trade off analysis. A summary of the comparison of alternative is included in Appendix C.

In Appendix D, three alternatives were developed for consideration as a separate project to address the current ADA access deficiencies to the East and North Breakwater. The recommendation is to implement Option #3 as soon as funding can be made available and design completed.

Appendix A – 2019 Concept Design Review Meeting Minutes

Appendix B – Revised Concept Design Calculations

Appendix C – Comparison of Alternatives - Matrix

Appendix D – Breakwater ADA Access Considerations

Background

The existing breakwater is currently accessed from a pier and gangway that provides access to the F floats, the activity/event float, and to the breakwater via connecting walkway floats and guide piles. This existing access exceeds slope requirements for ADA access. With the design and construction of a new breakwater, there is an assumed intent that ADA access will either be desired or required depending on potential funding requirements. Note that the F Floats and walkway floats are over 30 years old and a target for future replacement which could also include an ADA access improvement as part of that scope (versus a stand-alone project). The options considered do not include replacement of the entire system – only selected portions of that float system. The following options are very conceptual approaches to providing that ADA access.

Recommendation

Based on First Cost, the likely recommended option would be Option 3.

Option #1 - Develop new ADA Access Via Exiting Gate 4 - 100 ft Ramp Straight.

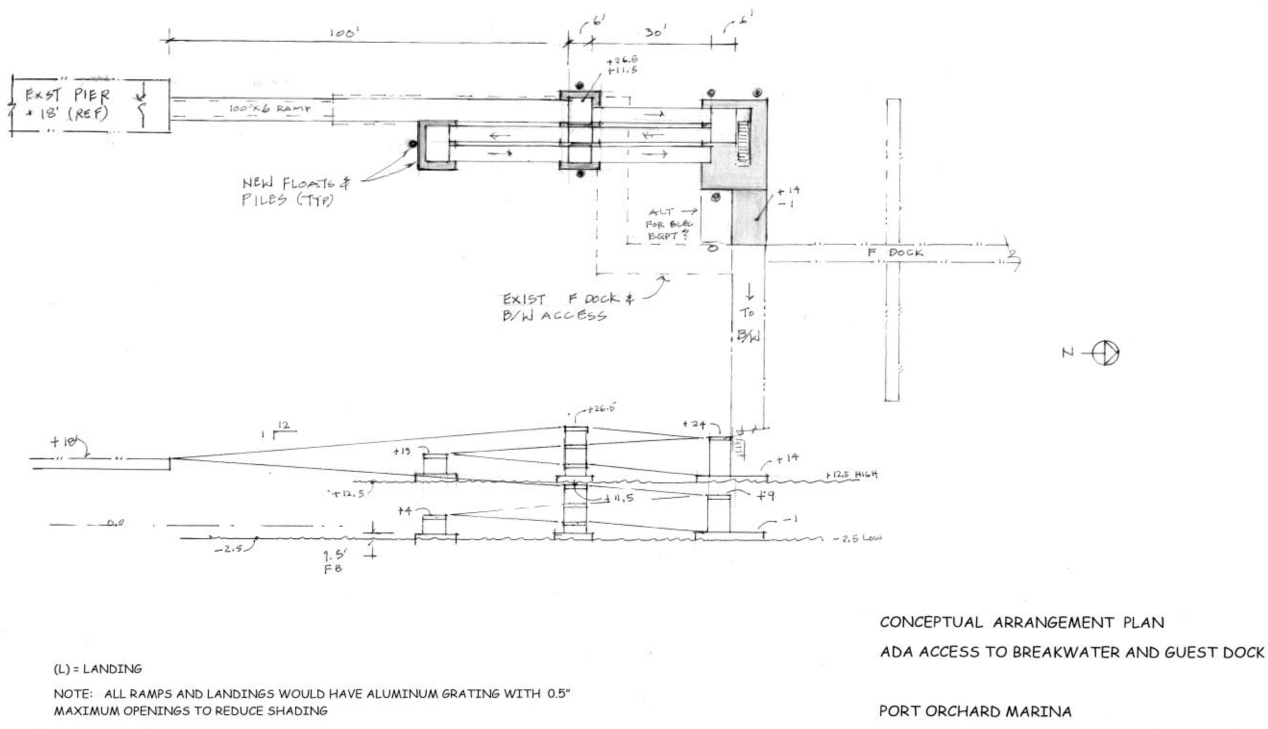
Description

Option #1 utilizes a 100-foot gangway from the fixed pier to a floating platform that then leads one to a series of 30-foot-long ramp sections with intermediate landings, as well as to a landing with stairs. This configuration is generically similar to the Bremerton marina access. ADA allows for the gangway to be compliant during a majority of tidal conditions. The 30-foot ramp sections with landings are strictly compliant with the ADA requirements. This option would eliminate the double 90-degree directions of the existing configuration but would also decrease the number of F float boat slips by two slips. This configuration would need three stair/ramp tower floats with piles and a connecting float section to the F float walkway that leads to the breakwater.

Cost Estimate

Detailed ROM cost estimate in Attachment 1. ROM costs are projected to be approximately $1.5 – 1.8 Million.

Option 1 Concept Sketch



Option #2 - Develop new ADA Access Via Exiting Gate 4 - 80 ft Ramp – 90 Degree

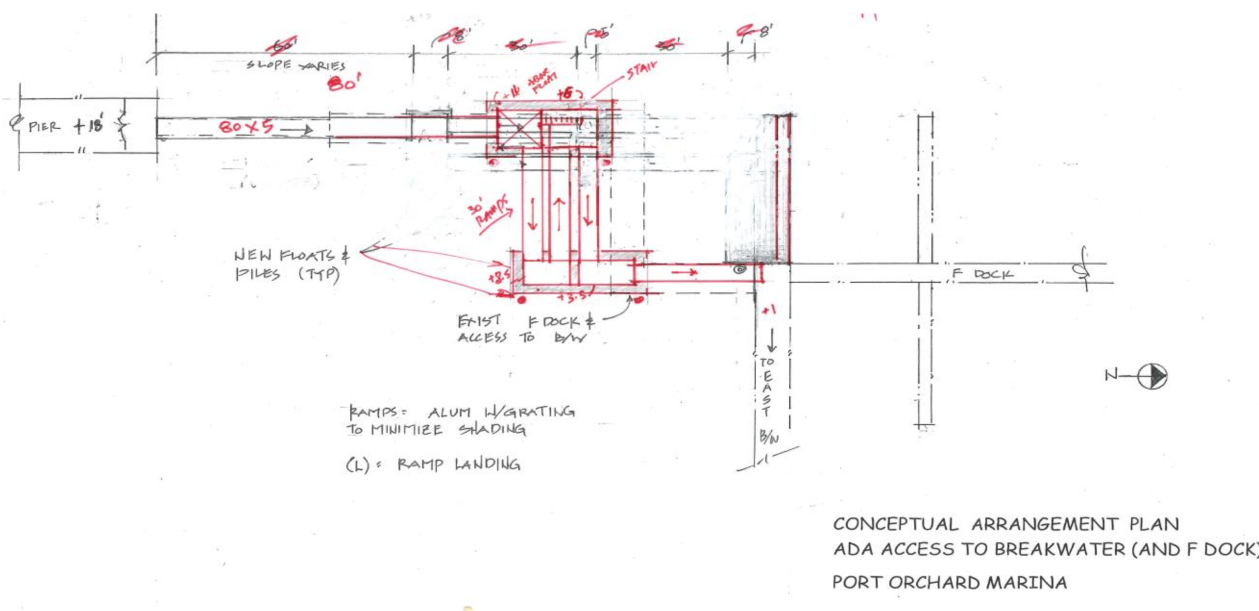
Descriptions

Option 2 is an attempt to decrease the impacts to the F float boat slip configuration and number of stair/ramp tower floats. This option utilizes an 80-foot gangway from the fixed pier to a floating stair and ramp tower that leads one to a series of 30-foot ramps and intermediate landings. The stairs in this configuration still lead to two of the ramp sections versus a full stair. As in Option #1, the gangway has more flexible ADA requirements while the rest of the ramps and landings are in strict compliance. This option removes the existing double 90-degree float configuration and decreases the number of boat slips by one versus two slips. This option would need two, larger stair/ramp floats with guide piles and final ramp connects to the existing walkway to the breakwater.

Cost Estimate

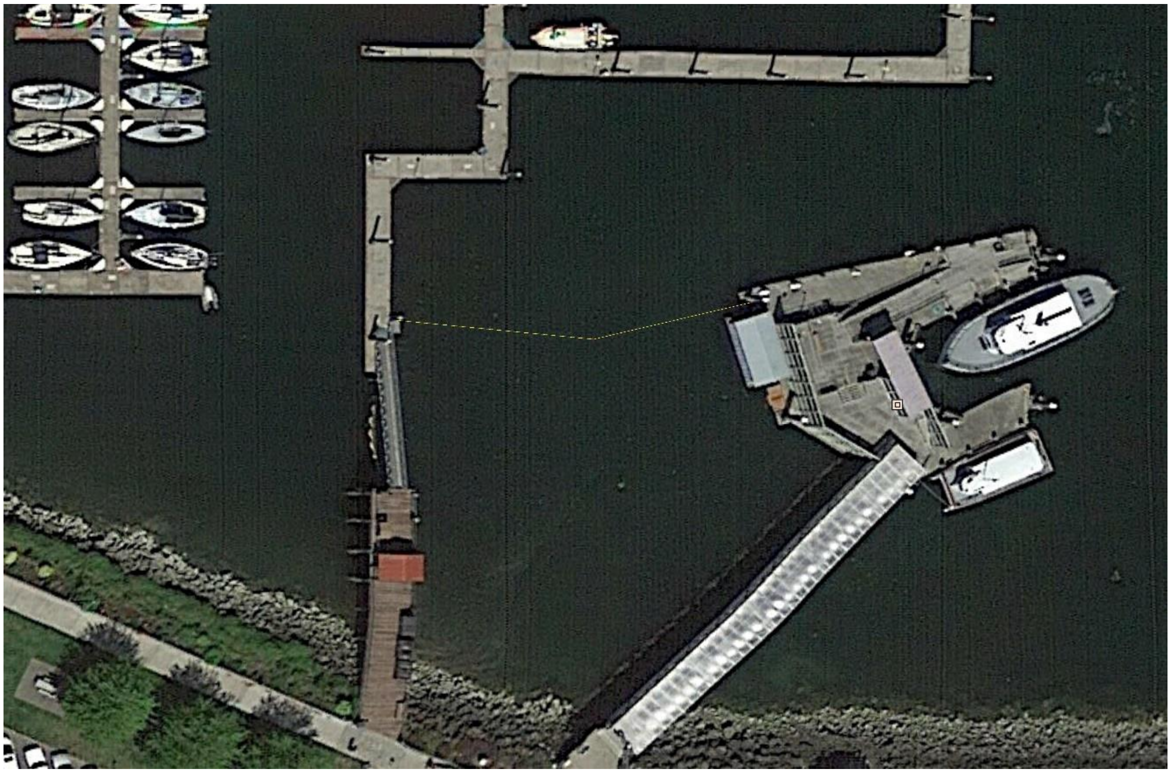
Detailed ROM cost estimate in Attachment 2. ROM costs are projected to be approximately $1.45 – 1.75 Million.

