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Subject: Vulnerability Assessment and Resilience Planning, Middle Pier, Rockland, 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 Middle Pier in Rockland, 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 ten 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 Resiliency Analysis Project, Wood conducted an assessment of the Middle Pier in Rockland, 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 scenarios; and
- Development of resilience measures, including strategies for incremental adaptation under the modelled sea level rise 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 5**) 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.

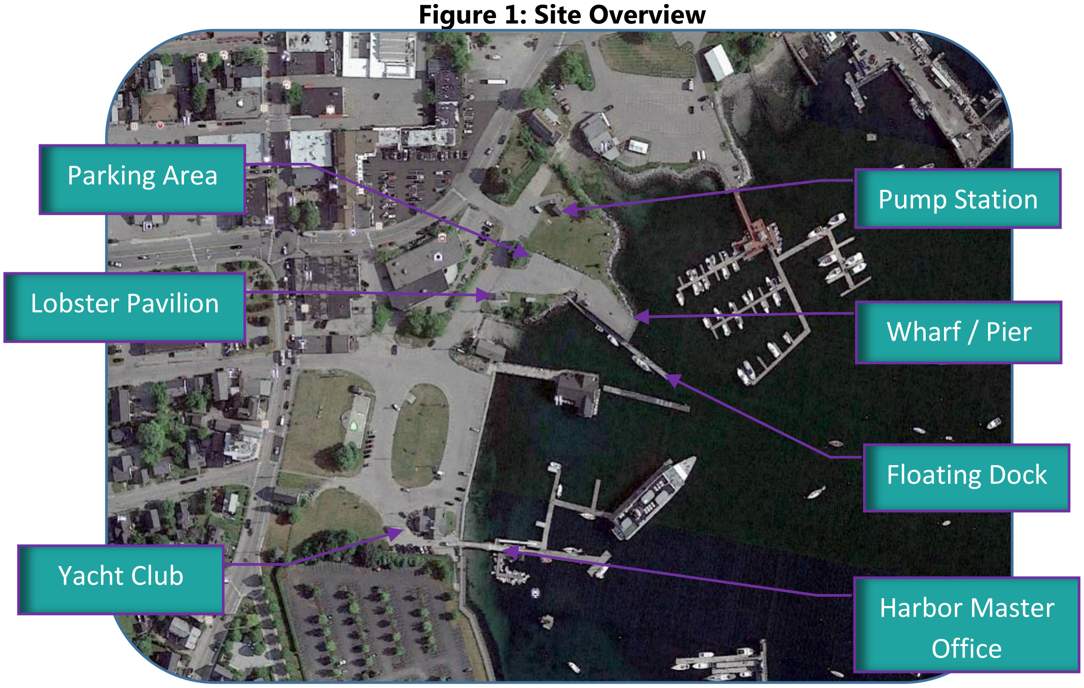
2.0 DOCUMENT REVIEW AND PERSONNEL INTERVIEWS

Wood was escorted by Mr. Matt Ripley, the Harbor Master, during a site visit on 19 June 2019. We discussed the site features and historical development of the site. Harbor Master Ripley indicated that the Patriots Day storm of April 2007 was the last notable storm event which impacted the site. Mr. Ripley also noted the current use of the site for public access and commercial passenger vessels. The Harbor Management Plan was noted as an effort taking place this year and will include discussion of the Middle Pier site, community needs, and plans for future improvements. Otherwise, they have been active in applying for federal grants to address pending capital improvement projects. The following is a summary of key site features identified by Harbor Master Ripley during our discussion:

- The site consists of the wharf, parking area, and a public park/greenspace (See **Figure 1** below).
- Structures located on site include a lobster cooking pavilion and a sewer pump station with a wet well.
- Adjacent to Middle Pier is the main harbour which includes a harbor master office, a yacht club and public restrooms.
- The wharf is constructed of quarried granite blocks, timber piles and timber framing.
- A wooden floating dock is located on the south side of the wharf.
- A breakwater constructed of quarried granite exists roughly 1.5 miles east of the site.
- There is no ongoing maintenance plan in place; maintenance is addressed, as needed, when a deficiency is identified.

