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Subject: Vulnerability Assessment and Resilience Planning, Hamilton Wharf, Searsport, Maine
Penobscot Bay Working Waterfront Resiliency Analysis
State of Maine, Department of Marine Resources

Wood Environment & Infrastructure Solutions, Inc. (Wood) is pleased to provide the Maine Department of Marine Resources (DMR) this report on the baseline characterization, vulnerability assessment and resilience planning for the Hamilton Wharf, Searsport, Maine. This report provides findings for one of ten sites included in DMR's Penobscot Bay Working Waterfront Resiliency Analysis project. Reports on the other nine sites are provided under separate cover. Our work was performed in general accordance with the scope of work and the terms and conditions included in Wood's proposal dated 1 March 2019.

1.0 INTRODUCTION

As proposed for DMR's Penobscot Bay Working Waterfront Resilience project, Wood conducted an assessment of the Hamilton Wharf in Searsport, Maine which included:

- Facility baseline characterization including a review of available site documents, interviews with community representatives, survey of site topography and elevations of key site features, and review of the general condition of existing site structures by a Wood structural engineer;
- Facility vulnerability analyses based on the baseline survey data, condition of structures, and modelling of potential storm surge and wave affects under three sea-level rise (SLR) scenarios; and
- Development of resilience measures, including strategies for incremental adaptation under the modelled storm and SLR scenarios.

This report contains a summary of our document review, personnel interviews, structural observations, photographs documenting our observations (**Appendix A**), and the approximate location of potential structural deficiencies. Following our analysis of the site and as part of the vulnerability analysis, we were able to identify the risks for the affected site features (see **Table 4**) from inundation data. Inundation maps developed for the site by Wood's consulting partner, Woods Hole Group (WHG) are provided in **Appendix B**. The vulnerability analysis establishes the future risk framework for the site and its structural features. Wood has evaluated the degree of impact of these site-specific vulnerabilities, and we have provided recommendations for improved resilience (e.g., repair, reinforcement) in relation to the feature's immediate performance and/or expected performance per the vulnerability analysis.

As part of the subsequent discussion, the following terms are defined below:

Base Flood Elevation (BFE) -	Elevation of flooding, including wave height, having a 1% chance of being equaled or exceeded in any given year.
Checks	A separation of the wood occurring across or through the rings of annual growth and usually as a result of seasoning.
Coastal High hazard Area (CHHA) -	Area within a special flood hazard area extending from off-shore to the inland limit of a primary frontal dune along an open coast and any other area that is subject to high velocity wave action.
Design Flood Elevation (DFE)	Based on the design flood, the DFE is the higher of the base flood elevation (BFE) shown on FIRMs prepared by FEMA or the flood elevations shown on the map adopted by a community.
FIRM -	Flood Insurance Rate Map. Official map of a community on which FEMA has delineated both special flood hazard areas and the risk premium zones applicable to the community.
Highest Annual Tide (HAT) –	The elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum Epoch.
Mean Higher High Water (MHHW) –	The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. The highest high tide or water height is referred to as the Highest Astronomical Tide (HAT) and is defined as the highest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.
National Tidal Datum Epoch –	The specific 19-year period (Currently 1983 to 2001) adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (Mean Lower Low Water, etc.) for tidal datums.
Pre-FIRM	Construction or substantial improvement occurred on or before December 31, 1974.
Shakes	Lengthwise separations of the wood along the grain, usually occurring between or through the rings of annual growth.
Splits	A separation of the wood through the piece to the opposite surface or to an adjoining surface due to tearing apart of the wood cells.
Still Water Elevation –	Elevation that the surface of the water would assume in the absence of waves referenced to a specified vertical datum at the defined recurrence interval.
Wave Height –	Vertical distance between the crest and the trough of a wave.

2.0 DOCUMENT REVIEW AND PERSONNEL INTERVIEWS

Wood was escorted by Mr. Wayne Hamilton, Harbor Master, and Mr. James Gillway, Town Manager, during a site visit on 25 June 2019. We discussed the site features and historical development of the site. Mr. Hamilton mentioned that the primary use of the wharf is for fishing, deviating from its original use as steamboat wharf. Both gentlemen also mentioned tentative plans to

expand the wharf to accommodate small cruise ships. A rough sketch was viewed but no schedule was provided for actual planning and construction. They also pointed out the previous phased construction and repair work which has taken place, as indicated from dated etching cast into the concrete deck. The most recent repair work was executed in 2015.

Mr. Hamilton stated that during a normal high tide, the water elevation is roughly 2 feet below the top of deck. Occasionally the high tide water level is above the top of the deck at the furthest end (Bay side). Storm events which were recalled for this area with substantial impact were Hurricane Gloria of 1985 and Hurricane Bob of 1991. He also mentioned that during low tides the floating docks will often bottom out. Maintenance dredging is performed as needed, following a larger dredging performed in the 1980's at the inner side or the furthest finger. A more expansive dredging effort would be necessary to allow larger ships, such as cruise lines, to enter the harbor. The following is a summary of key site features identified during the site visit:

- The site consists of the timber wharf, parking area, sea wall and a boat ramp (See **Figure 1** below).
- The boat ramp was paved roughly two years ago.
- The wharf was constructed during phases which included construction in 1997, 1999 and 2015.
- There were no other structures identified onsite specifically associated with the Hamilton Wharf.
- Three (5) wooden floating docks are located along the east side of the wharf (see **Photograph No. 11, Appendix A**).
- There is no formal ongoing maintenance plan in place; maintenance is addressed, as needed, when a deficiency is identified.
- The site is equipped with LED lighting and a security camera.

No structural plans or as-built drawings were available for our review. Our assessment is based on information provided onsite by our contact and details gathered during our site visit.

Figure 1: Site Overview

3.0 OBSERVATIONS AND FINDINGS

Tirrell Day and Lane Gray of Wood performed a site assessment and gathered geospatial data for key site features during the 25 June 2019 visit. This assessment included documenting the general condition and recording elevations of key features and structures. At the request of the Town, the limits of our investigation include the wharf, approach, attached floating docks, sea wall and a boat ramp. Photos of the sites and Wood's noteworthy observations are included in the Photolog (**Appendix A**). Elevations discussed in this report are with respect to North American Vertical Datum of 1988 (NAVD88). The site facilities and

their associated elevations are included in **Table 1** for reference. During our site visit the approximate tidal levels where between -4.31 ft and 4.29 ft (predicted min. of -4.62 ft, max. of 3.95 ft).

3.1 Property Overview

This site is a 1.5-acre property consisting of a timber wharf with floating docks, a sea wall, a parking area and boat ramp. The wharf is located at the south side of the property. There are five (5) floating docks attached to the structure via gangways and tie ropes or chain. Wood observed the function of the gangway and floats during tidal action and the system appeared to function as intended. The boat ramp is adjacent to the wharf at the north side. A sea wall forms the east perimeter of the parking area, framing the north side of the boat ramp, extending north parallel to the coastline and terminating before reaching the property line. A short run of shoreline protection in the form of large riprap fills this gap.

The wharf consists of a main section with two fingers extending from the east side. The structure appears to be constructed of a concrete deck on timber stringers, supported by timber posts and/or piles (**Photographs 3 – 10**). Details on timber pile embedment were not provided. The Subsurface conditions of the site were not probed or verified by testing as part of Wood's scope of work. We were only able to view exterior wood framing. The presence of interior stringers or otherwise any additional interior support of the concrete deck could not be viewed. Given we performed a visual assessment only, the size, frequency and presence of steel reinforcement could not be confirmed. Large rocks fill the interior of the wharf beneath the concrete deck (**Photograph 4 & 5**). A handrail with curb is provided at the perimeter of the wharf. Timber framing appears to be attached using a combination of what appears to be galvanized steel through bolts, nails, and/or screws.

Site utilities include electrical and water lines provided at select locations at the wharf and/or floating docks. No facilities were assessed as part of the site visit, such as an office building or public restroom.