Option 2 Concept Sketch



Option #3 ADA access Via Kitsap Transit Passenger Ferry Terminal.

Option#3 Concept Sketch



Description

Option 3 is based on a discussion with Port personnel who suggested a possible collaboration with Kitsap Transit (who often uses the breakwater). This option would provide walkway floats between the northwest corner of the Kitsap Transit passenger ferry float (which is ADA accessible) and the F Float walkway. The raised deck of the Kitsap Transit float will need to be extended towards the NW corner area and/or more ADA compliant ramps to that corner area. Two approximately 50' to 54' walkway floats with guide piles and with a midpoint transition platform attached to one of the two floats would accommodate the change in angle. Connecting transition ramps/plates at each end and at the midpoint transition will provide float-to-float access. This option potentially provides the least cost approach, but may result in a potentially mixed ownership/gates and security responsibility conditions that would need to be coordinated and formalized by the Port and KT.

Cost Estimate

Detailed ROM cost estimate in Attachment 3. ROM costs for this approach are projected to be approximately $700,000 – $800,000.

Appendix D, Attachment 1 – Option 1 ROM Cost Estimate

ITEMS	QUANTITY		ITEM COST			TOTALS
DESCRIPTION OF WORK	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Mobilization	1	LS	$70,000.00	$70,000.00		$70,000
Remove exst floats	1,140	SF	$15.00	$17,100.00		$17,100
New stair/ramp floats 5-8'deep+/-)	680	SF	$500.00	$340,000.00		$340,000
New connecting walkway float (3' deep +/-)	120	SF	$230.00	$27,600.00		$27,600
New guide piles	8	EA	$25,000.00	$200,000.00		$200,000
100' Gangway	600	SF	$150.00	$90,000.00		$90,000
ADA ramps and landings	5	EA	$6,000.00	$30,000.00		$30,000
Ramp/stair tower structures	1	LS	$80,000.00	$80,000.00		$80,000
Stairs and railings	1	LS	$25,000.00	$25,000.00		$25,000
Modify F float connection	1	LS	$5,000.00	$5,000.00		$5,000
Wet + drystandpipe fire suppression	1,000	SF	$25.00	$25,000.00		$25,000
Electrical power/distribution	1000	SF	$45.00	$45,000.00		$45,000
				$0.00		$0
				$0.00		$0
Demobilization	1	LS	$20,000.00	$20,000.00		$20,000
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
DIRECT LABOR/MATERIAL ITEM SUBTOTAL						$974,700
GENERAL CONDITIONS ITEMS	QUANTITY			COST		
Description of Item	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Project Manager/Field Supervision Cost	10%	LS		$97,470.00		$97,470
				$0.00		$0
				$0.00		$0
SUBTOTAL				$97,470.00	$0	$97,470
					$0	$0
CONTRACTOR'S OVERHEAD	15%					$160,826
CONTRACTOR'S PROFIT	10%					$107,217
BONDS/INSURANCE	3%					$32,165
SUBTOTAL						$268,043
BID ADDITIVE ITEMS						
N/A			$0.00	$0.00	$0.00	$0
N/A			$0.00	$0.00	$0.00	$0
LABOR & MATERIALS SUBTOTAL						$1,242,743
DESIGN/ENGINEERING FEE	10%					$124,274
DESIGN + CONSTRUCTION EST CONTINGENCY	15%					$186,411
SUBTOTAL						$1,553,428
						$0
GRAND TOTAL						$1,553,428

Appendix D, Attachment 2 – Option 2 ROM Cost Estimate

ROM ESTIMATE WORKSHEET

ART ANDERSON ASSOCIATES

ESTIMATED BY: AAA	PROJECT: PoM BW Replacement
PROJECT & CITY: PoM Breakwater Replacement, PO, WA	CONTRACT No.
DATE: Oct 2019	PURPOSE: ROM Concept Cost Est
EST. VALID TO: N/A ROM use only	SHEET 1 OF 1

SCOPE OF WORK:

option #2

ITEMS	QUANTITY		ITEM COST			TOTALS
DESCRIPTION OF WORK	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Mobilization	1	LS	$70,000.00	$70,000.00		$70,000
Remove exst floats	1,040	SF	$15.00	$15,600.00		$15,600
New stair/ramp floats (5-8'deep+/-)	750	SF	$500.00	$375,000.00		$375,000
New guide piles	8	EA	$25,000.00	$200,000.00		$200,000
80' Gangway	480	SF	$150.00	$72,000.00		$72,000
ADA ramps and landings	5	EA	$6,000.00	$30,000.00		$30,000
Ramp/stair tower structures	1	LS	$90,000.00	$90,000.00		$90,000
Stairs and railings	1	LS	$15,000.00	$15,000.00		$15,000
Modify F float connection	1	LS	$5,000.00	$5,000.00		$5,000
Wet + drystandpipe fire suppression	1,000	SF	$25.00	$25,000.00		$25,000
Electrical power/distribution	1000	SF	$45.00	$45,000.00		$45,000
				$0.00		$0
				$0.00		$0
Demobilization	1	LS	$20,000.00	$20,000.00		$20,000
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
DIRECT LABOR/MATERIAL ITEM SUBTOTAL						$962,600
GENERAL CONDITIONS ITEMS	QUANTITY			COST		
Description of Item	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Project Manager/Field Supervision Cost	10%	LS		$96,260.00		$96,260
				$0.00		$0
				$0.00		$0
SUBTOTAL				$96,260.00	$0	$96,260
					$0	$0
CONTRACTOR'S OVERHEAD	15%					$158,829
CONTRACTOR'S PROFIT	10%					$105,886
BONDS/INSURANCE	3%					$31,766
SUBTOTAL						$264,715
BID ADDITIVE ITEMS						
N/A			$0.00	$0.00	$0.00	$0
N/A			$0.00	$0.00	$0.00	$0
LABOR & MATERIALS SUBTOTAL						$1,227,315
DESIGN/ENGINEERING FEE	10%					$122,732
DESIGN + CONSTRUCTION EST CONTINGENCY	15%					$184,097
SUBTOTAL						$1,534,144
						$0
GRAND TOTAL						$1,534,144

Appendix D, Attachment 3 – Option 3 ROM Cost Estimate

ART ANDERSON ASSOCIATES

ESTIMATED BY: AAA	PROJECT: PoM BW Replacement
PROJECT & CITY: PoM Breakwater Replacement, PO, WA	CONTRACT No.
DATE: Oct 2019	PURPOSE: ROM Concept Cost Est
EST. VALID TO: N/A ROM use only	SHEET 1 OF 1

SCOPE OF WORK:

option #3 floats btwn KT and F dock

ITEMS	QUANTITY		ITEM COST			TOTALS
DESCRIPTION OF WORK	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Mobilization	1	LS	$50,000.00	$50,000.00		$50,000
New stair/ramp floats (8'deep+/-)	0	SF	$500.00	$0.00		$0
New walkway floats (8'w x 3' deep)	840	SF	$230.00	$193,200.00		$193,200
New guide piles	4	EA	$25,000.00	$100,000.00		$100,000
Custom transition angle	1	EA	$5,000.00	$5,000.00		$5,000
Float-to-float transition plates/hinges	3	EA	$4,000.00	$12,000.00		$12,000
Modify KT float decking	600	SF	$100.00	$60,000.00		$60,000
Modify F float connection	1	LS	$5,000.00	$5,000.00		$5,000
Wet + drystandpipe fire suppression	0	SF	$25.00	$0.00		$0
Electrical power/distribution for lighting/fixtures	1	LS	$10,000.00	$10,000.00		$10,000
				$0.00		$0
				$0.00		$0
Demobilization	1	LS	$20,000.00	$20,000.00		$20,000
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
				$0.00		$0
DIRECT LABOR/MATERIAL ITEM SUBTOTAL						$455,200
GENERAL CONDITIONS ITEMS	QUANTITY			COST		
Description of Item	#	UNIT	UNIT($)	SUM TOT ($)		SUM TOTS ($)
Project Manager/Field Supervision Cost	10%	LS		$45,520.00		$45,520
				$0.00		$0
				$0.00		$0
SUBTOTAL				$45,520.00	$0	$45,520
					$0	$0
CONTRACTOR'S OVERHEAD	15%					$75,108
CONTRACTOR'S PROFIT	10%					$50,072
BONDS/INSURANCE	3%					$15,022
SUBTOTAL						$125,180
BID ADDITIVE ITEMS						
N/A			$0.00	$0.00	$0.00	$0
N/A			$0.00	$0.00	$0.00	$0
LABOR & MATERIALS SUBTOTAL						$580,380
DESIGN/ENGINEERING FEE	10%					$58,038
DESIGN + CONSTRUCTION EST CONTINGENCY	15%					$87,057
SUBTOTAL						$725,475
						$0
GRAND TOTAL						$725,475

Port Orchard Marina Breakwater Concept Design Report Review Meeting

October 22, 2019

Art Anderson's Conference Room

Attendees:

Patrick Vasicek, P.E.	Project Manager	Art Anderson
Brad Ginn, P.E.	Sr. Civil Engineer	Art Anderson
Andrew Thorsen, EIT	Civil Engineer	Art Anderson
Sean Hoynes, P.E.	Chief Engineer	Art Anderson
Vern Schager	Architect	Art Anderson
Schelie Hoynes	Sr. Project Coordinator	Art Anderson
Willy Ahn, PhD, P.E.	Project Manager	Reid Middleton
James Weaver	Director of Marine Facilities	Port of Bremerton
Fred Salisbury		Port of Bremerton

10:05 – Introductions

10:11 – Background

Reviewed plan view diagram showing history of Port Orchard Marina since early 1970's.

Presented the PowerPoint presentation given to the Port Commissioners in 2007 – provided history of the Port orchard Marina and background information discussed in the previous Concept Design report.

Discussed the context of the Port Orchard Marina with the Bremerton Marina, which was completely rebuilt in 2007-8. Discussed prior completed projects that impact the Marina and downtown area.