Prior to the site visit, Harbor Master Ripley provided a plot plan, parcel map and flood map published by the Federal Emergency Management Agency (FEMA) for the site. No structural plans or as-built drawings were available for our review. Following our site visit we received a copy of the building permit application for an expansion of the Chamber of Commerce/Harbor Master office.

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 19 June 2019 visit. This assessment included documenting the general condition and recording elevations of key features and structures. At the request of the City of Rockland, two city-owned properties at the Middle Pier were evaluated and are referenced herein as Sites 1 and 2. Photos of the sites and Wood's noteworthy observations are included in the Photolog

(**Appendix A**). The site facilities and their associated elevations can be found in **Table 1** for reference. During our site visit we observed a change in tidal elevation of roughly eight (8) feet, with documented elevations between -3.4 ft and 4.6 ft (predicted min. of -6.3 ft, max. of 5.8 ft). This fluctuation is in line with normal values for this time of year and location. These conditions were taken into consideration during our assessment.

3.1 Property Overview

Site 1

This site is a 2-acre property containing a combination waterfront pier and wharf structure, parking lot, and public park/greenspace (**See Photographs 1 - 10, Appendix A**). The pier and wharf are located at the southeast corner of the site. A floating dock is located on the south side of the wharf for access to the charter boats (**Photograph 11 - 15**). The floating dock gangway is attached to the wharf via anchorage to a concrete footing. The floats are attached to the wharf's exterior timber piles with mooring chains. Wood observed the function of the gangway and floats during tidal action and the system appeared to function as intended. Access to the floating dock is provided at the wharf via the parking lot. The paved area covers roughly half of the site, some of which is access or parking, whereas the remaining portion extends over the wharf.

The wharf appears to be constructed of stacked granite blocks as a substructure with crushed stone fill of large to medium diameter between the granite blocks and the surface above (**Photograph 9 & 10**). Subsurface conditions for the site were not verified by testing, however information provided from the United States Geological Survey (USGS) indicate silty and gravelly sandy loams are typical for this area.

The adjacent pier, at the perimeter of the south and east side of the wharf, is constructed of timber framing on timber piles. Timber framing is attached using a combination of through bolts and large diameter nails, is supported at the extremity by piles and at the wharf interface by either a concrete abutment or granite blocks. The abutment is a concrete structure which appears to be cast on the granite substrate (**Photograph 16**). Attachment of the timber framing to the abutment or granite blocks with an anchor or other fastening mechanism could not be confirmed. Decking is attached to framing via framing nails. Perimeter piles were commonly capped with vinyl covers where exposed from above. Shoreline protection exists beyond the extents of the wharf and pier in each direction and is provided by means of large riprap (**Photographs 24 & 25**). Site utilities include electrical and water, whereas only water is provided at the floating dock (**Photographs 15, 17 & 18**).

Table 1: Site Elevations

Facility	***Lowest Horizontal Member***	***Lowest Deck or Adjacent Grade***	***First Finished Floor***	***Lowest Opening/ Critical Elevation***
Source*	***Estimate (ft)***	***Survey (ft)***	***Estimate (ft)***	***Estimate (ft)***
Pier	9.5	10.5	n/a	n/a
Wharf	9.5	10.2	n/a	n/a
Floating Dock	9.5	11.36	n/a	n/a
Pavilion	n/a	11	11.33	11.33
Pump Station	n/a	14.4	15.07	16.4
Shoreline Protection	n/a	11	n/a	16
Harbor Master Office	9	n/a	9	12
Yacht Club/ Restrooms	10.5	n/a	11	14

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

Site structures include a sewage pump station and lobster pavilion for cooking during events. The pump station appears to be a wood-framed structure on stem wall with gable type roof (**Photographs 19 & 20**). The building has four (4) windows, one main access door, and a large rear louver. Exterior cover appears to be vinyl siding and asphalt shingle roofing. What appears to be a concrete slab on grade exists at the north side of the building to provide access to the door and the associated sewer well. The top of grade at the building is roughly 15 feet with a finish floor elevation (FFE) approximately 8 inches above the current grade.