Table 1: Site Elevations

Location	***Lowest Horizontal Member***	***Lowest Deck or Adjacent Grade***	***First Finished Floor / Mid Mark***	***Lowest Opening/ Critical Elevation***
Source	***Estimate***	***Survey***	***Survey***	***Survey***
Facility	***[ft]***	***[ft]***	***[ft]***	***[ft]***
Wharf	5.81	7.56	n/a	n/a
Floating Dock 1	n/a	n/a	n/a	n/a
Floating Dock 2	n/a	n/a	n/a	8.05
Floating Dock 3	n/a	n/a	n/a	7.7
Floating Dock 4	n/a	n/a	n/a	8.05
Floating Dock 5	n/a	n/a	n/a	7.73
Shoreline Protection	n/a	0.9	n/a	7.38
Boat Ramp	n/a	-3.54	1	6

**Estimates indicate measurements referenced or derived from the actual site survey data.*

3.2 Noted Deficiencies

The wharf was viewed from above during access to the deck and from below at the adjacent grade or from the floating docks (**Photographs 12 – 24**). We noted weathered timber members throughout which exhibited signs of checking, splitting and shakes. Severity of these observed conditions ranged from minor to major, depending on the location. Members which were part of the most recent repair or renovation work exhibited minimal weathering. The most advanced deterioration was observed at Finger A (See **Photograph 11** for wharf key). Major settling or deflection of the wharf was observed at this location which also exhibited signs of previous remediation work. The concrete deck has been re-poured over the previous settled deck (**Photograph 18 – 20, & 29**). Despite these remedial actions, it is not clear whether the structure can transfer load successfully or otherwise provide a suitable load path to the subgrade in the repaired area (**Photographs 13 – 16**). Timber members experiencing major weathering exist at the opposite side of Finger A (**Photograph 17**) which appear to provide support for the already deflected section of concrete deck. Signs of distress, such as a through cracking, were noted.

The floating docks appears to be in good condition with some decking exhibiting minor weathering (**Photographs 25 – 36**). The pontoons appear to function as intended, however, the floats appear to be secured for temporary use only based on the attachment to the wharf using ropes or small chains. In addition, the gangway attachment for Floating Dock 3 exhibits corrosion at the header, as noted from the corrosion bleeding (**Photograph 30**). The connection to the wharf was concealed from view and we were unable to observe the extent of damage.

As previously mentioned, the site is equipped with water and electrical services, including lighting (**Photographs 37 – 42**). Overall, electrical conduits and connections are secured under fixtures and covers which are suitable for damp or wet conditions. We noted exposed and corroded water conduit at several locations at the underside of the deck (**Photographs 39 & 40**).

The boat ramp was recently paved, and the surface appears in reasonably good condition. The slope of the ramp varies over its length, ranging from about 14% (preferred) near the shore, to about 7% further down the ramp. We estimate that this condition is of concern only during low tide.

We reviewed visible surfaces of the seawall at the east side of the property (**Photographs 44 – 47**) and noted no obvious delamination or settlement. We were informed that one location along the backside of the wall may experience piping (**Photograph 47**), where the asphalt cover has eroded into a hole behind the wall. The Town has temporarily filled this area with curb inlet filters (sacks constructed of gravel wrapped in filter fabric).

3.3 Risk Framework

As a basis for the vulnerability analysis, water surface elevation (WSE) exposure profiles were developed by WHG which summarize current and potential future tidal and storm surge inundation/wave impacts. The key flood elevation profiles provided include the Mean Higher High Water (MHHW), the Highest Astronomical Tide (HAT), the 1% Still Water Level, and the Base Flood Elevation (BFE). Values for these scenarios are site specific and take into consideration the topographic survey data obtained by Wood.

The MHHW and HAT tidal datums (present day) were sourced from the nearest long-term NOAA tide station and from spatial files developed by Maine Geological Survey[1]. The 1%-annual-chance still water level (present day) was obtained from the 2016 FEMA Flood Insurance Study for Knox County.

[1] https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml

Table 2: Flood Modelling Data Summary

Scenario	*MHHW*	*HAT*	*1% Still Water Level*	*1% Wave Crest Elevation (BFE)*
Present day	4.7	7.0	9.7	11-15
Short Term (+1 ft)	5.7	8.0	10.7	13-16
Mid Term (+2 ft)	6.7	9.0	11.7	14-17
Long Term (+4 ft)	8.7	11.0	13.7	16-19

Site-specific wave modelling was conducted for existing and future sea levels to better quantify wave hazards and potential increases in wave heights at the site. Wave modelling was conducted using FEMA's overland wave modelling approach for consistency in providing an estimate of the 1% BFE for the future scenarios.

For potential future flood impacts, relative SLR scenarios were reviewed using the U.S. Army Corps of Engineers' Sea-Level Change Curve Calculator (Version 2017.55), specifying the Bar Harbor long-term tide gauge, a regionally-informed vertical land movement rate (from NOAA), and the NOAA et. al (2017)[2] SLR curves.

In discussion with the project team, the preferred SLR scenarios defined for evaluating short-term, mid-term, and long-term impacts were selected as 1 ft, 2 ft, and 4 ft, respectively. These projected increases in sea level roughly correspond with NOAA's Intermediate scenario for the years 2030, 2050, and 2085 with a rather low exceedance probability (17%) and are within the range of the SLR scenarios recommended by Maine DOT for design of transportation infrastructure.

3.4 Site Vulnerabilities

The flood modelling data provided above in **Table 2** includes scenarios for the Short Term, Mid Term, and Long Term SLR scenarios. NOAA's Intermediate scenario mentioned above compared with these timeframes should be taken into consideration for the identified return periods as illustrated in **Table 3**.

Table 3: Flood Return Period

Event Return Period	Percent Chance of Occurrence per Period			
	5 Years	10 Years	25 Years	50 Years
100 Year Flood (1%)	4.9%	9.6%	22.2%	39.5%
500 Year Flood (0.2%)	1%	2%	4.9%	9.5%

The various site features have been summarized in **Table 4** for each facility, indicating the associated risk and flood scenario which result in inundation. Those elevations noted as 0 ft indicate an elevation equal to the identified feature of the facility. No elevations are noted in Appendix B where no inundation of the feature was identified (i.e., flood elevation is lower than that of the site feature). Below are the site-specific vulnerabilities based on our review of the property.

[2] https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

Table 4: Site Elevations and Risks

Facility			Inundation above Elevation of Facility															
Description			Present Day				Short Term Scenario				Mid Term Scenario				Long Term Scenario			
		Elevation (ft) to NAVD88	MHHW [ft]	HAT [ft]	1% Stillwater [ft]	BFE [ft]	MHHW [ft]	HAT [ft]	1% Stillwater [ft]	BFE [ft]	MHHW [ft]	HAT [ft]	1% Stillwater [ft]	BFE [ft]	MHHW [ft]	HAT [ft]	1% Stillwater [ft]	BFE [ft]
Wharf	Lowest Horizontal	5.81 ft		1.19	3.89	9.2		2.19	4.89	10.2	0.89	3.19	5.89	11.2	2.89	5.19	7.89	13.2
	Lowest Deck or Adjacent Grade	7.56 ft			2.14	7.4		0.44	3.14	8.44		1.44	4.14	9.44	1.14	3.44	6.14	11.4
Floating Dock 1	Buoy Chain max elevation																	
	Gangway support																	
Floating Dock 2	Buoy Chain max elevation																	
	Gangway support	8.05 ft			1.65	7			2.65	7.95		0.95	3.65	8.95	0.65	2.95	5.65	11
Floating Dock 3	Buoy Chain max elevation																	
	Gangway support	7.7 ft			2	7.3		0.3	3	8.3		1.3	4	9.3	1	3.3	6	11.3
Floating Dock 4	Buoy Chain max elevation																	
	Gangway support	8.05 ft			1.65	7			2.65	7.95		0.95	3.65	8.95	0.65	2.95	5.65	11
Floating Dock 5	Buoy Chain max elevation																	
	Gangway support	7.73 ft			1.97	7.3		0.27	2.97	8.27		1.27	3.97	9.27	0.97	3.27	5.97	11.3
Seawall	Toe of wall	0.9 ft	3.8	6.1	8.8	14	4.8	7.1	9.8	15.1	5.8	8.1	10.8	16.1	7.8	10.1	12.8	18.1
	Top of Wall	7.38 ft			2.32	7.6		0.62	3.32	8.62		1.62	4.32	9.62	1.32	3.62	6.32	11.6
Boat Ramp	Toe	-3.54 ft	8.24	10.5	13.24	19	9.24	11.5	14.24	19.5	10.24	12.5	15.24	20.5	12.24	14.5	17.24	22.5
	Mid-Mark	1 ft	3.7	6	8.7	14	4.7	7	9.7	15	5.7	8	10.7	16	7.7	10	12.7	18
	Top/Slope	6 ft		1	3.7	9		2	4.7	10	0.7	3	5.7	11	2.7	5	7.7	13