Discussed the Parking Study conducted by AAA in 2005 for the core of Port Orchard, which was more of a revitalization study. This initiative is finally showing movement forward, the scope of which integrates with the improvements needed at the Port Orchard Marina.

Discussed the impact and importance of the American Cruise Lines vessels coming into the Bremerton Marina and the desire to make both Bremerton and Port Orchard as permanent destinations on their printed schedule.

Discussed the recent forensic study and damage assessment conducted to assess the damage by an allision on the outside of the Bremerton Breakwater It emphasized the challenges posed by extensive marine growth when dive inspection video was analyzed. Corrosion protection is a key challenge for marine facilities in Sinclair Inlet.

Reviewed ROM Cost Estimate for Float Replacement handout from the previous Concept design report. It was noted that these costs have been updated to the new scope considerations in the draft copy of the revised report, but that the numbers must be escalated to 2021.

10:45 – Review Draft Report

Feedback from commissioners and POB staff was to concept design and analyze the costs/impacts of a breakwater that is similar to the Bremerton Breakwater. There is an intention to allow temporary mooring of a Cruise ship in Port Orchard as currently being accomplished at the Bremerton Breakwater.

The AAA/Reid Middleton team carried out a study to include both 20’ and a 25” wide float systems and determined guide pile and cable concept designs for all float options according to current codes. There are now nine alternatives identified and analyzed in the revised report, which was sent to all participants in preparation for this meeting.

Design review Comments include:

1. Per above comment under background – escalate all costs to 2021.
2. Include a separate line for Sales Tax in the estimates.
3. The Commissioners are more concerned regarding first cost that we originally thought when preparing the draft. The Port goal is to not use a bond, so the source of funding is going to be from savings and grants. The high costs of the wider float options are probably going to be non-starters for them. We need to refine the trade-off analysis criteria and process based on this knowledge. We need a way to discern which of the 12’ wide options is the best alternative.
4. There is much interest in using the new Breakwater as a Park and community amenity, so space on the floats is a bigger issue that we had originally expected.
5. In the context of no. 4 above, guide piles, especially interstitial guide piles for the 12’ wide float options is a bigger challenge than we expected in the original report. We need to revisit the feasibility of using guide piles for this breakwater.
6. Previous desired alternative was Alternative #3, which included guide pile mooring.
7. Use 400’ length for cruises ship moorage.
8. Discussed alternatives to deal with the ADA deficiencies for access to the East and North breakwaters. Reviewed two ADA Access arrangement plans AAA prepared in 2017 for the 10-year maintenance and repair program. The Port suggested a third alternative involving a new float system from the Kitsap Transit passenger ferry terminal to F float. It was decided to add sketches of these three alternatives, ROM cost estimates and a short one-page narrative to an appendix in the final report. This will likely be a separate project, possibly funded prior to construction of the new East and North Breakwater project. Since the Port will be replacing the guest float (F dock) in the near future, it is important to consider the appropriate methodology for solving the ADA access issues
9. Need to include a paragraph acknowledging how we addressed seal level rise in report.

11:30 – Lunch

12:00 – Continue to Discuss options

1. AAA will send sketches of alternatives to James for him to include in his PowerPoint presentation to the commissioners.

2. The Port felt that the report was good work.

3. The Port thought it would be helpful to have a spreadsheet with all the information on a single page, including costs, trade-off analysis scoring, benefits and challenges that drive the decision regarding the most suitable alternative.

4. Option 3 or 4 are probably what will stick with the commissioners, with the addition of alternative 2, now that cable mooring appears to be an attractive option at this point in time.

5. The City, the cruise ship, and customers are pushing for the marina upgrades.

6. AAA will revisit and adjust the weighting factors in the decision matrix, make all the changes as indicated above and revise the report for final review and comment in the next two weeks.

7. The Port would like to have another similar meeting after review of the final. Intent is to brief the Commissioners at their December 10 meeting (10:00AM – 12:00 Noon).

8. James will present with Willy Ahn and Patrick Vasicek attending in a supporting role.

12:49 - Adjourn

Port Orchard Breakwater Preliminary Concept Design

Owner: Port of Bremerton

October 14, 2019

Prepared for:
Art Anderson Associates

CALCULATIONS

WOOSUK AHN
STATE OF WASHINGTON
42028
REGISTERED
PROFESSIONAL ENGINEER
10/14/2019

Prepared By:

Willy Ahn, Ph.D., P.E.

ReidMiddleton

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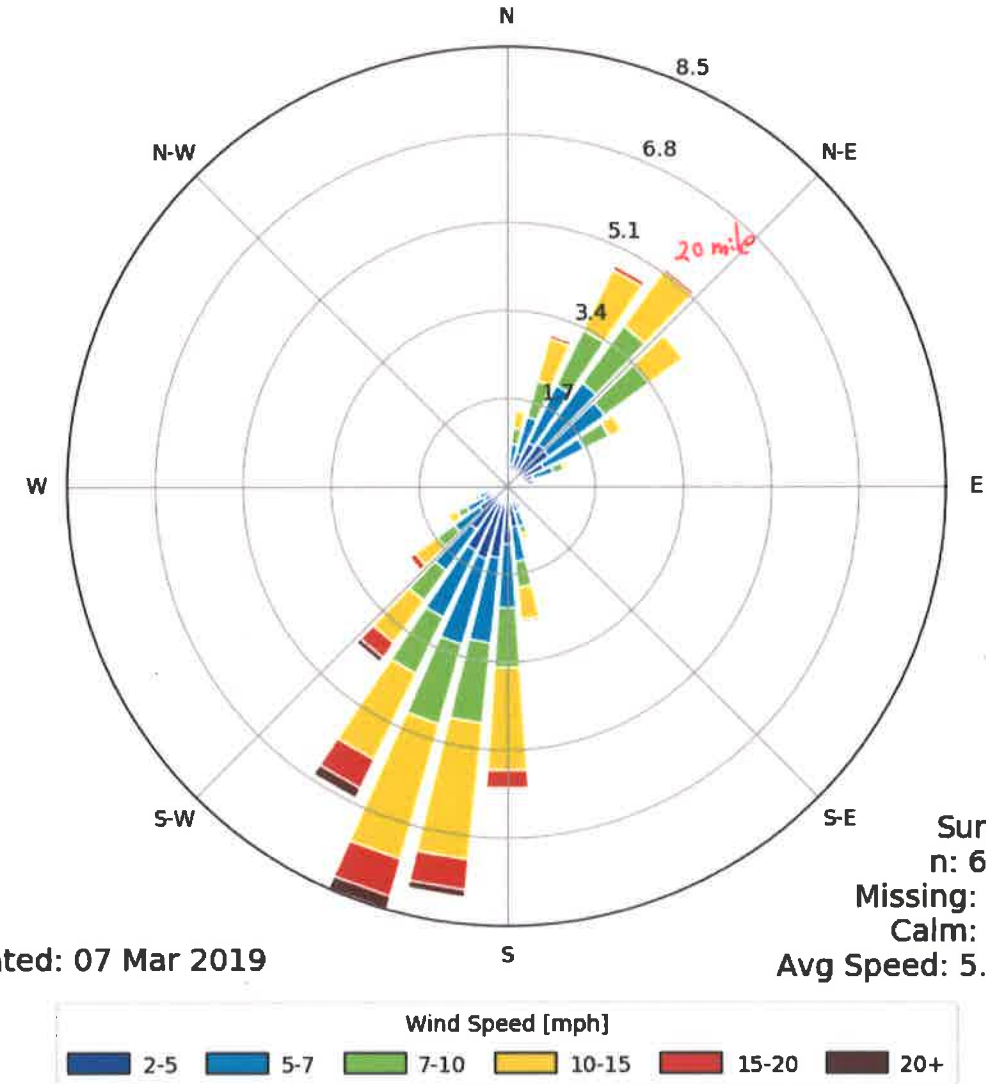
File No. 242019.018

Calculations
Environmental Loads

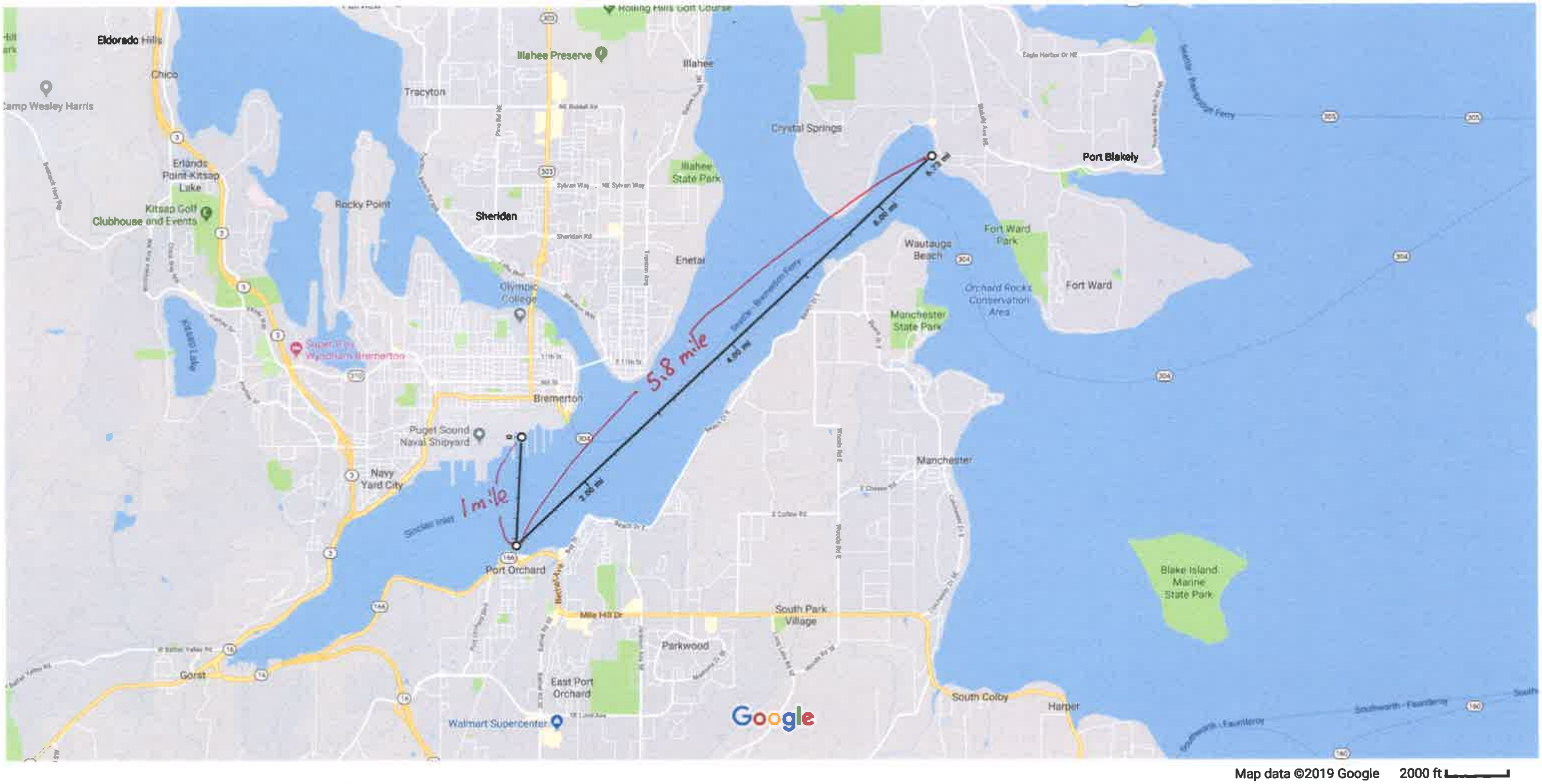
[PWT] BREMERTON NTNL AWOS
Windrose Plot [All Year]
Period of Record: 31 Dec 1972 - 07 Mar 2019