The lobster pavilion (**Photographs 21 – 23**) appears to be a metal-framed building with brick façade on block infill walls, with an asphalt-shingled open gable roof. The structure has no doors or windows but constructed with large openings framed by stem walls on three sides and open on the remaining side. Support for the openings and subsequently the roof framing is provided by steel beams. A large chimney exists at the northeast corner of the roof which appears to be wood-framed. Lighting and other utilities are provided at the building interior.

Site 2

At the request of the City of Rockland, Site 2 was added to the inundation/flood analysis conducted by WHG. Site features observed by Wood include the Harbor Master's Office (**Photograph 28**), a building which houses a yacht club, and public restrooms (**Photograph 29**). The Harbor Master's office is located on a narrow wharf which appears to be constructed of stacked granite blocks. The yacht club building is located adjacent to the paved area, with the restrooms accessible from the west side. The FFE of the building is roughly 2 ft above the top of pavement elevation (approx. elevation 9 feet). The subsurface construction of the site could not be readily observed. A sea wall constructed of stacked granite borders the site at the shoreline. The site is largely paved as it extends up to the access road elevation (approx. elevation 16 ft). A series of gangways and floating docks provide access to boats and the various vessels for mooring (**Photographs 26 & 27**).

3.2 Noted Deficiencies

The wharf structure, particularly the stacked granite foundation, exhibited no apparent signs of translation or dislodgment for the large members. Smaller stone material was noted between the surface and granite blocks, observable through the large openings between the blocks. Above this area on the pavement, large cracks and dips are observed (**Photographs 30 – 32**). Previous repair work was also noted at some locations (**Photographs 31 & 32**).

As earlier mentioned, an abutment is used to support the pier framing at one end. Positive attachment (anchorage or other mechanical fastener) of the concrete abutment to the granite blocks or attachment of the wood framing to the abutment and/or the granite blocks could not be confirmed. The abutment stem and footing appear to be composed of two separately poured elements (**Photograph 16**). Wooden members, which include piles, stringers, and decking exhibit signs of moderate deterioration due to weathering and/or microbial attack. Some minor to moderate conditions of shakes, checks and splits were observed throughout. For those piles observed, signs of infestations such as marine borers were not noted in the tidal zone.

3.3 Risk Framework

As a basis for the vulnerability analysis, water surface elevation exposure profiles under various projected environmental conditions 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 - Site 1

Scenario	***MHHW***	***HAT***	***1% Still Water Level***	***1% Wave Crest Elevation (BFE)***
Present day	4.8	7.1	9.0	11-15
Short Term (+1 ft)	5.8	8.1	10.0	12-17
Mid Term (+2 ft)	6.8	9.1	11.0	13-18
Long Term (+4 ft)	8.8	11.1	13.0	15-20

Table 3: Flood Modelling Data Summary - Site 2

Scenario	**MHHW**	***HAT***	***1% Still Water Level***	***1% Wave Crest Elevation (BFE)***
Present day	4.8	7.1	9.0	11-15
Short Term (+1 ft)	5.8	8.1	10.0	12-17
Mid Term (+2 ft)	6.8	9.1	11.0	13-18
Long Term (+4 ft)	8.8	11.1	13.0	16-20

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 sea level rise (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 foot, 2 feet, and 4 feet, 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 and Table 3** include scenarios for the Short Term, Mid Term, and Long Term sea-level rise 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 4**.