3.4.1 Wharf

From our preliminary non-destructive investigation, most areas of the wharf appear to be of sound condition, securely fastened and restrained against movement with fasteners or other mechanical means. The behaviour of the wharf for the Present Day scenario, where the 1% Stillwater elevation is above the lowest horizontal member, is dependent on these elements being properly attached. The Finger A of the wharf has undergone considerable deflection and it appears the support system for the previous concrete deck has failed or the original deck itself has failed due to improper design and/or construction. Given the wharf does not appear to have been properly remediated to prevent further deflection, an event such as the BFE, with wave heights up to 5 or more feet, could substantially damage this section of the wharf. Moving toward the Long Term scenario, continuing the trend of roughly 5 ft waves for the BFE, the possibility of local failure increases in the future. The function of the wharf becomes critical for the Long Term scenario when the HAT is estimated at almost 3.5 ft above top of deck elevation. Considering a MHHW over 1 foot above the deck elevation, which occurs more frequently than the HAT, the usability of the wharf is at risk of being compromised at this period in time.

Site utilities at the wharf, which include water and electricity, are exposed to wave action under the Present Day BFE. It is not until the Long Term condition that electrical equipment becomes inundated, and many electrical components appear to be protected from exposure to moisture (e.g., shields, coverings). In contrast, water lines are already at risk of inundation for the Present Day scenario, being located either below the deck or at the deck surface.

3.4.2 Floating Docks

The floating dock assembly consists of the gangway and pontoons. The critical elevation for proper function of the floating docks is the MHHW. As is indicated on **Table 4** for the Present Day Scenario, minimal risk is foreseen for damage to the wharf from tidal action forces exerted from the gangway. However, the risk of damage increases for all future scenarios, with the risk greatest risk of damage for the Long Term MHHW, which is over 1 ft above the top of deck elevation. Varying attachment methods for the gangways to the wharf were noted at this site. These connections and assemblies will differ in how they transfer load to the wharf and should be evaluated separately in detail to conservatively determine the impact. In addition, the current means for attachment of the docks using only ropes or chains allows for excessive movement and increases the potential for damage to the wharf during a storm event.

3.4.3 Shoreline Protection

Shoreline protection exists in the form of a seawall, which essentially protects the parking lot and boat ramp from erosion. During our site visit, water levels were near the top of the seawall (Elevation 7.38 ft) which is consistent with previous observations by Town officials. Our analysis indicates that the Stillwater BFE would exceed the wall height for the Present Day scenario. There already appears to be concerns with the function of the wall for at least one location where seepage or piping was noted. Rock size appears to be sufficient, however improper subgrade material and poor compaction may be the cause of the settlement issue.

3.4.4 Boat Ramp

We expect the boat ramp to remain operational during the Present Day and Short Term scenarios. During the Mid and Long Term scenarios, the MHHW levels increase to exceed elevations of the most preferred conditions of loading and unloading, between 2 ft and 5 ft (NAVD88). Due to rising water levels the ramp may become too deep to access during times of higher tides. During these periods, the accessible areas are sloped below the minimum recommended for boat ramps, creating undesirable conditions for loading and unloading.

4.0 RECOMMENDATIONS

4.1 General Recommendations

In accordance with American Society of Civil Engineers / Structural Engineering Institute Standard 24 – Flood Resistant Design and Construction (ASCE 24), existing structures that sustain substantial damage, or that are substantially improved, are treated as new construction. This standard considers damage beyond routine maintenance or otherwise minimal damage following an event, which nonetheless requires major improvements and even applies to structures classified as pre-FIRM. **For new construction we recommend, in light of the forecasted increase in water levels and the schedule for these events in relationship to the life of the structure, design should be based on the either BFE plus 2 feet of freeboard, the DFE, or 500-year event, whichever is higher**. It is understood that local requirements coupled with available resources will dictate the ability for the communities to incorporate proactive designs. The following recommendations are provided with regard to areas of the site which fall within a special flood hazard area:

- All new construction, substantially improved, and substantially damaged buildings must be elevated on pilings, posts, wharfs, or columns so that the bottom of the lowest horizontal structural member of the lowest floor is at or above the BFE with any applicable freeboard (or DFE), per ASCE 24.
- The foundation system must be anchored to resist flotation, collapse, lateral movement due to wind and water loads acting simultaneously on all components of the building.
- Use of flood damage-resistant materials above the BFE per ASCE 24 and the local Building Code.

- Electrical and Plumbing Equipment should be located on the landward side of any building and/or behind structural elements. They must be elevated and designed to prevent flood waters from entering and accumulating in components during flooding.
- Install shutoff and isolation valves on water and sewer lines that extend into the flood-prone areas.

This list is not comprehensive but rather applies to site features observed during our site visit. There may exist other relevant items addressed in any of the above-mentioned design standards which are applicable for the site at a future date. We recommend a detailed site assessment be performed during the design stage to ensure implementation of all applicable items.

4.2 Site Specific Recommendations

Although the risks, vulnerabilities, and associated recommendations addressed herein are in reference to features located within the property limits of the Hamilton Wharf, there may be features of similar construction in close proximity and exposed to similar risks as described in this report but fall outside the property limits. We recommend that these sites and features undergo a similar assessment with the assumption that similar or greater risks may apply. The following are recommendations for the features identified at risk within the Hamilton Wharf, Searsport.

4.2.1 Wharf

The following recommendations are provided in reference to the **Present Day** scenario for flood values provided in **Table 2** above:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Incorporate redundancies in design as needed based on a detailed structural analysis. Repair or replace damaged section designated as Finger A herein.
- Utilities and equipment should be properly secured to resist design wind and water loading or relocated above the flood elevation as specified in ASCE 24. Watertight enclosures should be incorporated for electrical equipment and conduits.

The following recommendations are provided in reference to the **Short Term and all future scenarios** for inundation values provided in Table 2 above:

- Consider raising the wharf in response to rising water levels and into flood zone of less impact, and reconstruction incorporating a sustainable design at the current location.

While raising the wharf may reduce the impact of rising sea levels and storm events, such construction is expensive, particularly considering the need to accommodate impacts to adjacent parking lots, roads and utilities. A cost-benefit analysis should be conducted which considers the impacts of wharf reconstruction and the lifecycle of the structure relative to sea level trends, among other factors. It may be more feasible to invest in proactive wharf maintenance and assuring that the structures are properly secured against anticipated design forces, with the understanding that waterfront structures may not be accessible during certain flood events.

4.2.2 Floating Docks

The following recommendation is provided in reference to the **Present Day scenario** with regard to construction of the floating dock assemblies:

- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed.
- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is reasonable condition to resist the intended design loading
- Confirm the gangway attachments are sufficient to resist the design loading and repair or replace as needed.

The following recommendation is provided in reference to the **Short Term and all future scenarios** with regard to construction of the floating dock assembly:

- In the event the wharf elevation is not scheduled to be raised, consider raising the gangway and gangway platform to accommodate the rising water level. This alternative will provide an elevated gangway platform above the deck elevation, and greater resilience during future extreme high tide and storm events. Although raising the wharf is should be considered for subsequent scenarios, this option may be an economically-viable.

4.2.3 Shoreline Protection

The following recommendation is provided in reference to the **Present Day and all future scenarios** with regard to the current sea wall:

- An analysis should be performed to model the behaviour of the structure for the Mid Term scenario at a minimum; any reconstruction or retrofit design should be based on this analysis.