Generated: 07 Mar 2019

Summary
n: 612441
Missing: 13609
Calm: 30.5%
Avg Speed: 5.7 mph

Google Maps



Measure distance

Total distance: 6.73 mi (10.82 km)

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Wave Prediction based on the SPM, Chapter 3, IV Estimation of Surface Winds for Wave Prediction

Max fastest wind speed = 45 mph from NE (from 2008 Bremerton Marina Breakwater Design)

$U_f := 45\text{mph}$ maximum fastest windspeed at EL= 33 ft. (50 year return period)

find 1hr (3600 sec) average wind speed,

$t := \frac{1\text{mile}}{U_f}$ time to travel one mile

$t = 80\,s$ $U_{80} := U_f$

SPM Fig.3-13

$\frac{U_t}{U_{3600}} := 1.277 + 0.296 \cdot \tanh\left(0.9 \log\left(\frac{45s}{t}\right)\right)$ for $1 < t < 3{,}600$ s

$\frac{U_t}{U_{3600}} := -0.15 \cdot \log(t) + 1.534$ for $3{,}600\text{ s} < t < 36{,}000$ s

$$U_{3600} := \frac{U_f}{1.277 + 0.296 \cdot \tanh\left(0.9 \log\left(\frac{45s}{t}\right)\right)}$$ one hour average wind speed

$U_{3600} = 37.143 \cdot \text{mph}$ for 1 hour duration

find 30 min (1800 sec) average wind speed,

$$1.277 + 0.296 \cdot \tanh\left(0.9 \log\left(\frac{45s}{1800s}\right)\right) = 1.012$$

$$U_{1800} := \left(1.277 + 0.296 \cdot \tanh\left(0.9 \log\left(\frac{45s}{1800s}\right)\right)\right) \cdot U_{3600} = 37.602 \cdot \text{mph}$$

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find 2 hr (7200 sec) average wind speed,

$-0.15 \cdot \log(7200) + 1.534 = 0.955$

$U_{7200} := (-0.15 \cdot \log(7200) + 1.534) \cdot U_{3600} = 35.486 \cdot mph$

Project:
Group: Wave

Case: Port Orchard BW

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	35.50	mph
Air Sea Temp. Diff. (dT)	-10.00	deg F
Dur of Observed Wind (DurO)	2.00	hours
Dur of Final Wind (DurF)	2.00	hours
Lat. of Observation (LAT)	47.25	deg
Results		
Wind Fetch Length (F)	5.80	MILES
Eq Neutral Wind Speed (Ue)	32.87	mph
Adjusted Wind Speed (Ua)	43.29	mph
Wave Height (Hmo)	3.13	feet
Wave Period (Tp)	3.52	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep openwater

Wave Growth: Deep

Project:
Group: Wave

Case: Port Orchard BW

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	37.60	mph
Air Sea Temp. Diff. (dT)	-10.00	deg F
Dur of Observed Wind (DurO)	0.50	hours
Dur of Final Wind (DurF)	0.50	hours
Lat. of Observation (LAT)	47.25	deg
Results		
Wind Fetch Length (F)	5.80	MILES
Eq Neutral Wind Speed (Ue)	34.73	mph
Adjusted Wind Speed (Ua)	46.47	mph
Wave Height (Hmo)	1.52	feet
Wave Period (Tp)	2.38	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep openwater

Wave Growth: Deep

Project:
Group: Wave

Case: Port Orchard BW

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	37.00	mph
Air Sea Temp. Diff. (dT)	-10.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	47.25	deg
Results		
Wind Fetch Length (F)	5.80	MILES
Eq Neutral Wind Speed (Ue)	34.20	mph
Adjusted Wind Speed (Ua)	45.56	mph
Wave Height (Hmo)	2.43	feet
Wave Period (Tp)	3.12	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep openwater

Wave Growth: Deep

Environmental loadings

Current

current speed = 0.1 knots

unit area subjected to environmental loading

current force calculation (MIL- HDBK 102/4A)

mass density of seawater $\rho_w := 1.9905 \cdot \frac{slug}{ft^3}$ current velocity, $V_c := 0.1knot$

current angle $\theta_c := 90$ float draft $d_f := 3ft$

float length $l_f := 120ft$

current force/ft $F_{yc} := 0.5 \cdot \rho_w \cdot V_c^{\,2} \cdot \sin(deg \cdot \theta_c) \cdot d_f \cdot l_f$

$F_{yc} = 0.01 \cdot kip$

Wind

vessel windage area, $A_{yv} := 100ft20 \cdot ft$ vessel length 100 ft and 20 ft profile height

mass dendity of air, $\rho_a := 0.00237 \cdot \frac{slug}{ft^3}$ wind speed (fastest mile), $U_f := 95mph$

wind only

typical wind drag coefficient $C_y := 1.0$

Find 30 second average wind speed

time to travel 1 mile, $t_{1m} := \frac{1 \cdot mile}{U_f} = 37.89s$ from Figure 3-13 Shore Protection Manual

$\frac{U_{38}}{U_{3600}} := 1.28$ $U_{3600} := \frac{U_f}{1.28} = 74.22 \cdot mph$

from Figure 3-13, $\frac{U_{30}}{U_{3600}} := 1.32$ $U_{30} := U_{3600} \cdot 1.32 = 97.97 \cdot \mathrm{mph}$

shape function related with angle between wind direction and vessel $f_y := 1$

wind force $F_y := 0.5 \cdot \rho_a \cdot U_{30}^{\,2} \cdot \frac{A_{yv}}{100\mathrm{ft}} \cdot C_y \cdot f_y$

$F_y = 0.49 \cdot \mathrm{klf}$

based on UFC 4-159-03

Environmental loadings

Current

current speed = 0.1 knots

unit area subjected to environmental loading

current force calculation (MIL- HDBK 102/4A)

mass density of seawater $\rho_w := 1.9905 \cdot \frac{slug}{ft^3}$ current velocity, $V_c := 0.1knot$

current angle $\theta_c := 90$ float draft $d_f := 3ft$

float length $l_f := 120ft$

current force/ft $F_{yc} := 0.5 \cdot \rho_w \cdot V_c^2 \cdot \sin(deg \cdot \theta_c) \cdot d_f \cdot l_f$

$F_{yc} = 0.01 \cdot kip$

Wind

vessel windage area, $A_{yv} := 100ft20 \cdot ft$ vessel length 100 ft and 20 ft profile height

mass dendity of air, $\rho_a := 0.00237 \cdot \frac{slug}{ft^3}$ wind speed (fastest mile), $U_f := 45mph$

case 2
with
wave loading

typical wind drag coefficient $C_y := 1.0$

Find 30 second average wind speed

time to travel 1 mile, $t_{1m} := \frac{1 \cdot mile}{U_f} = 80\,s$ from Figure 3-13 Shore Protection Manual

$\frac{U_{38}}{U_{3600}} := 1.28$ $U_{3600} := \frac{U_f}{1.28} = 35.16 \cdot mph$

from Figure 3-13, $\frac{U_{30}}{U_{3600}} := 1.32$ $U_{30} := U_{3600} \cdot 1.32 = 46.41 \cdot mph$

shape function related with angle between wind direction and vessel $f_y := 1$

wind force $F_y := 0.5 \cdot \rho_a \cdot U_{30}^{\;2} \cdot \frac{A_{yv}}{100ft} \cdot C_y \cdot f_y$

based on UFC 4-159-03

$F_y = 0.11 \cdot klf$

ReidMiddleton

Job Number: 242017013
Date: August 8, 2017

POCM BW

Horizontal Wave Load (perpendicular to float)

Calculate Wave Lengths

Project Site	Float Type	Min water Depth	Max Water Depth	Design Water Depth (d)	Design Wave - H10, Wave Height (ft)	Design Wave Period Seconds	Lo (gt*t) / (2*pi)	Max water depth 2*pi*d	Min Water Depth 2*pi*d	Calculated Wave Length - Max. Water Depth	Calculated Wave Length - Min. Water Depth	Use solver to find wave length for max water depth	Use solver to find wave length for min water depth
		25	35	30	3.94	3.5	62.720	219.9	157.08	61.50	62.00	1.121759628	-0.0655353
										A	B	A-Solve for this by changing K7	B-Solve for this by changing L7

Calculate Wave Force per Miche Rundgren

		Reflection Coefficient x=		w=			From Fig 7-93 SPM			
		1		63.8			Deep water			
MAX. WATER DEPTH				PSF						
		(1+x)/2	cosh(2*pi*d/l)	Pressure P1	hi/g*t*t	Hi/d	ho/HI	h0	yc	yt
		1	17.88	14.1	0.0100	0.11	0.160	0.63	36.97	28.25

		Reflection Coefficient x=		w=			From Fig 7-93 SPM			
		1		63.8						
MIN. WATER DEPTH				PSF						
		(1+x)/2	cosh(2*pi*d/l)	Pressure P1	hi/g*t*t	Hi/d	ho/HI	h0	yc	yt
		1	6.34	39.7	0.0100	0.16	0.170	0.67	26.97	23.03

RESULTS

Calculate Wave Forces using equal lateral force triangles and based on Shore Protection Manual Vol 2 Fig. 7-89 for deep water condition