Table 4: Flood Return Period

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

The various site features have been summarized in **Table 5** for each facility, indicating the associated risk and flood scenario which result in inundation. Those elevations noted as 0 ft indicate an elevation similar to the identified feature of the facility. No elevations are noted in Table 5 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 5: 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***	***HAT***	***1% Stillwater***	***BFE***	***MHHW***	***HAT***	***1% Stillwater***	***BFE***	***MHHW***	***HAT***	***1% Stillwater***	***BFE***	***MHHW***	***HAT***	***1% Stillwater***	***BFE***
			[ft]	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***	***[ft]***
Pier	Lowest Horizontal	9.5 ft				1.5			0.5	2.5			1.5	4.5		1.6	3.5	7.5
	Lowest Deck or Adjacent Grade	10.5 ft				0.5				1.5			0.5	3.5		0.6	2.5	6.5
Wharf	Lowest Horizontal	9.5 ft				1.5			0.5	2.5			1.5	4.5		1.6	3.5	7.5
	Lowest Deck or Adjacent Grade	10.2 ft				0.8				1.8			0.8	3.8		0.9	2.8	6.8
Floating dock	Buoy Chain max elevation	9.5 ft				1.5			0.5	2.5			1.5	4.5		1.6	3.5	7.5
	Gangway footing	11.36 ft								0.64				2.64			1.64	5.64
Pavillion	Adjacent Grade	11 ft				0				1			0	3		0.1	2	6
	First Finished Floor	11.33 ft								0.67				2.67			1.67	5.67
	Lowest Opening	11.33 ft								0.67				2.67			1.67	5.67
Pump Station	Adjacent Grade	14.4 ft																2.6
	First Finished Floor	15.07 ft																1.93
	Lowest Opening	16.4 ft																0.6
Shoreline Protection	Top of riprap	11 ft				0				1			0	2		0.1	2	6
	Critial Elevation	16 ft																1
Harbor Master Office	Lowest Horizontal	9 ft				3			1	4			2	5		2.1	4	8
	First Finished Floor	9 ft				3			1	4			2	5		2.1	4	8
	Lowest Opening	9 ft				3			1	4			2	5		2.1	4	8
Yacht Club/ Restrooms	Lowest Horizontal	10.5 ft				1.5				2.5			0.5	3.5		0.6	2.5	6.5
	First Finished Floor	11 ft				1				2			0	3		0.1	2	6
	Lowest Opening	11 ft				1				2			0	3		0.1	2	6

Note: Facility elevations presented in this Table are referenced to NAVD88.

3.4.1 Pier and Wharf

Based on the present-day model for BFE of 11 to 15 feet which includes a wave height of 2 to 6 feet, the pier substructure and decking would be potentially impacted by high velocity wave action. In the case that any elements such as the abutment, stringers, etc., are not positively attached to subsequent load carrying members, dislodgement or delamination of material at the top of deck should be expected. Otherwise we would not expect any impact beyond minor delamination at the deck. A granite block or other material appears to be missing which would provide transfer of bearing loads from the pier (**See Photograph 10**). We were unable to view and assess other locations of the pier and wharf to note similar conditions at other locations due to limited access around the pier, which was provided only via the floating dock. The wharf can be expected to experience loss of smaller diameter crushed rock at the sub-base from washout resulting in deflection of the pavement and possibly complete delamination. Similar behaviour of the pier and wharf can be expected for future floor scenarios and the possibility of impact more likely as the return period for conditions representing the present day BFE decreases.

Site utilities which include water and electricity are exposed to wave action and inundation at the pier and the floating dock. A timber pipe bridge, which supports an electrical conduit, is located in the plane of the deck and near the floating dock entrance (**Photograph 18**). The structure does not appear to be securely fastened or designed to resist impact from wave action. In addition, the electrical cabinet and conduit at the wharf do not appear to be of waterproof construction (**Photograph 17**). Given the current position of the cabinet, we would expect some exposure to waver during the BFE for the Mid Term Scenario.

3.4.2 Floating Dock

The floating dock assembly consists of the gangway and the floats. The gangway attachment allows for rotation with a maximum limited by the elevation of the float at or beneath hinge elevation (**Photograph 14**). Normal operation does not appear to be influenced by the MHHW for all scenario. However, for the Short Term scenario, the gangway will be subjected to wave loading and uplift forces from the Stillwater elevation. In addition, the floats are moored to the perimeter piles at the south side of the pier via mooring chains. This attachment allows for a maximum mooring elevation roughly 15 inches below the top of pier deck (**Photograph 15**). Estimating some flexibility in this connection, the dock will be limited from traveling beyond elevation 9.5 feet (9 ft 6 inches) and begin to exert loading on the pier at water levels above this elevation. These potential vertical and lateral loadings already during the Present Day scenario under the BFE will continue to increase for subsequent scenarios based on the data in **Table 5**.