The following recommendation is provided in reference to the **Long Term scenario** with regard to construction of the revetment:

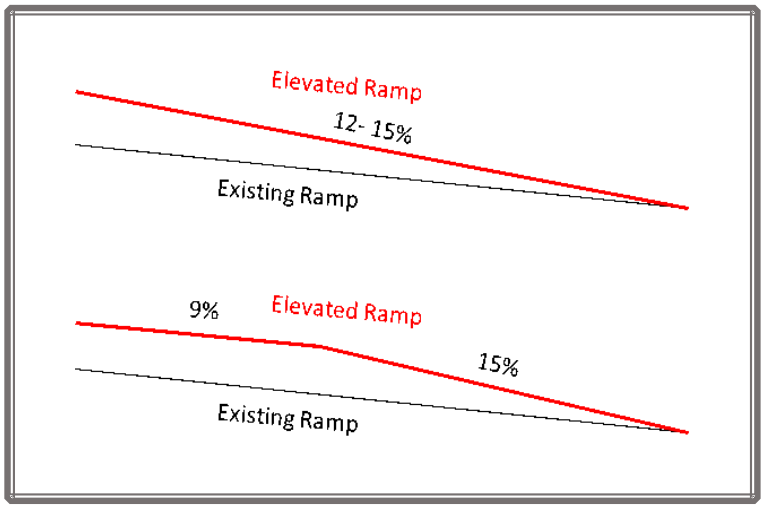
- Recommend re-grading and raising the parking area, providing a structural or natural slope, and erosion protection for the parking area and shoreline.

4.2.4 Boat Ramp

The following recommendation is provided in reference to the **Mid Term and Long Term scenarios** with regard to existing boat ramp:

- Recommend raising the ramp commensurate with the rising tide and providing the recommended slope between 12% and 15% (See **Figure 2** below). Depending on available space, options which incorporate varying slopes may be necessary to transition from the parking lot to the shore.

Figure 2: Ramp Remediation Options



5.0 OPINION OF PROBABLE CONSTRUCTION COSTS

The costing information below is based on our recommendations for remedial action considering the flood modelling and observation of structures reported herein. These estimated costs include the associated design and engineering services where applicable. **Table 5** provides a summary of the estimated cost for repair or replacement of the identified vulnerabilities. A cost savings may also be expected for combined efforts for items similar in nature, for example, replacing an electrical cabinet while updating and/or securing electrical conduits. We have not considered this variable in our values. Where a complete replacement option is provided, this option and associated costs may be implemented sooner depending on the priorities and funding available to the Town. Costing for the referenced scenario represents summation of all non-complementary improvements. That is, where other repairs or intermediate retrofitting are performed during preceding scenarios the associated costs become additive. All costs are based on present value without inflation. Provided below is a more detailed description of the items included for the associated risk scenario.

Table 5: Repair / Replacement / Retrofitting Costs

Facility	Present Day	Short Term	Mid Term	Long Term
Pier / Wharf	$625,000	$3,000,000	$3,000,000	$3,000,000
Floating Docks	$600,000	$600,000	$600,000	$600,000
Shoreline Protection	$600,000	$600,000	$600,000	$3,450,000
Boat Ramp			$195,000	$195,000
TOTAL:	**$1,825,000**	**$4,200,000**	**$7,245,000**	**$8,795,000**

5.1 Present Day Scenario

The following costs should be expected to accommodate events associated with the Present Day scenario.

Wharf:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Incorporate redundancies in design as needed based on a detailed structural analysis. Repair or replace damaged section designated as Finger A herein. Design and Construction **$350,000 - $600,000.**
- Utilities and equipment should be properly secured to resist design wind and water loading or relocated above the flood elevation as specified in ASCE 24. Watertight enclosures should be incorporated for electrical equipment and conduits. **$10,000 - $25,000.**

Floating Docks:

- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$250,000.**
- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is in decent condition to resist the intended design loading. Design and Construction **$65,000.**
- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$285,000.**

Shoreline Protection:

- An analysis should be performed to model the behaviour of the structure for the Mid Term scenario at a minimum; any reconstruction or retrofit design should be based on this analysis. Design and Construction **$600,000.**

5.2 Short Term Scenario

Items addressed for this section include any unaddressed items of the previous scenario (Present Day) and new risks related to the Short Term scenario. The following costs should be expected to accommodate events associated with the Short Term scenario:

Wharf:

- Raise wharf to accommodate at least the Mid Term scenario. Construction should include sustainable design based on 50 year plus design life. Design and Construction **$2,000,000 - $3,000,000.**

Floating Docks:

- Raise the gangway and gangway platform to accommodate the rising water level. Design and Construction. **$350,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$250,000.**

Shoreline Protection:

- An analysis should be performed to model the behaviour of the structure for the Mid Term scenario at a minimum; any reconstruction or retrofit design should be based on this analysis. Design and Construction **$600,000.**

5.3 Mid Term Scenario

Wharf:

- Raise wharf to accommodate at least the Long Term scenario. Construction should include sustainable design based on 50 year plus design life. Design and Construction **$2,000,000 - $3,000,000.**

Floating Docks:

- Raise the gangway and gangway platform to accommodate the rising water level. Design and Construction. **$350,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$250,000.**

Shoreline Protection:

- An analysis should be performed to model the behaviour of the structure for the Mid Term scenario at a minimum; any reconstruction or retrofit design should be based on this analysis. Design and Construction **$600,000.**

Boat Ramp:

- Recommend grading for steeper slope and adding structural support of slope to retain dimensions. Design and Construction **$195,000.**

5.4 Long Term Scenario

This section includes costs which are expected due to the need for substantial site improvements, however some of these actions are recommended as early as the Short Term scenario. Items which are not addressed in earlier time periods are included here when not addressed during the course of other referenced improvements.

Wharf:

- Raise wharf to accommodate at least the Long Term scenario. Construction should include sustainable design based on 50 year plus design life. Design and Construction **$2,000,000 - $3,000,000.**

Floating Docks:

- Raise the gangway and gangway platform to accommodate the rising water level. Design and Construction **$350,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$250,000.**

Shoreline Protection:

- Recommend re-grading and raising the parking area, providing a structural or natural slope, and erosion protection for the parking area and shoreline. Design and Construction **$2,000,000 - $3,450,000.**

Boat Ramp:

- Recommend grading for steeper slope and adding structural support of slope to retain dimensions. Design and Construction **$195,000.**

6.0 QUALIFICATIONS OF THE REPORT

The DMR should understand that our observations may be inconclusive, or it may not be possible to identify a definitive cause of distress based on a structural inspection and visual observations alone/without further testing. The recommendations are made based on these limitations.

The "Opinion of Probable Construction Costs" is made on the basis of Wood PLC's judgment, as experienced and qualified professionals generally familiar with the construction industry. However, since Wood, PLC has no control over the cost of labor, materials, equipment, or services furnished by others, or over the construction contractor's methods of determining prices, or over competitive bidding or market conditions, Wood cannot, and does not, guarantee that proposals, bids, or actual construction cost will not vary from the Opinion of Probable Construction Costs prepared by Wood PLC. We have attempted to consider the general nature of the work and site conditions, based on information made available to us at this stage of the project. All costs are based on actual costs as provided by RS Means Costworks 2018, additional or other specified suppliers vendors and contractors.

7.0 CLOSING

Wood appreciate the opportunity to provide these services to DMR on this project. Please contact us with any questions or comments.

Sincerely,
Wood Environment & Infrastructure Solutions, Inc.