		Float Draft	Float Freeboard	Hydrostatic Pressure at mudline	Hydrostatic pressure plus wave pressure at mudline	SWL to wave crest height	Bottom of float to crest height	Pressure on Float above SWL	Total pressure at bottom of float	Hydrostatic pressure at bottom of float	Total pressure at top of float	Total force along side of float - wave and hydrostatic	Total force static pressure	Wave Force	Reduction factor for short crested waves 50%	Reduction factor for short crested waves 75%
		feet	feet	psf	psf	feet	feet	psf	psf	psf	plf	plf	plf	plf	plf	plf
		5	1.5	2233	2247	1.97	6.97	120	424	160	8	1403	399	1004	502	753

Calculate Wave Forces using equal lateral force triangles and based on Shore Protection Manual Vol 2 Fig. 7-89 for shallow water condition

		Float Draft	Float Freeboard	Hydrostatic Pressure at mudline	Hydrostatic pressure plus wave pressure at mudline	SWL to wave crest height	Bottom of float to crest height	Pressure on Float above SWL	Total pressure at bottom of float	Hydrostatic pressure at bottom of float	Total pressure at top of float	Total force along side of float - wave and hydrostatic	Total force static pressure	Wave Force	Reduction factor for short crested waves 50%	Reduction factor for short crested waves 75%
		feet	feet	psf	psf	feet	feet	psf	psf	psf	plf	plf	plf	plf	plf	plf
		5	1.5	1595	1635	1.97	6.97	119	422	160	8	1399	399	1000	500	750

ASSUME CURRENT FORCES ON FLOAT SYSTEM IS NEGLIGIBLE

Wave force (perpendicular to BW float)

linear wave theory used

wave period $T_w := 3.5sec$

significant wave height, $H_s := 3.1 \cdot ft$

root mean square wave height $H_{rms} := \frac{H_s}{1.416}$ $H_{10} := 1.8 \cdot H_{rms} = 3.941\,ft$

water depth, $h := 30ft$

wave length deep water, $L_o := \frac{g \cdot T_w^{\,2}}{2\pi} = 62.728\,ft$ $L_d := L_o$

wave length transitional water, $L_t := \frac{g \cdot T_w^{\,2}}{2\pi} \cdot \tanh\left(\frac{2\pi \cdot h}{L_o}\right) = 62.421\,ft$

$\frac{1}{25} = 0.04$ < $\frac{h}{L_t} = 0.481$ < $\frac{1}{2} = 0.5$ transitional water

wave number, $k := \frac{2 \cdot \pi}{L_t} = 0.101 \frac{1}{ft}$

mass density of seawater, $\rho_w := 1.9905 \cdot \frac{slug}{ft^3}$ * draft, $l_z := 4 \cdot ft$

unit weight, $\gamma_w := 63.8 \cdot \frac{lbf}{ft^3}$ average depth below SWL, $z := -1.25ft$

dynamic pressure, $p_d := \gamma_w \cdot H_{10} \cdot \frac{\cosh[k \cdot (h + z)]}{\cosh(k \cdot h)}$ $p_d = 221.841 \cdot psf$

50% reduction in wave forces based on Jurgen Battjes "Effects of Short-Crestedness on Wave Loads on Long Structures, Applied Ocean Science Research, 1982, Vol. 4. No. 3, and Permanenant International Association of Navigation Congress (PIANC) Report of Working Group No. 13 Report Entitled "Floating Breakwaters, A Practical Guide fo Design and Construction," 1994.

$p_d \cdot l_z = 0.887 \cdot \frac{kip}{ft}$ $0.5p_d \cdot l_z = 0.444 \cdot \frac{kip}{ft}$ $0.75p_d \cdot l_z = 0.666 \cdot \frac{kip}{ft}$

Calculations
Breakwater Dimensions and Freeboard

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Ph: 425 741-3800
Fax: 425 741-3900

Client: Art Anderson Associates
Project: Port Orchard Breakwater
Project No. 242019.018.000

Design by: WWA
Date: 10/14/2019
Checked by:
Date:

Summary - Maximum Sizes (Approx.) of Individual Breakwater Pontoons

Manufacturers	Facility and/or Equipment for Launching and Lifting	Max. Effective Capacities (kip)	Max. Effective Length for 25 ft. Wide Float (ft.)	Max. Effective Length for 12 ft. Wide Float (ft.)
Concrete Tech.	Graving Dock	802	200	200
Concrete Tech.	Precast Plant	120	25	50
Bellingham Marine	150 ton Travel Lift	250	50	100
Bellingham Marine	Precast Plant Crane	120	25	50
Manson Construction	Submersible Ocean Barge	642	160	160

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Project #: 242019.018
POM BW Replacement

FLOAT DIMENSIONS, FREE BOARD, & DRAFT

BW float: 100' long 25 ft wide concrete float with two 50' long individual pontoons connected

wall thickness, $b_w := 4in$ width, $b := 25ft$ depth, $h := 66in$ length, $l_f := 100ft$

top slab thickenss, $h_{ts} := 5in$ bottom slab thickenss, $h_{bs} := b_w$

top slab volume, $V_{ts} := b \cdot h_{ts} \cdot l_f = 1.042 \times 10^3 \cdot ft^3$

bottom slab volume, $V_{bs} := b \cdot h_{bs} \cdot l_f = 833.333 \cdot ft^3$

side & mid wall volume, $V_{ws} := 3 \cdot (h - h_{ts} - h_{bs}) \cdot b_w \cdot l_f = 475 \cdot ft^3$

end wall volume, $V_{ew} := 4 \cdot (b - 3 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 152 \cdot ft^3$

notch wall volume, $V_{nw} := 2(4.5ft + 4.5ft) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 28.5 \cdot ft^3$

notch cavity volume, $V_{nc} := 2(4.5ft \cdot 4.5ft) \cdot b_w = 13.5 \cdot ft^3$

total concrete volume, $V_{con} := V_{ts} + V_{bs} + V_{ws} + V_{ew} + V_{nw} - V_{nc} = 2.517 \times 10^3 \cdot ft^3$

unit weight of seawater, $\gamma_w := 63.8pcf$ unit weight of concrete, $\gamma_c := 155pcf$

unit weight of foam, $\gamma_{ps} := 1pcf$

volume of foam filled, $V_{foam} := (b - 3 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot (l_f - 2b_w) = 1.132 \times 10^4 \cdot ft^3$

weight of breakwater 100' long pontoon unit incl addtional DL & ballast (say additional 50%),

$W_{bw} := (\gamma_c \cdot V_{con} + \gamma_{ps} \cdot V_{foam}) = 401.459 \cdot kip$ $1.5 \cdot W_{bw} = 602.188 \cdot kip$

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live load (uniformly distributed - PIANC Marina Design Guideline 149 Part IV),

$$LL := 5.0\frac{kN}{m^2} = 104.427 \cdot psf$$

uniformly distributed live load for walkway over 10 meter can be reduced as follows:

length of walkway (m), $L_w := 175$

$$p_v := 2.0\frac{kN}{m^2} + \left(\frac{120}{L_w + 30}\right)\frac{kN}{m^2} = 2.585 \cdot \frac{kN}{m^2}$$

Eqn 1 - PIANC Marina Design Guideline 149 Part IV, 9.3.1

$$p_v = 53.996 \cdot psf$$

use 60 psf live load

$$W_{ll} := 60psf \cdot b \cdot l_f = 150 \cdot kip$$

draft under DL only, $$dr_{dl} := \frac{1.5W_{bw}}{\left[b \cdot l_f - 2 \cdot (4.5ft)^2\right] \cdot \gamma_w} = 46.052 \cdot in$$

free boards, $$fb_{dl} := h - dr_{dl} = 19.948 \cdot in$$

draft,under DL + LL $$dr_{ll} := \frac{1.5W_{bw} + W_{ll}}{\left[b \cdot l_f - 2 \cdot (4.5ft)^2\right] \cdot \gamma_w} = 57.523 \cdot in$$

$$fb_{ll} := h - dr_{ll} = 8.477 \cdot in$$

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Project #: 242017.013
POM BW Replacement

FLOAT DIMENSIONS, FREE BOARD, & DRAFT

BW float: 110' long 20 ft wide concrete float with two 50' long individual pontoons connected

wall thickness, $b_w := 4in$ width, $b := 20ft$ depth, $h := 69in$ length, $l_f := 110ft$

top slab thickenss, $h_{ts} := 5in$ bottom slab thickenss, $h_{bs} := b_w$

top slab volume, $V_{ts} := b \cdot h_{ts} \cdot l_f = 916.667 \cdot ft^3$

bottom slab volume, $V_{bs} := b \cdot h_{bs} \cdot l_f = 733.333 \cdot ft^3$

side & mid wall volume, $V_{ws} := 3 \cdot (h - h_{ts} - h_{bs}) \cdot b_w \cdot l_f = 550 \cdot ft^3$

end wall volume, $V_{ew} := 4 \cdot (b - 3 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 126.667 \cdot ft^3$

notch wall volume, $V_{nw} := 2(4.5ft + 4.5ft) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 30 \cdot ft^3$

notch cavity volume, $V_{nc} := 2(4.5ft \cdot 4.5ft) \cdot b_w = 13.5 \cdot ft^3$

total concrete volume, $V_{con} := V_{ts} + V_{bs} + V_{ws} + V_{ew} + V_{nw} - V_{nc} = 2.343 \times 10^3 \cdot ft^3$

unit weight of seawater, $\gamma_w := 63.8pcf$ unit weight of concrete, $\gamma_c := 155pcf$

unit weight of foam, $\gamma_{ps} := 1pcf$

volume of foam filled, $V_{foam} := (b - 3 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot (l_f - 2b_w) = 1.039 \times 10^4 \cdot ft^3$

weight of breakwater 100' long pontoon unit incl addtional DL & ballast (say additional 50%),

$W_{bw} := (\gamma_c \cdot V_{con} + \gamma_{ps} \cdot V_{foam}) = 373.577 \cdot kip$ $1.5 \cdot W_{bw} = 560.366 \cdot kip$

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live load (uniformly distributed - PIANC Marina Design Guideline 149 Part IV),

$$LL := 5.0\frac{kN}{m^2} = 104.427 \cdot psf$$

uniformly distributed live load for walkway over 10 meter can be reduced as follows:

length of walkway (m), $L_w := 175$

$$p_v := 2.0\frac{kN}{m^2} + \left(\frac{120}{L_w + 30}\right)\frac{kN}{m^2} = 2.585 \cdot \frac{kN}{m^2}$$