3.4.3 Site Structures

<u>Site 1</u>
The two structures observed at the site are the lobster pavilion and the sewer pump station. The estimated top of slab elevation at the pump station is elevation 14.4 feet. The BFE at this location as shown in Table 2 for the Present Day scenario is 15 feet; however, waves can be expected to dissipate at this inland distance to equal the 1% Stillwater elevation of 9 feet NAVD 88. The roughly 15 ft FFE of the building is also above the Short, Mid and Long Term scenarios' Stillwater elevation. At Long Term scenarios, above-ground architectural and structural elements will likely be impacted, during which coatings, coverings and their fastenings will be subjected to moisture. Also, openings such as doors, windows, and louvers will be a means for moisture intrusion. Depending on the interior architectural finishes, some delamination and material degradation can be expected. Given the elevation of the pump station and wet well hatch, inundation at the long term and possibly the Mid Term scenario is of concern. During our site visit we were unable to confirm whether these elements are sealed systems due to lack of access.

Similar concerns exist for the lobster pavilion, which sits at a FFE of approximately 11.3 feet NAVD88. During the Long Term Scenario, flooding of the area can be expected from the design Stillwater elevation. No serious wave action however is expected at this inland location for this scenario. We expect more frequent inundation of the area during the Long Term scenario for the HAT. For the type of construction, minimal material degradation is expected from inundation, however factors such as the existence of horizontal ties, reinforced and/or grouted cells, or type of footing will define the behaviour of the structure from moisture intrusion, which can be expected for the Long Term scenario.

<u>Site 2</u>
During our preliminary walkthrough of the park/open space, no notable deficiencies related to the buildings or the site features were documented. Site structures, such as the Harbor Master's office and the yacht club building were visually evaluated from the exterior only, revealing no obvious defects which would compromise the structural integrity of the buildings. The FFE of the Harbor Master's office (**Photograph 28**) sits at roughly elevation 9 feet. Given the structure's proximity to the coast, we expect wave action to be a contributing factor in the hydrodynamic loading. The 1% Stillwater elevation of 9 feet and 6 additional feet at the BFE indicates this structure already lies within the 100-year return period for the Present Day scenario. Subsequent scenarios exhibit values which increase for all data sets with the Long Term BFE exceeding the structure's roof height. It is noteworthy that the HAT of elevation 9.1 feet roughly coincides with the current site elevation for the Mid Term scenario (See Table 3).

The building which houses the yacht club and public restrooms is constructed with portions of the structure's FFE near grade and others with floor elevations 1.5 to 2 feet above the grade (**Photograph 29**). For the Present Day scenario, portions of the building, in particular the office and restrooms, are above the 1% Stillwater elevation but lie approximately at the BFE of 11 feet.

For the Present Day scenario, the foundation of both structures will be inundated and the building envelope will be subjected to wave action primarily dependant on its inland location. Information was not readily available regarding the type of foundation, specifications of the building design or framing system. Similar to Site 1, the possibility of damage to structural components and architectural finishes, at a minimum, can be expected for all scenarios with increasing severity advancing into the future. For the Long Term scenario, a combination of SLR and 100-year storm events creates a risk for both the Harbor Master Office and the Yacht Club to high velocity wave action.

3.4.4 Shoreline Protection

Site 1

Shoreline protection is provided by a revetment ranging in elevation from about 11 feet to 12 feet. Large diameter (roughly 1.5 to 4 ft) riprap is provided along the perimeter of the site extending from below the low tide level to the top of grade (**Photographs 24 & 25**). The estimated slope is a maximum of 3 to 1, horizontal to vertical, and gradation appears to be suitable based on condition of slope. No signs of material degradation or slope instability or piping were noted. Based on existing conditions, the risk of overtopping during the Present Day scenario is relatively low. Overtopping is more likely for the Short and Mid Term scenarios. Some landward flooding in the range of 2 to 7 feet will occur during the overtopping during these scenarios but it will not undermine the revetment. Under wave attack, randomly placed riprap will experience some settlement and readjustment; however, the risk of wide-scale riprap slope failure appears low. The risk of localized scour or dislodging of riprap is low and given their inherent stability they will likely require minimal remediation for the Short Term and future scenario.