Tirrell Day, PE
Senior Structural Engineer

D. Todd Coffin
Associate Project Manager

Attachments: Appendix A - Photolog
Appendix B – Site Elevations and Risks
Appendix C – Inundation Maps

Appendix A - Photolog for Hamilton Wharf Searsport, ME

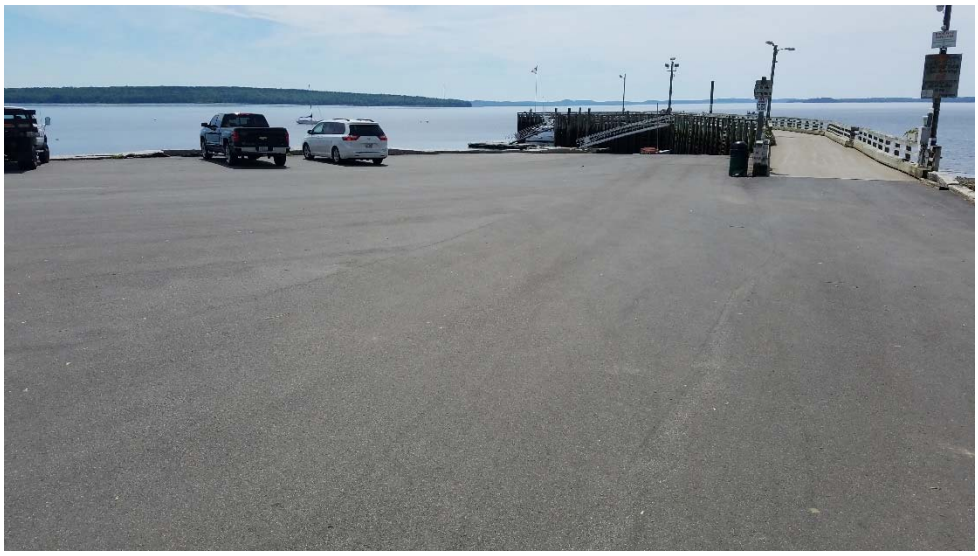
By: T. Day *Date:* 10OCT2019 *Reviewed:* K. Sun *Date:* 11OCT2019

Photograph No. 1:

Comment:

Overview of Site

Photograph No. 2:



Comment:

View of wharf from parking area.

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 3: 	**Comment:** **View of wharf and boat ramp.**
Photograph No. 4: 	**Comment:** **View looking west at northeast side of wharf.** **Construction of wharf noted as concrete deck on timber framing and piles.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 5: 	**Comment:** **Close up of previous photo. View of gravel fill.**
Photograph No. 6: 	**Comment:** **View looking east at west side of wharf, near entrance.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 7: 	**Comment:** **Overview of wharf and wharf approach.** **View of ground conditions as gravel throughout.**
Photograph No. 8: 	**Comment:** **Closer view of west side of wharf approach.** **Construction similar as viewed from east side of structure.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 9:

Comment:

View of interior of wharf from a void.

1. **Indicates the presence of longitudinal framing. Member does not support the concrete deck.**

Photograph No. 10:

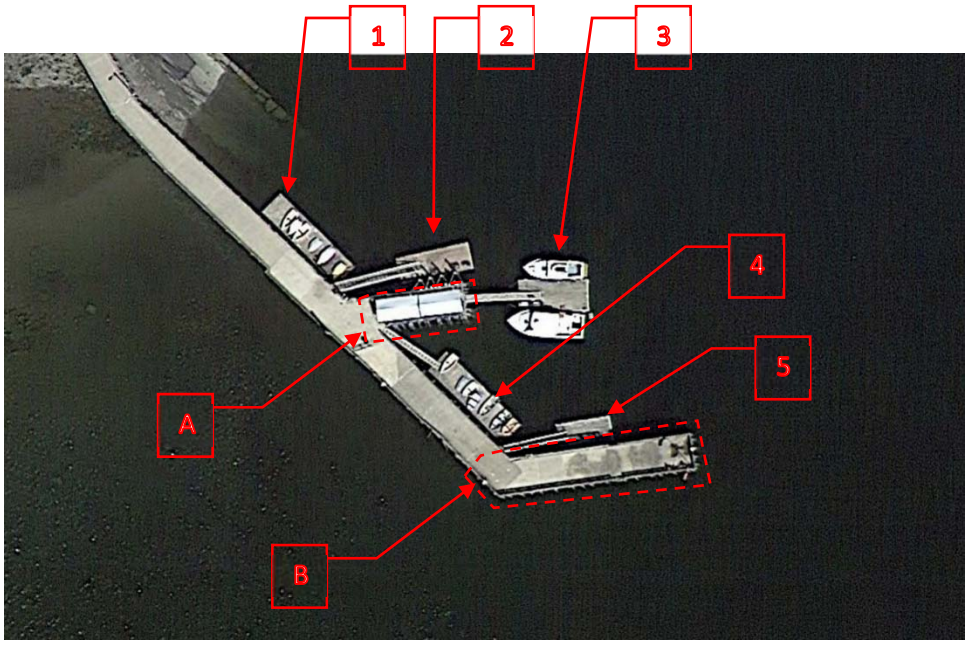
Comment:

Typical view of deck of wharf main section.

View of most recently renovated section of wharf.

By: T. Day *Date:* 10OCT2019 *Reviewed:* K. Sun *Date:* 11OCT2019

Photograph No. 11:



Comment:

Wharf and floating dock Key:

A. Wharf Finger A
B. Wharf Finger B

1. Floating Dock 1
2. Floating Dock 2
3. Floating Dock 3
4. Floating Dock 4
5. Floating Dock 5

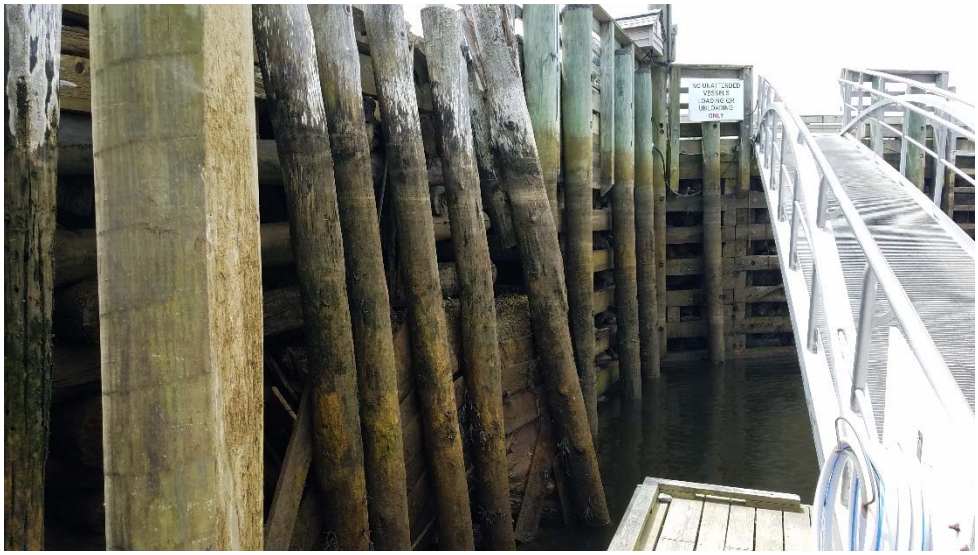
Photograph No. 12:

Comment:

View of Finger A from south side of wharf.

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 13:

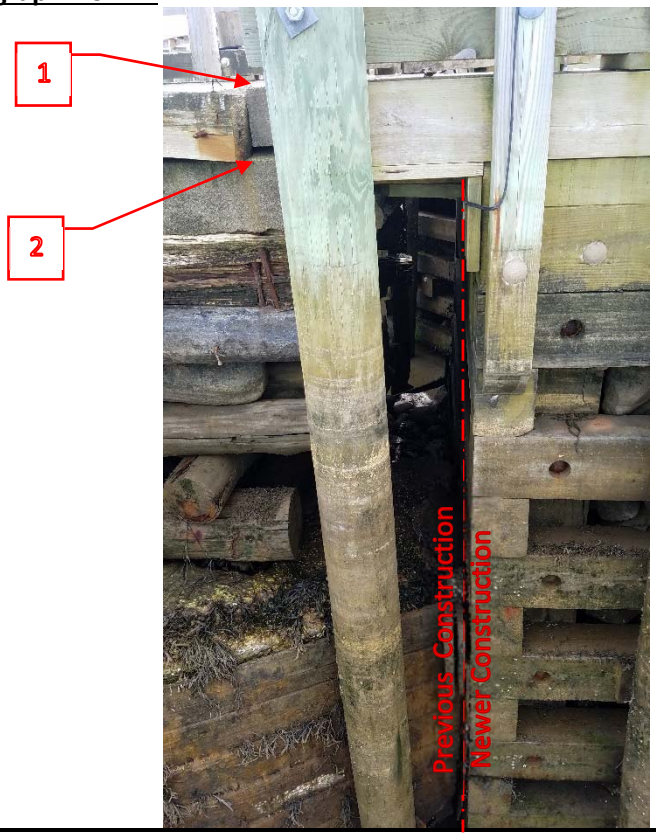


Comment:

View of north side of wharf Finger A.