Eqn 1 - PIANC Marina Design Guideline 149 Part IV, 9.3.1

$$p_v = 53.996 \cdot psf$$

use 60 psf live load

$$W_{ll} := 60psf \cdot b \cdot l_f = 132 \cdot kip$$

draft under DL only, $$dr_{dl} := \frac{1.5W_{bw}}{\left[b \cdot l_f - 2 \cdot (4.5ft)^2\right] \cdot \gamma_w} = 48.807 \cdot in$$

free boards, $fb_{dl} := h - dr_{dl} = 20.193 \cdot in$

draft,under DL + LL $$dr_{ll} := \frac{1.5W_{bw} + W_{ll}}{\left[b \cdot l_f - 2 \cdot (4.5ft)^2\right] \cdot \gamma_w} = 60.304 \cdot in$$

$$fb_{ll} := h - dr_{ll} = 8.696 \cdot in$$

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Project #: 242017.013
POM BW Replacement

FLOAT DIMENSIONS, FREE BOARD, & DRAFT

BW float: 120' long 12 ft wide concrete float with two ~~50'~~ 60' long individual pontoons connected

wall thickness, $b_w := 4in$ width, $b := 12ft$ depth, $h := 69in$ length, $l_f := 120ft$

top slab thickenss, $h_{ts} := 5in$ bottom slab thickenss, $h_{bs} := b_w$

top slab volume, $V_{ts} := b \cdot h_{ts} \cdot l_f = 600 \cdot ft^3$

bottom slab volume, $V_{bs} := b \cdot h_{bs} \cdot l_f = 480 \cdot ft^3$

side wall volume, $V_{ws} := 2 \cdot (h - h_{ts} - h_{bs}) \cdot b_w \cdot l_f = 400 \cdot ft^3$

end wall volume, $V_{ew} := 4 \cdot (b - 2 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 75.556 \cdot ft^3$

notch wall volume, $V_{nw} := (4.5ft + 4.5ft) \cdot (h - h_{ts} - h_{bs}) \cdot b_w = 15 \cdot ft^3$

notch cavity volume, $V_{nc} := (4.5ft \cdot 4.5ft) \cdot b_w = 6.75 \cdot ft^3$

total concrete volume, $V_{con} := V_{ts} + V_{bs} + V_{ws} + V_{ew} + V_{nw} - V_{nc} = 1.564 \times 10^3 \cdot ft^3$

unit weight of seawater, $\gamma_w := 63.8pcf$ unit weight of concrete, $\gamma_c := 155pcf$

unit weight of foam, $\gamma_{ps} := 1pcf$

volume of foam filled, $V_{foam} := (b - 2 \cdot b_w) \cdot (h - h_{ts} - h_{bs}) \cdot (l_f - 2b_w) = 6.762 \times 10^3 \cdot ft^3$

weight of breakwater 120' long pontoon unit incl addtional DL & ballast (say additional 50%),

$W_{bw} := (\gamma_c \cdot V_{con} + \gamma_{ps} \cdot V_{foam}) = 249.152 \cdot kip$ $1.5 \cdot W_{bw} = 373.728 \cdot kip$

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live load (uniformly distributed - PIANC Marina Design Guideline 149 Part IV),

$$LL := 5.0\frac{kN}{m^2} = 104.427 \cdot psf$$

uniformly distributed live load for walkway over 10 meter can be reduced as follows:

length of walkway (m), $L_w := 175$

$$p_v := 2.0\frac{kN}{m^2} + \left(\frac{120}{L_w + 30}\right)\frac{kN}{m^2} = 2.585 \cdot \frac{kN}{m^2}$$

Eqn 1 - PIANC Marina Design Guideline 149 Part IV, 9.3.1

$$p_v = 53.996 \cdot psf$$

use 60 psf live load

$$W_{ll} := 60psf \cdot \left(b \cdot l_f - 4.5^2 ft^2\right) = 85.185 \cdot kip$$

draft under DL only, $dr_{dl} := \dfrac{1.5W_{bw}}{\left(b \cdot l_f - 4.5^2 ft^2\right) \cdot \gamma_w} = 49.511 \cdot in$

free boards, $fb_{dl} := h - dr_{dl} = 19.489 \cdot in$

draft,under DL + LL $dr_{ll} := \dfrac{1.5W_{bw} + W_{ll}}{\left(b \cdot l_f - 4.5^2 ft^2\right) \cdot \gamma_w} = 60.797 \cdot in$

$$fb_{ll} := h - dr_{ll} = 8.203 \cdot in$$

Calculations
Capacity of Float Guide Piling

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Estimation of Effective Pile Length Parameter,

modulus of elasticity of steel, $E_s := 29000\text{ksi}$ moment of inertia,

moment of inertia 30" (1" thk) diameter steel piling,

$I_{30} := 9591\text{in}^4$

soil modulus of subgrade reaction for medium dense send, $f_{sr} := 20\dfrac{\text{lbf}}{\text{in}^3}$

Effective pile length parameter, $T_{30} := \sqrt[5]{\dfrac{E_s \cdot I_{30}}{f_{sr}}}$

$T_{30} = 8.9\,\text{ft}$ Point of fixity, below top of the layer, $POF_{30} := 1.8T_{30}$

$POF_{30} = 16.02\,\text{ft}$

Estimation of Load Applied on Piling for Large Floats

section moduli, $S_{30} := 639.4\text{in}^3$

yield strength, $F_y := 60\text{ksi}$

$M_{n30} := 1.3 \cdot S_{30} \cdot F_y$ $\Omega_p := 1.67$

max moment capacity for 30" (1" thk) pile, $M_{a30} := \dfrac{M_{n30}}{\Omega_p} = 2.49 \times 10^3 \cdot \text{kip} \cdot \text{ft}$

pile length for -35 MLLW (deep), including point of fixity, highest water elevation,and free board

$L_{dp} := \left(POF_{30} + 35\text{ft} + 15\text{ft} + 1.5\text{ft}\right) = 67.52\,\text{ft}$

BW length (-35 MLLW), $l_d := 700\text{ft}$ **for 25' wide BW**

pile length for -30 MLLW (intermediate), including point of fixity, highest water elevation,and free board

$L_{ip} := POF_{30} + 30\text{ft} + 15\text{ft} + 1.5\text{ft}$

BW length (-30 MLLW), $l_i := 415ft$

pile length for -25 MLLW (shallow), including point of fixity, highest water elevation,and free board

$L_{sp} := POF_{30} + 25ft + 15ft + 1.5ft$

BW length (-25 MLLW), $l_s := 705ft$

environmental load applied on BW float (wind + wave) at -35 MLLW, $P_d := (0.11 + 0.75)klf \cdot l_d = 602 \cdot kip$

with consideration of 0.8 for soil spring

$0.8P_d = 481.6 \cdot kip$

total moment applied on piling along 700 ft long float at -35 MLLW, $M_d := 0.8P_d \cdot L_{dp} = 3.25 \times 10^4 \cdot kip \cdot ft$

moment applied @ each piling, $\frac{M_d}{14} = 2.32 \times 10^3 \cdot kip \cdot ft$ < $M_{a30} = 2.49 \times 10^3 \cdot kip \cdot ft$ OK

environmental load applied on BW float (wind + wave) at -30 MLLW, $P_i := (0.11 + 0.75)klf \cdot l_i = 356.9 \cdot kip$

total moment applied on piling along 415 ft long float at --30 MLLW, $M_i := 0.8P_i \cdot L_{ip} = 1.79 \times 10^4 \cdot kip \cdot ft$

moment applied @ each piling, $\frac{M_i}{8} = 2.23 \times 10^3 \cdot kip \cdot ft$ < $M_{a30} = 2.49 \times 10^3 \cdot kip \cdot ft$ OK

environmental load applied on BW float (wind + wave) at -25 MLLW, $P_s := (0.11 + 0.75)klf \cdot l_s = 606.3 \cdot kip$

total moment applied on piling along 680 ft long float at -25 MLLW, $M_s := 0.8P_s \cdot L_{sp} = 2.79 \times 10^4 \cdot kip \cdot ft$

moment applied @ each piling, $\frac{M_s}{12} = 2.33 \times 10^3 \cdot kip \cdot ft$ < $M_{a30} = 2.49 \times 10^3 \cdot kip \cdot ft$ OK

Calculations
Deck Capacity

Client: Art Anderson Associates
Project: Port Orchard BW
Project No. 242019.018

Sheet 1 of 1
Design by WWA
Date 09/30/2019
Checked by WWA
Date

- Deck Capacity

DL for 4" top slab. (1' uniform width)

155 pcf × 0.33' × 1' ≈ 51.2 plf

DL for 5" top slab (1' Uniform Width)

155 pcf × 0.42' × 1' ≈ 65.1 plf

LL = 60 psf

60 psf × 1' = 6 plf

Combination (4" THK) : $W_u = 1.4DL + 1.6LL$ = 1.4 × 51.2 plf + 1.6 × 60 plf = 167.7 plf

(5" THK) : W_u = " " = 1.4 × 65.1 plf + 1.6 × 60 plf = 187.1 plf

Span (conservative) = 12' − 0.33' = 11.67 ft

$$M_u = \frac{w_u \, l_n^2}{8} = \frac{0.168k \times 11.67^2}{8} = 2.86 \text{ k-ft} = 34.32 \text{ k-in}$$

$$M_u = \text{"} = \frac{0.187k \times 11.67^2}{8} = 3.18 \text{ k-ft} = 38.2 \text{ k-in}$$

Flextural strength of concrete

ACI Code:

7.12 - Shrinkage and temperature reinforcement

10.5 - Minimum reinforcement of flexural members

Given: Concrete Strength, f'_c: 5000 psi

Steel Strength, f_y: 60 ksi

Element Size:

width, b: 12 in.

Depth, d: 2 in.

for 4" thk concrete slab

Computing:

concrete section area, A_c = 24 in.^{2}

β_1 = 0.8

f_r = 530.3301 psi

steel ratio for balanced conditions, ρ_b = 3.3537%

moment of inertia of the gross concrete section I_g = 64 in.^{4}

y_t = 2 in.

Criteria:

Maximum steel ratio: $0.75\rho_b$ = 2.5153%

Minimum steel ratio: ACI (10-3) $200/f_y$ = 0.3333% or 0.3536% ($\rho_{min\ for\ shrinkage\ \&\ temperature}$:0.14%)

cracking moment: M_{cr} = 16970.56275 (lb-in.), or 16.97056 (k-in.)