Site 2

Shoreline protection at this location was not directly assessed however appears to be a stacked granite sea wall which may also support the wharf. Delamination of material was not observed, and structure appears to function as intended.

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, piers, or columns so that the bottom of the lowest horizontal structural member of the lowest floor is at or above the design BFE plus 1 to 2 feet of freeboard, per American Society of Civil Engineers / Structural Engineering Institute Standard 24, Flood Resistant Design and Construction (ASCE 24).
- For inland building/structures, the First Floor Elevation should be above the 1% Stillwater elevation plus 1 to 2 feet of freeboard.
- 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.
- Erosion control structures shall not be attached to the building or its foundation. Riprap or revetment should be installed at a minimum height above the 1% Stillwater elevation but below the BFE, where some overtopping is allowed.
- Use of flood damage-resistant materials above the BFE per ASCE 24 and the local Building Code.
- Slab on grade construction in this zone is not permitted and should be avoided.

- Electrical, heating, ventilation, Plumbing and Air Conditioning 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 apply 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 Town Dock, there may be features of similar construction in close proximity and exposed to similar risks as described in this report but fall outside the limits of assessment. **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 for Middle Pier and associated project specific areas.

4.2.1 Pier and Wharf

The following recommendations are provided in reference for the **Present Day and all future scenarios** for flood values provided in **Table 2 and 3** above:

- A detailed structural assessment is recommended for the deck and substructures. Confirm positive attachment of all structural members to their substrate or load-bearing elements. Straps should be designed and incorporated for purposes of hold-down against wind and water loads.
- Utilities should be properly secured to resist design wind and water loading or relocated above the design flood elevation as specified in ASCE 24. Watertight and stainless-steel electrical fixtures should be incorporated. Confirm that all building utilities are placed 2 feet above the flood elevation and/or sealed from inflow of flood water.

The following additional recommendations are provided in reference for the **Short Term scenario** for flood values provided in **Table 2 and 3** above:

- Subgrade conditions under paved areas of the wharf should be verified, voids should be filled, and the subgrade should be compacted per local requirements.

The following recommendations are provided in reference for the **Mid Term scenario** for flood values provided in **Table 2 and 3** above:

- The structure should be re-evaluated based on the current design loading with regard to wind and wave action. Subgrade conditions under paved areas of the wharf should be verified, voids should be filled, and the subgrade should be compacted per local requirements. Damaged or inadequate elements of the structure should be replaced or repaired as needed.

The following recommendations are provided in reference for the **Long Term scenario** for flood values provided in **Table 2 and 3** above:

- Based on the elevated wave action, we recommend installation of a reinforced concrete deck and piles which is able to support design loading independent of the supportive conditions below the granite blocks and at an elevation to accommodate requirements of ASCE 24, Flood Design Manual

For future flood scenarios, it may be necessary to reconstruct the wharf and/or pier to accommodate sea level rise and increased risk of damage due to more frequent events. Raising the elevation of the breakwater, which provides protection for the coastline, is also a consideration. Modelling of the scenario which incorporates an elevated breakwater may be valuable in providing comparative values for a repair/replacement feasibility study. This analysis is not a part of this assessment.

4.2.2 Floating Dock

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

- Conduct a detailed evaluation for the mooring system of the floating dock and the buoyancy and wave loads imposed on the float and wharf structures due to future water level rise and storms. Design and install separate mooring piles for the floats to avoid attachment to the pier. Piles should be installed to accommodate a BFE of at least the Mid Term condition with the addition of 2 ft of freeboard.

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

- Confirm the gangway attachments are sufficient to resist the design loading and repair or replace as needed.