1. **Deflection of timbers noted.**

Photograph No. 14:



Comment:

View of apparent newer and previous construction at beginning of Finger A.

1. **Top of new slab**
2. **Apparent top of previous slab**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 15:

Comment:

Close-up of condition noted in previous photo.

System has begun to fail exhibiting extensive deflection and breaching of supplementary support.

Listing and leaning noted at adjacent piles.

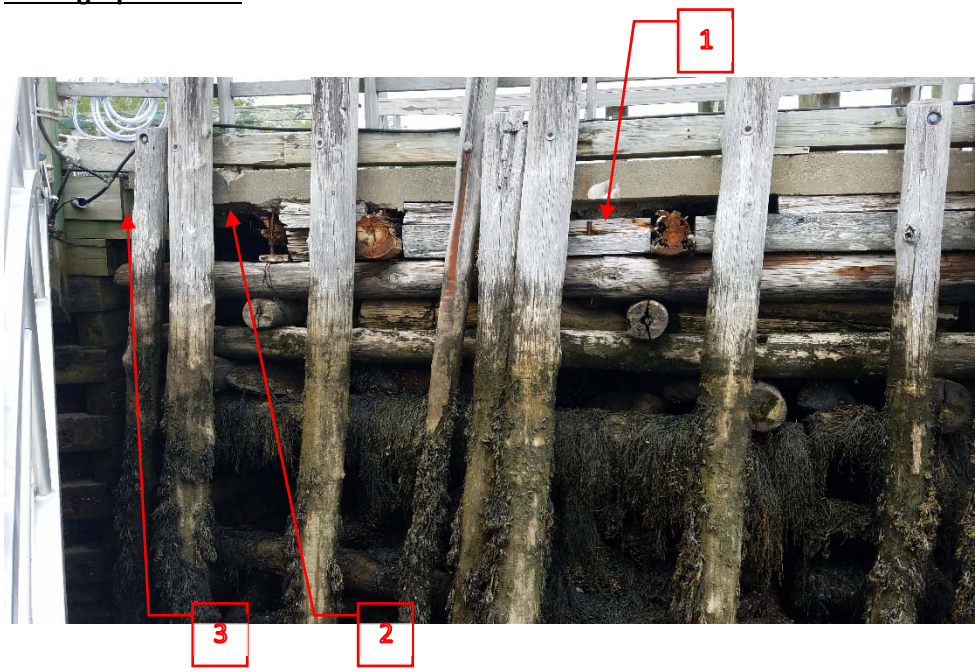
Photograph No. 16:

Comment:

View of possible breach allowing material to settle beneath the wharf deck above.

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 17:



Comments:

View of south side of wharf Finger A.

1. **Weathered timbers which appear to support the concrete deck noted.**
2. **A through crack in concrete section noted at location of minimal support.**
3. **Location of concrete joint.**

Photograph No. 18:

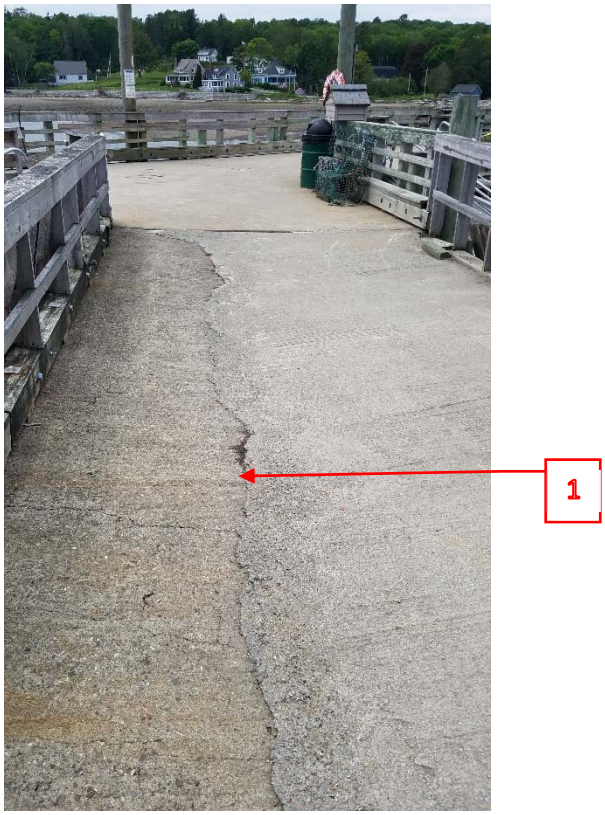
Comments:

View of Finger A from above.

1. **Location of concrete joint noted from previous photo.**
2. **Cold joint noted where a fill coat was poured to apparently remediate the previously deflecting slab.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 19:

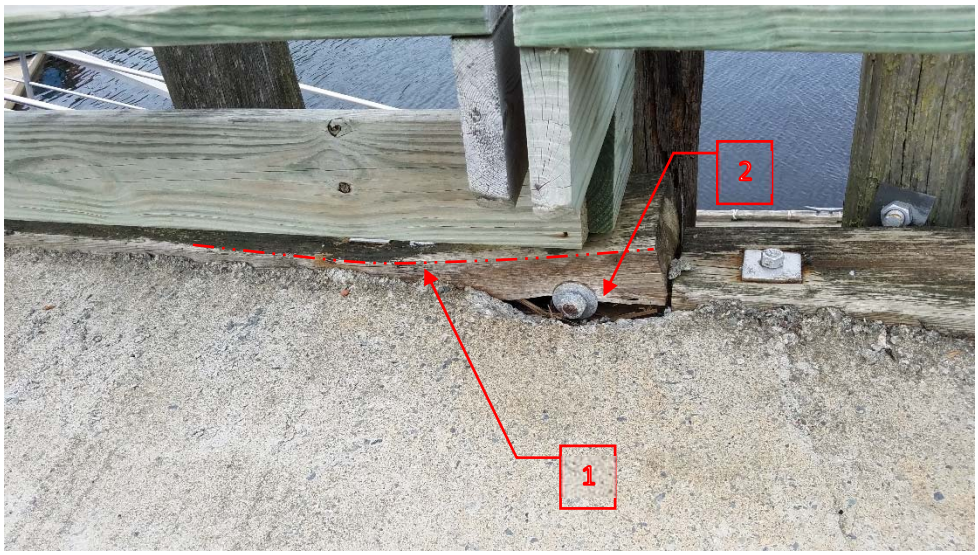


Comment:

Similar view of deflecting concrete deck looking west on Finger A.

1. **Cold joint noted in previous photo.**

Photograph No. 20:



Comment:

At north side of Finger A.

Signs of deflection and distress of a timber support member.