Flextural Capacity

ρ	A_s	a	c	M_n	ϕM_n	*Required Number of Bars by entering bar #*			
	(in.^{2})	(in.)	(kips)	(k-in)	(k-in)	5	6	7	8
0.3333%	0.080	0.094	4.800	9.37	8.44	0.3	0.2	0.1	0.1
0.4333%	0.104	0.122	6.240	12.10	10.89	0.3	0.2	0.2	0.1
0.5333%	0.128	0.151	7.680	14.78	13.30	0.4	0.3	0.2	0.2
0.6333%	0.152	0.179	9.120	17.42	15.68	0.5	0.3	0.3	0.2
0.7333%	0.176	0.207	10.560	20.03	18.02	0.6	0.4	0.3	0.2
0.8333%	0.200	0.235	12.000	22.59	20.33	0.7	0.5	0.3	0.3
0.9333%	0.224	0.264	13.440	25.11	22.60	0.7	0.5	0.4	0.3
1.0333%	0.248	0.292	14.880	27.59	24.83	0.8	0.6	0.4	0.3
1.1333%	0.272	0.320	16.320	30.03	27.03	0.9	0.6	0.5	0.3
1.2333%	0.296	0.348	17.760	32.43	29.18	1.0	0.7	0.5	0.4
1.3333%	0.320	0.376	19.200	34.79	31.31	1.0	0.7	0.5	0.4
1.4333%	0.344	0.405	20.640	37.10	33.39	1.1	0.8	0.6	0.4
1.5333%	0.368	0.433	22.080	39.38	35.44	1.2	0.8	0.6	0.5
1.6333%	0.392	0.461	23.520	41.62	37.45	1.3	0.9	0.7	0.5
1.7333%	0.416	0.489	24.960	43.81	39.43	1.4	0.9	0.7	0.5
1.8333%	0.440	0.518	26.400	45.97	41.37	1.4	1.0	0.7	0.6
1.9333%	0.464	0.546	27.840	48.08	43.27	1.5	1.1	0.8	0.6
2.0333%	0.488	0.574	29.280	50.15	45.14	1.6	1.1	0.8	0.6
2.1333%	0.512	0.602	30.720	52.19	46.97	1.7	1.2	0.9	0.7
2.2333%	0.536	0.631	32.160	54.18	48.76	1.7	1.2	0.9	0.7
Given ρ =	2.515%								
2.5153%	0.604	0.710	36.220	59.58	53.62	2.0	1.4	1.0	0.8
Given ρ =	0.300%								
0.3000%	0.072	0.085	4.320	8.46	7.61	0.2	0.2	0.1	0.1

Flextural strength of concrete

Given: Concrete Strength, f'_c: 5000 psi
Steel Strength, f_y: 60 ksi
Element Size:
width, b: 12 in.
Depth, d: 3 in.

ACI Code:
7.12 - Shrinkage and temperature reinforcement
10.5 - Minimum reinforcement of flexural members

for 5" thk concrete slab

Computing:
concrete section area, A_c = 36 in.^{2}
β_1 = 0.8
f_r = 530.3301 psi
steel ratio for balanced conditions, ρ_b = 3.3537%
moment of inertia of the gross concrete section I_g = 125 in.^{4}
y_t = 2.5 in.

Criteria:
Maximum steel ratio: $0.75\rho_b$ = 2.5153%
Minimum steel ratio: ACI (10-3) $200/f_y$ = 0.3333% or 0.3536% ($\rho_{min\ for\ shrinkage\ \&\ temperature}$: 0.14%)
cracking moment: M_{cr} = 26516.50429 (lb-in.), or 26.5165 (k-in.)

Flextural Capacity

ρ	A_s	a	c	M_n	ϕM_n	*Required Number of Bars by entering bar #*			
	(in.^{2})	(in.)	(kips)	(k-in)	(k-in)	5	6	7	8
0.3333%	0.120	0.141	7.200	21.09	18.98	0.4	0.3	0.2	0.2
0.4333%	0.156	0.184	9.360	27.22	24.50	0.5	0.4	0.3	0.2
0.5333%	0.192	0.226	11.520	33.26	29.93	0.6	0.4	0.3	0.2
0.6333%	0.228	0.268	13.680	39.21	35.28	0.7	0.5	0.4	0.3
0.7333%	0.264	0.311	15.840	45.06	40.55	0.9	0.6	0.4	0.3
0.8333%	0.300	0.353	18.000	50.82	45.74	1.0	0.7	0.5	0.4
0.9333%	0.336	0.395	20.160	56.50	50.85	1.1	0.8	0.6	0.4
1.0333%	0.372	0.438	22.320	62.08	55.87	1.2	0.8	0.6	0.5
1.1333%	0.408	0.480	24.480	67.56	60.81	1.3	0.9	0.7	0.5
1.2333%	0.444	0.522	26.640	72.96	65.67	1.4	1.0	0.7	0.6
1.3333%	0.480	0.565	28.800	78.27	70.44	1.6	1.1	0.8	0.6
1.4333%	0.516	0.607	30.960	83.48	75.13	1.7	1.2	0.9	0.7
1.5333%	0.552	0.649	33.120	88.61	79.75	1.8	1.3	0.9	0.7
1.6333%	0.588	0.692	35.280	93.64	84.27	1.9	1.3	1.0	0.7
1.7333%	0.624	0.734	37.440	98.58	88.72	2.0	1.4	1.0	0.8
1.8333%	0.660	0.776	39.600	103.43	93.08	2.2	1.5	1.1	0.8
1.9333%	0.696	0.819	41.760	108.18	97.36	2.3	1.6	1.2	0.9
2.0333%	0.732	0.861	43.920	112.85	101.56	2.4	1.7	1.2	0.9
2.1333%	0.768	0.904	46.080	117.42	105.68	2.5	1.7	1.3	1.0
2.2333%	0.804	0.946	48.240	121.91	109.71	2.6	1.8	1.3	1.0
Given ρ =	2.515%								
2.5153%	0.906	1.065	54.331	134.05	120.65	3.0	2.1	1.5	1.2
Given ρ =	0.300%								
0.3000%	0.108	0.127	6.480	19.03	17.13	0.4	0.2	0.2	0.1

Calculations
Wave Transmission Coefficients

Transmission conefficient - Simplified Analytical Methods for Exiting Port Orchard Breakwater (North & East)

floating breakwater dimension: 12' wide x 3' deep and 15" freeboard

Based on Macagno's analytical formula, (1953)

linear wave theory used

wave period $T_w := 3.5sec_*$ gravity, $g = 32.174 \frac{ft}{s^2}$ significant wave height, $H_s := 3.1 \cdot ft_*$

water depth, $h := 35ft_*$ draft, $D_f := 1.75 \cdot ft_*$

wave length, $L_0 := \frac{g \cdot T_w^{\ 2}}{2\pi} = 62.728\,ft$

$\frac{1}{25} = 0.04 < \frac{h}{L_0} = 0.558 < \frac{1}{2}$ ---- transitional water

$$L_w := \frac{g \cdot T_w^{\ 2}}{2 \cdot \pi} \cdot \tanh\left(\frac{2\pi \cdot h}{L_0}\right) = 62.615\,ft$$

$$\sigma := \frac{2 \cdot \pi}{T_w} = 1.795 \frac{1}{s}$$

wave number, $k := \frac{2 \cdot \pi}{L_w} = 0.1 \frac{1}{ft}$ mass density of seawater

width of floating body, $B := 12 \cdot ft_*$

Transmission coefficient,

$$K_{tm} := \frac{1}{\sqrt{1 + \left(\frac{\pi \cdot B \cdot \sinh\left(\frac{2\pi\,h}{L_w}\right)}{L_w \cdot \cosh\left(2\pi \frac{h - D_f}{L_w}\right)}\right)^2}} = 0.813$$

Based on studies from Cox and Simpson, (1989 and 1993) -- from Floating Wave Attenuator Study for Bremerton Marina, Pacific International Engineering, 2003

semi-empirical transmission coefficient,

$$K_{ts} := \sqrt{\frac{\dfrac{\dfrac{4\pi\left(h-D_f\right)}{L_w}+\sinh\left[\dfrac{4\cdot\pi\cdot\left(h-D_f\right)}{L_w}\right]}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}{1+\dfrac{\dfrac{4\cdot\pi\cdot h}{L_w}}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}}\cdot\left[\frac{2\cdot\sqrt{1+\left(\dfrac{2\cdot\pi\cdot B}{L_w}\right)^2}}{2+\left(\dfrac{2\pi B}{L_w}\right)^2}\right]$$

$K_{ts} = 0.763$

adjusted transmission coefficient by a regression analysis of theoratical and observed coefficient,

$K_{ta} := 0.9631\cdot K_{ts} = 0.735$

average, $\dfrac{K_{tm}+K_{ta}}{2} = 0.774$

Transmission conefficient - Simplified Analytical Methods for New 12' Wide Port Orchard Breakwater (North & East)

floating breakwater dimension: 12' wide x 5.75' deep and 18" freeboard

Based on Macagno's analytical formula, (1953)

linear wave theory used

wave period $T_w := 3.5sec_*$ gravity, $g = 32.174\frac{ft}{s^2}$ significant wave height, $H_s := 3.1\cdot ft_*$

water depth, $h := 35ft_*$ draft, $D_f := 4.25\cdot ft_*$

wave length, $L_0 := \frac{g\cdot T_w^2}{2\pi} = 62.728\,ft$

$$\frac{1}{25} = 0.04 < \frac{h}{L_0} = 0.558 < \frac{1}{2}$$ —— transitional water

$$L_w := \frac{g\cdot T_w^2}{2\cdot\pi}\cdot\tanh\left(\frac{2\pi\cdot h}{L_0}\right) = 62.615\,ft$$

$$\sigma := \frac{2\cdot\pi}{T_w} = 1.795\frac{1}{s}$$

wave number, $k := \frac{2\cdot\pi}{L_w} = 0.1\frac{1}{ft}$ mass density of seawater

width of floating body, $B := 12\cdot ft_*$

Transmission coefficient,

$$K_{tm} := \frac{1}{\sqrt{1 + \left(\frac{\pi\cdot B\cdot\sinh\left(\frac{2\pi\,h}{L_w}\right)}{L_w\cdot\cosh\left(2\pi\frac{h - D_f}{L_w}\right)}\right)^2}} = 0.736$$

Based on studies from Cox and Simpson, (1989 and 1993) – from Floating Wave Attenuator Study for Bremerton Marina, Pacific International Engineering, 2003

semi-empirical transmission coefficient,

$$K_{ts} := \left[\sqrt{\frac{\dfrac{\dfrac{4\pi(h-D_f)}{L_w} + \sinh\left[\dfrac{4\cdot\pi\cdot(h-D_f)}{L_w}\right]}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}{1 + \dfrac{\dfrac{4\cdot\pi\cdot h}{L_w}}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}} \right] \cdot \left[\frac{2\cdot\sqrt{1 + \left(\dfrac{2\cdot\pi\cdot B}{L_w}\right)^2}}{2 + \left(\dfrac{2\pi B}{L_w}\right)^2} \right]$$