4.2.3 Site Structures

The basis of our recommendation for buildings or other structures is the inland location of the structure and behaviour of the event at that location. For structures located in close proximity to the shoreline, wave impact from the BFE is a threat and the possibility of immediate damage more likely. For inland structures where wave action has subsided, concerns of static flooding are more prevalent. For these cases, we are concerned about inundation, such as for the Stillwater and MHHW at the FFE, where the usefulness of the structure is compromised.

The following recommendations are provided in reference to the **Present Day scenario** provided in Table 2 and 3 above:

- Based on the BFE and associated wave action, the Harbor Master's office should be evaluated to confirm ability to resist the design loading from wave and wind and retrofitted based on results of this analysis.

The following recommendations are provided in reference to the **Short Term scenario** provided in Table 2 and 3 above:

- Based on the design Stillwater and its influence on the Harbor Master's office, re-evaluation of the structure will be required based on its functionality (Serviceability requirements). The assessment will be per current design standards to estimate adequacy to support the intended design loads. Following analysis, a likely recommendation is to retrofit or replace the existing building. This may constitute the minimum, whereas relocation may be recommended based on cost.

The following recommendations are provided in reference to the **Mid Term scenario** provided in Table 2 above:

- Install erosion control measures at the perimeter of the Lobster Pavilion against scour.

The following recommendations are provided in reference to the **Long Term scenario** provided in Table 2 above:

- Where the Sewer Pump Station and associated wet well are impacted by future scenarios, incorporation of a flood-proof design is recommended such as stem walls extending above the design flood elevation as dry floodproofing, sealed openings, and sealed or gasketed floor/ground openings. Confirm that all building utilities are placed above the design flood elevation and/or sealed from inflow of flood water. In general, existing structures and their foundations should be assessed for the applicable design loading. Repairs, retrofits, or improvements should be per the local

Building Code and performed under recommendation and guidance of a Professional Engineer Registered in the State of Maine.

- The Yacht Club and associated facilities should be evaluated for flood and wind loading per the current design standard. The pressure to relocate the structure due to frequent inundation of the MHHW is not predicted, but nonetheless flooding in expected for this period during the design Stillwater with some influence of residual wave action based on the structure's proximity to the shore. Some repair effort is foreseen of minimal to substantial improvements for the scenario, and considering the BFE and Stillwater elevations, it will be practical to re-build the structure completely either with a FFE above the BFE and 2 feet of freeboard. Design for improvements should be per the local Building Code and performed under recommendation and guidance of a Professional Engineer Registered in the State of Maine.

4.2.4 Shoreline Protection

Based on our field observations and analysis data for the Present Day and Short Term scenario, we are of the opinion that minimal damage should be expected or otherwise no catastrophic failure of the revetment. Preliminary calculations, given certain assumptions, indicate the current riprap size can be expected to perform as expected for these events. For subsequent higher scenarios, we would expect increased overtopping which would allow for upstream flooding. The behaviour of the revetment during extreme events is dependant heavily on the average rock diameter, the height of revetment in relation to the wave height, and the layer thickness. Behaviour of the structure under extreme conditions (excessive wave height) can only be estimated with confidence by means of hydraulic model tests. We therefore recommend the following:

- Verification of the layer thickness is at least 2.5 feet.
- Sample verification of the D_{50} size of material to be 1.3 ft or greater.
- For extreme events or wave height is beyond 5 feet, a hydraulic model test is recommended for existing conditions.

5.0 OPINION OF PROBABLE CONSTRUCTION COSTS

The costing information provided below corresponds with our recommendations for remedial action for the corresponding events as outlined in **Table 2 and 3** of this report. These estimated costs include the associated design and engineering services where applicable. In **Table 6** is a summary of the estimated cost for repair or replacement of the identified vulnerabilities. A cost savings may also be expected for combined effort for items similar in nature, for example, replacing the 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 City. Costing for the referenced scenario represents summation of all non-complementary improvements. That is, where other repairs, such as 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.