1. **Deflection of the timber sill or curb.**
2. **Splitting at the bolted connection indicating previous deflection.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 21: 	**Comment:** **View of Finger B framing and sub-framing.**
Photograph No. 22: 	**Comment:** **Close-up of Finger B framing and connections.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 23:  	**Comment:** **View of Finger B from above.** **View of cold joint adjoining Finger B to latest renovated main section of wharf.**
Photograph No. 24:  	**Comment:** **View from Finger B looking west.** **1. Discoloration indicating migration of salt to the surface (efflorescence) and/or residue from previous submerged condition.**

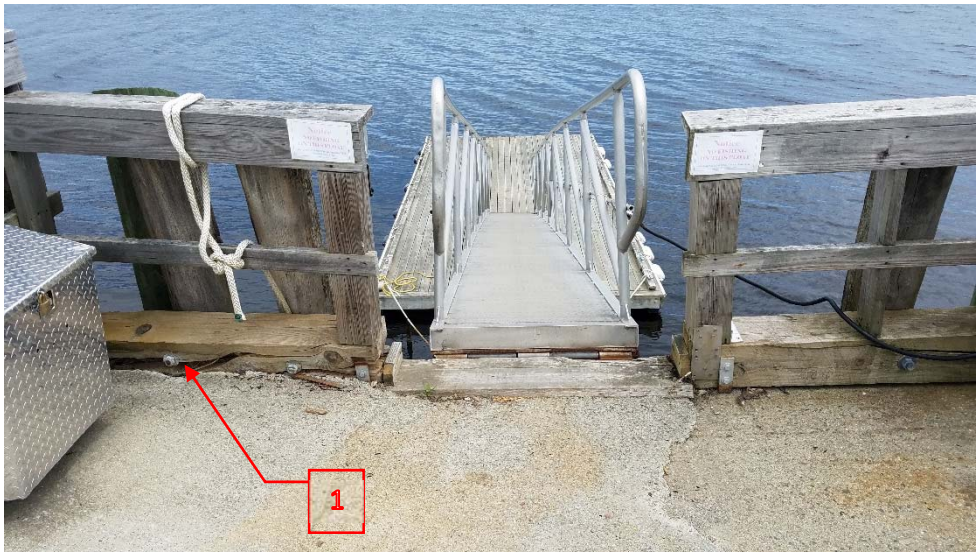
By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 25: 	**Comment:** **View of Floating Dock 1 and boat ramp. This dock is not provided access with a gangway.** **1. Indicates chain used to secure dock to wharf.**
Photograph No. 26: 	**Comment:** **View of gangway and pontoon for Floating Dock 2.**

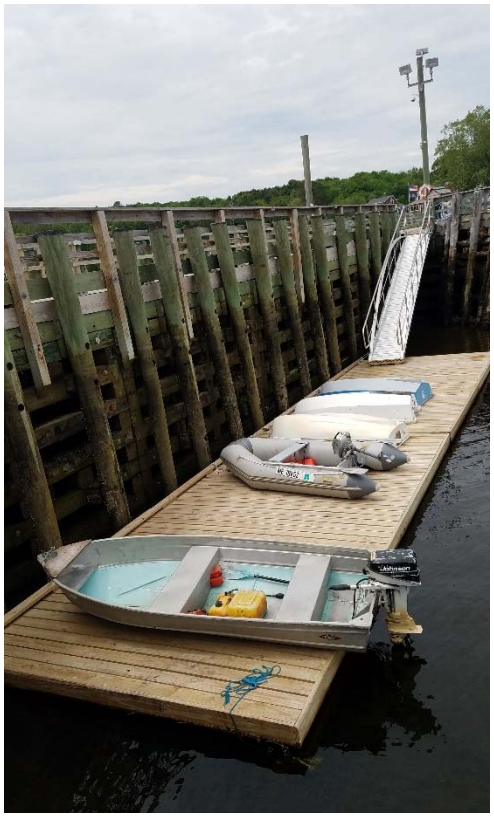
By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 27:  	**Comment:** **View of connection for gangway to Floating Dock 2.** **1. Corroded anchors noted.**
Photograph No. 28: 	**Comment:** **View of Floating Dock 3 and gangway.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 29:  	**Comment:** **View of gangway attachment to Finger A at wharf.** **1. Additional signs of deflection noted at curb connection**
Photograph No. 30: 	**Comment:** **Corrosion bleeding on adjacent structural members.** **Wooden cover plate and other adjacent members appear weathered.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 31: 	**Comment:** **View of Floating Dock 4 and gangway.**
Photograph No. 32: 	**Comment:** **Closer view of gangway indicating location of connection to wharf.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 33: 	**Comment:** **Close up of gangway attachment to wharf for Floating Dock 4**
Photograph No. 34: 	**Comment:** **View of Floating Dock 5 and associated gangway.**

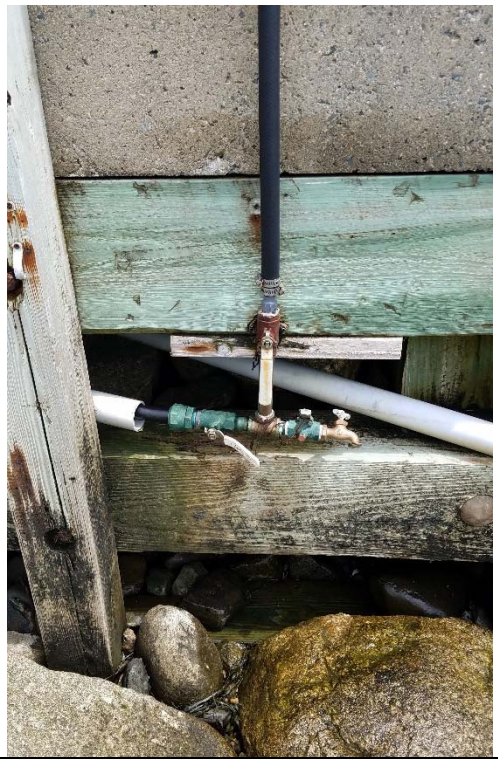
By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 35: 	**Comment:** **View of gangway attachment to wharf for Floating Dock 5.**
Photograph No. 36: 	**Comment:** **Closer view of float at Floating Dock 5.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 37: 	**Comment:** **View of lighting and security equipment near entrance of wharf.**
Photograph No. 38: 	**Comment:** **View of electrical meter and panel at entrance to wharf.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 39: 	**Comment:** **Water fittings observed with signs of corrosion near entrance of wharf.**
Photograph No. 40: 	**Comment:** **Water supply line visible through opening in the wharf deck.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 41: 	**Comment:** **Electrical fixtures at wharf finger 2.** **Fixtures appear to be shielded from splash.**
Photograph No. 42: 	**Comment:** **1. View of electrical fixtures; green shield removed.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 43: 	**Comment:** **Overview of boat ramp.**
Photograph No. 44: 	**Comments:** **Overview of sea wall as revetment.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

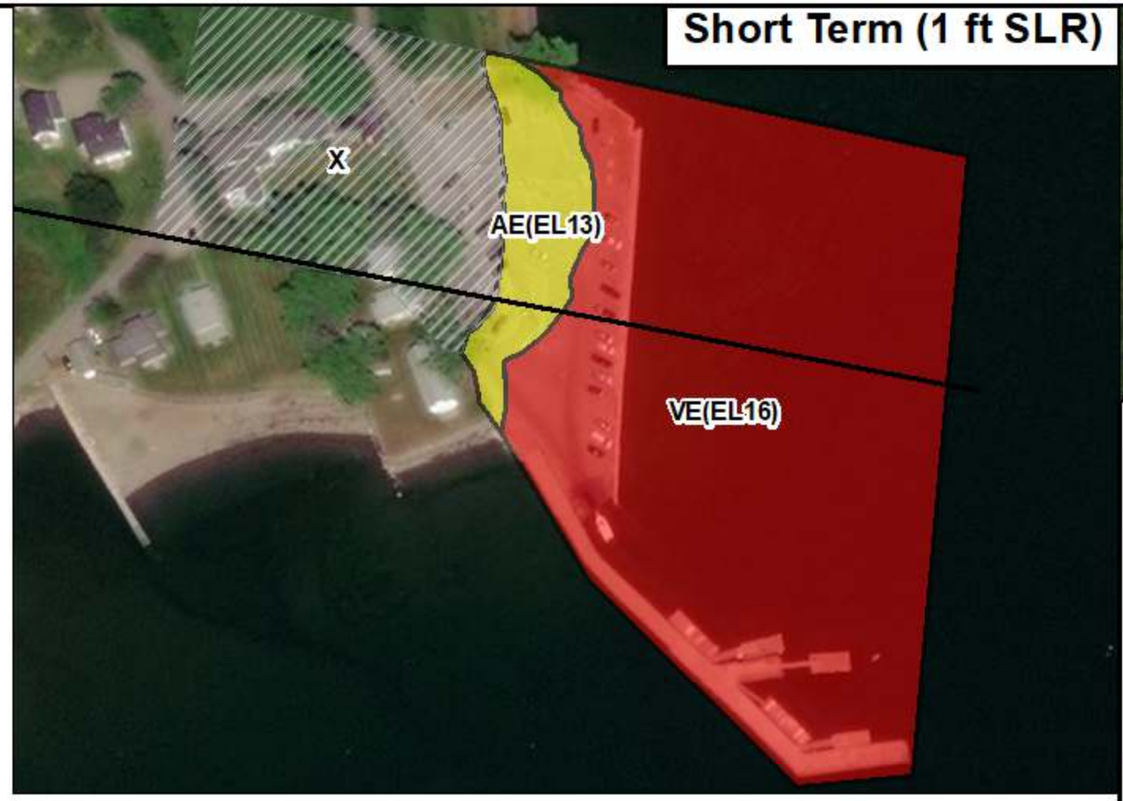
Photograph No. 45: 	**Comments:** **View of seawall and riprap at north end and extents of property.**
Photograph No. 46: 	**Comments:** **View of seawall during lower tide.**