$K_{ts} = 0.596$

adjusted transmission coefficient by a regression analysis of theoratical and observed coefficient,

$K_{ta} := 0.9631\cdot K_{ts} = 0.574$

average, $\dfrac{K_{tm} + K_{ta}}{2} = 0.655$

Transmission conefficient - Simplified Analytical Methods for New 20' Wide Port Orchard Breakwater (North & East)

floating breakwater dimension: 20' wide x 5.75' deep and 18" freeboard

Based on Macagno's analytical formula, (1953)

linear wave theory used

wave period $T_w := 3.5sec_*$ gravity, $g = 32.174\frac{ft}{s^2}$ significant wave height, $H_s := 3.1 \cdot ft_*$

water depth, $h := 35ft_*$ draft, $D_f := 4.25 \cdot ft_*$

wave length, $L_0 := \frac{g \cdot T_w^2}{2\pi} = 62.728\,ft$

$\frac{1}{25} = 0.04 < \frac{h}{L_0} = 0.558 < \frac{1}{2}$ ---- transitional water

$$L_w := \frac{g \cdot T_w^2}{2 \cdot \pi} \cdot \tanh\left(\frac{2\pi \cdot h}{L_0}\right) = 62.615\,ft$$

$$\sigma := \frac{2 \cdot \pi}{T_w} = 1.795\frac{1}{s}$$

wave number, $k := \frac{2 \cdot \pi}{L_w} = 0.1\frac{1}{ft}$ mass density of seawater

width of floating body, $B := 20 \cdot ft_*$

Transmission coefficient,

$$K_{tm} := \frac{1}{\sqrt{1 + \left(\frac{\pi \cdot B \cdot \sinh\left(\frac{2\pi h}{L_w}\right)}{L_w \cdot \cosh\left(2\pi \frac{h - D_f}{L_w}\right)}\right)^2}} = 0.546$$

Based on studies from Cox and Simpson, (1989 and 1993) -- from Floating Wave Attenuator Study for Bremerton Marina, Pacific International Engineering, 2003

semi-empirical transmission coefficient,

$$K_{ts} := \sqrt{\frac{\dfrac{\dfrac{4\pi\left(h-D_f\right)}{L_w}+\sinh\left[\dfrac{4\cdot\pi\cdot\left(h-D_f\right)}{L_w}\right]}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}{1+\dfrac{\dfrac{4\cdot\pi\cdot h}{L_w}}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}}\cdot\left[\frac{2\cdot\sqrt{1+\left(\dfrac{2\cdot\pi\cdot B}{L_w}\right)^2}}{2+\left(\dfrac{2\pi B}{L_w}\right)^2}\right]$$

$K_{ts} = 0.489$

adjusted transmission coefficient by a regression analysis of theoratical and observed coefficient,

$K_{ta} := 0.9631\cdot K_{ts} = 0.471$

average, $\dfrac{K_{tm}+K_{ta}}{2} = 0.509$

Transmission conefficient - Simplified Analytical Methods for New 25' Wide Port Orchard Breakwater (North & East)

floating breakwater dimension: 25' wide x 5.5' deep and 18" freeboard

Based on Macagno's analytical formula, (1953)

linear wave theory used

wave period $T_w := 3.5sec_*$ gravity, $g = 32.174\frac{ft}{s^2}$ significant wave height, $H_s := 3.1 \cdot ft_*$

water depth, $h := 35ft_*$ draft, $D_f := 4 \cdot ft_*$

wave length, $L_0 := \frac{g \cdot T_w^{\ 2}}{2\pi} = 62.728\,ft$

$\frac{1}{25} = 0.04 < \frac{h}{L_0} = 0.558 < \frac{1}{2}$ ----- transitional water

$$L_w := \frac{g \cdot T_w^{\ 2}}{2 \cdot \pi} \cdot \tanh\left(\frac{2\pi \cdot h}{L_0}\right) = 62.615\,ft$$

$$\sigma := \frac{2 \cdot \pi}{T_w} = 1.795\frac{1}{s}$$

wave number, $k := \frac{2 \cdot \pi}{L_w} = 0.1\frac{1}{ft}$ mass density of seawater

width of floating body, $B := 25 \cdot ft_*$

Transmission coefficient, $$K_{tm} := \frac{1}{\sqrt{1 + \left(\frac{\pi \cdot B \cdot \sinh\left(\frac{2\pi h}{L_w}\right)}{L_w \cdot \cosh\left(2\pi \frac{h - D_f}{L_w}\right)}\right)^2}} = 0.472$$

Based on studies from Cox and Simpson, (1989 and 1993) -- from Floating Wave Attenuator Study for Bremerton Marina, Pacific International Engineering, 2003

semi-empirical transmission coefficient,

$$K_{ts} := \left[\sqrt{\frac{\dfrac{\dfrac{4\pi(h-D_f)}{L_w}+\sinh\left[\dfrac{4\cdot\pi\cdot(h-D_f)}{L_w}\right]}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}{1+\dfrac{\dfrac{4\cdot\pi\cdot h}{L_w}}{\sinh\left(\dfrac{4\cdot\pi\cdot h}{L_w}\right)}}}\right]\cdot\left[\frac{2\cdot\sqrt{1+\left(\dfrac{2\cdot\pi\cdot B}{L_w}\right)^2}}{2+\left(\dfrac{2\pi B}{L_w}\right)^2}\right]$$

$K_{ts} = 0.439$

adjusted transmission coefficient by a regression analysis of theoratical and observed coefficient,

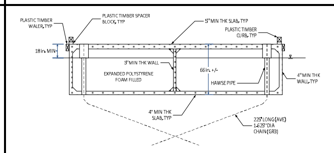
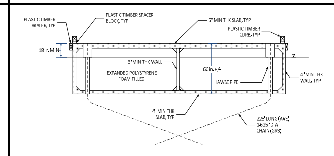
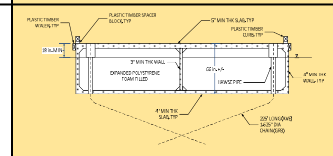
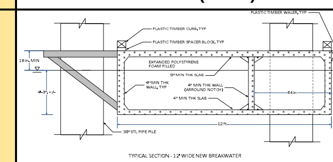
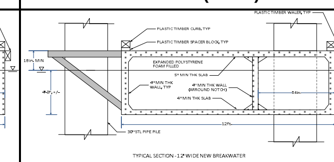
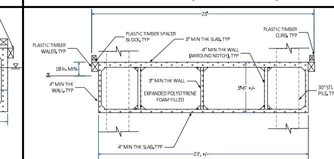
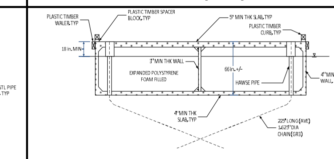
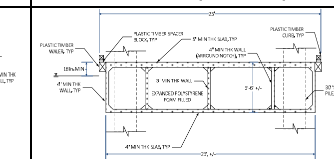
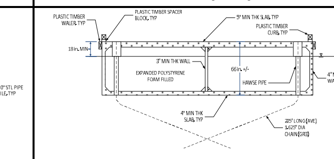
$K_{ta} := 0.9631\cdot K_{ts} = 0.422$

average, $\dfrac{K_{tm}+K_{ta}}{2} = 0.447$

Table : Breakwater Performance for Wave Height 3.1 ft.

Breakwaters	Transmission Coefficient, K_t	Transmitted Wave Height (ft.) inside Marina
Existing – 12′ wide x 3′ deep	0.77	2.4′
New – 12′ wide x 5.75′ deep	0.66	2.0′
New – 20′ wide x 5.75′ deep	0.51	1.6′
New – 25′ wide x 5.5′ deep	0.45	1.4′

ALTERNATIVE COMPARISON
ART ANDERSON ASSOCIATES

Comparison Item	Alt #0 - 12' Wide, Thinner Walls, Cable Moored (New)	Alt #1 - 12' Wide, Thinner Walls, Cable Moored (Use 75% Existing)	Alt #2 - 12' Wide, Thicker Walls, Cable Moored (New)	Alt #3 - 12' Wide, Thicker Walls, Interstitial Guide Piles (1 side)	Alt #4 - 12' Wide, Thinner Walls, Interstitial Guide Piles (1 side)	Alt #5 - 25' Wide, Thicker Walls, Interstitial Guide Piles (both sides)	Alt #6 - 25' Wide, Thicker Walls, Cable Moored (New)	Alt #7 - 20' Wide, Thicker Walls, Interstitial Guide Piles (both sides)	Alt #8 - 20' Wide, Thicker Walls, Cable Moored (New)
Cross Section									
First Cost	$14,460,000	$13,140,000	$15,710,000	$15,560,000	$14,660,000	$31,620,000	$32,290,000	$26,190,000	$26,850,000
Annual Maint. Cost	$584,000	$527,000	$636,000	$622,000	$586,000	$1,265,000	$1,300,000	$1,048,000	$1,083,000
Life Cycle	35	0	50	50	30	50	50	50	50
Benefits - 1	Low First and Maint. Cost	Lowest First Cost	Low First and Maint. Cost	Low First and Maint. Cost	Low First and Maint. Cost	17' of Useable Deck Space at Piles	Greatest Deck Surface Available	11' of Useable Deck Space at Piles	19' of Useable Deck Space at Piles
Benefits - 2	Moderate Life Cycle	-	High Life Cycle	High Life Cycle	Moderate Life Cycle	High Life Cycle	High Life Cycle	High Life Cycle	High Life Cycle
Benefits - 3	Good Wave Attentuation	-	Good Wave Attentuation	Good Wave Attentuation		Best Wave Attentuation	Best Wave Attentuation	Excellent Wave Attentuation	Excellent Wave Attentuation
Challenges - 1	Lower Life Cycle	Not Viable	None	Pile Hoops/Piles Interfere w/ Moorings	Pile Hoops/Piles Interfere w/ Moorings	High First and Maint. Cost	Highest First and Maint. Cost	High First and Maint. Cost	High First and Maint. Cost
Challenges - 2	Deck Loading Constraints	-	-	Pile Hoops/Piles Interfere w/ Events	Pile Hoops/Piles Interfere w/ Events	Increased Permitting and Mitigation Effort and Cost	Increased Permitting and Mitigation Effort and Cost	Increased Permitting and Mitigation Effort and Cost	Increased Permitting and Mitigation Effort and Cost
Challenges - 3	-	-	-	Float Notches make Construction more difficult	Float Notches make Construction more difficult	Float Notches Create Construction and Use Complieities		Float Notches Create Construction and Use Complieities	
Trade-Off Grade	45	40	54	50	48	40	42	43	45