By: T. Day Date: 10OCT2019 Reviewed: K. Sun Date: 11OCT2019

Photograph No. 47:  	**Comment:** **View of seawall during elevated tide.** **1. Location of eroded pavement behind wall.**
Photograph No. 48: 	**Comment:** **Overview of parking area looking south.**

Appendix B – Inundation Maps

Site: Searsport, ME

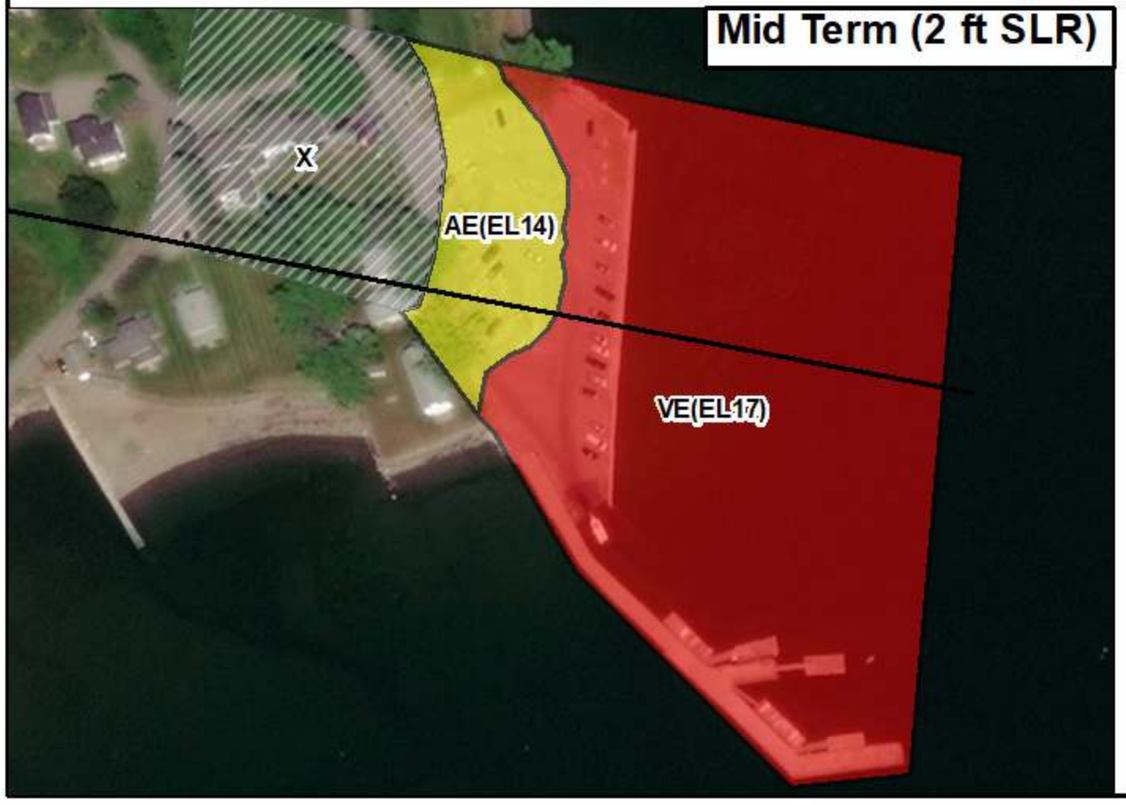


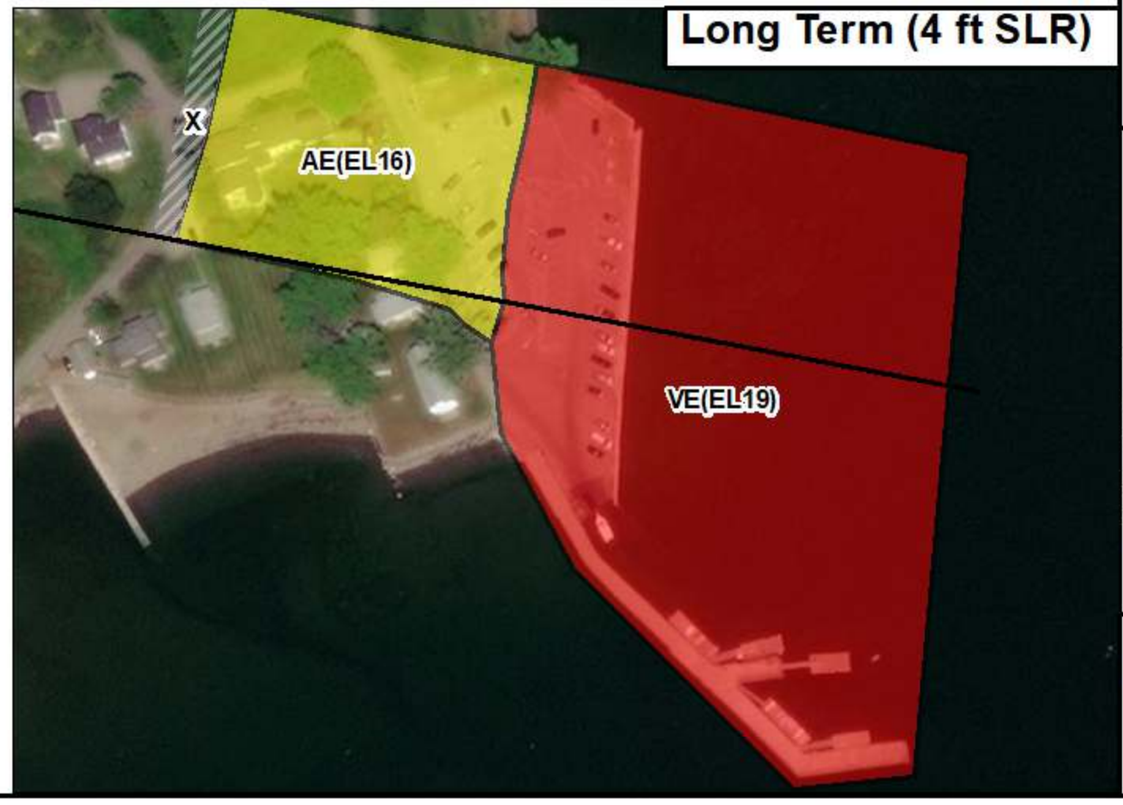
1. Maps indicate the 1%-annual-chance flood zones and base flood elevations.

2. This does not constitute a revision to the FEMA FIRM map which is done through FEMA's Letter of Map Revision process for which additional analysis and/or modeling may be required.

3. Flood mapping was developed for planning purposes only. No other use of this map should be made.

4. Elevations in reference to vertical datum NAVD88





Searsport Transect

AE

VE

X

N

Zone AE : Coastal flood zone. Base Flood Elevations determined.

Zone VE : Coastal flood zone with velocity hazard (wave action). Base Flood Elevations determined.

Zone X : Areas determined to be outside the 1% annual chance floodplain.

0 37.5 75 150 Feet

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