5.1 Present Day Scenario

Pier and Wharf:

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

- Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$12,000.**
- Utilities should be properly secured to resist design wind and water loading or relocated above the design flood elevation as specified in ASCE 24. Design and Construction **$175.000.**

Table 6: Repair / Replacement / Retrofitting Costs

Facility	*Present Day*	*Short Term*	*Mid Term*	*Long Term*
Pier / Wharf	$297,000	$332,000	$812,000	$2,687,000
Floating Dock	$70,000	$175,000	$175,000	$175,000
Pavilion			$150,000	$200,000
Pump Station				$450,000
Shoreline Protection				$250,000
Harbor Master Office	$250,000	$625,000	$625,000	$625,000
Yacht Club/ Restrooms				$450,000
TOTAL:	**$617,000**	**$1,132,000**	**$1,762,000**	**$4,837,000**

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Straps and hold-downs should be designed and incorporated for the purpose to resist wind and water loads. Design and Construction **$110,000.**

Floating Dock:

- Moor the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$70,000.**

Site Structures:

<u>Harbor Master Office</u>

- Evaluate structure per current design standards to support the intended design loads. Retrofit as needed. Design and Construction **$250,000.**

5.2 Short Term Scenario

Pier and Wharf:

The following costs should be expected to accommodate events associated with the Short Term scenario:

- Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$12,000.**
- Utilities should be properly secured to resist design wind and water loading or relocated above the design flood elevation as specified in ASCE 24. Design and Construction **$175.000.**
- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Verify subgrade conditions, fill and/or replace material and compact, as needed. Design and Construction **$145,000.**

Floating Dock:

- Moor the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$70,000.**
- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$105,000**

Site Structures:

Harbor Master Office

- Re-evaluation of the structure per current design standards to support the intended design loads. Retrofit, replace or relocate the existing structure. Design and Construction **$625,000.**

5.3 Mid Term Scenario

This section exhibits costs which are expected due to the need for substantial improvements, however some of these actions are recommended as early as the Present Day scenario.

Pier and Wharf:

- Re-evaluate the structure per current design standards to estimate adequacy to support the intended design loads. Following analysis, a likely recommendation is to reinforce or replace damaged, deteriorated or missing elements of the wooden pier to include railing, posts, decking and piles and in addition, provide positive attachment of all elements per the International Building Code with State of Maine amendments. This may constitute the minimum, whereas complete replacement may be recommended based on performance results. Design and Construction **$625,000.**
- Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$12,000.**
- Utilities should be properly secured to resist design wind and water loading or relocated above the design flood elevation as specified in ASCE 24. Design and Construction **$175.000.**

Floating Dock:

- Moor the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$70,000.**
- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$105,000**

Site Structures:

Harbor Master Office

- Re-evaluation of the structure per current design standards to support the intended design loads. Retrofit, replace or relocate the existing structure. Design and Construction **$625,000.**

Lobster Pavilion

- Install erosion control measures. Design and Construction **$150,000.**

5.4 Long Term Scenario

This section exhibits costs which are expected due to the need for substantial improvements, however some of these actions are recommended as early as the Present Day scenario and could lead to decreased costs later.

Pier and Wharf:

- Install a reinforced concrete deck which capable of supporting design loading independent of the subgrade conditions above the granite blocks and at an elevation to accommodate requirements of ASCE 24, Flood Design Manual. Design and Construction **$2,500,000.**

- Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$12,000.**

- Utilities should be properly secured to resist design wind and water loading or relocated above the flood elevation as specified in ASCE 24. Design and Construction **$175.000.**

Floating Dock:

- Moor the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$70,000.**

- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$105,000**

Site Structures:

<u>Pump Station</u>

- Verify and incorporate flood-proof design and construction for all utilities and opening at site. Provide repairs, retrofits, or improvements as needed. Design and Construction **$450,000.**

<u>Lobster Pavilion</u>

- Abandon existing Lobster Pavilion in flood zone and build a new lobster pavilion on higher elevation 2 ft above the design flood elevation. Design and Construction **$200,000**.

<u>Harbor Master Office</u>

- Re-evaluation of the structure per current design standards to support the intended design loads. Retrofit, replace or relocate the existing structure. Design and Construction **$625,000.**

<u>Yacht Club</u>

- Re-build the structure completely at higher elevation with sustainable design per local and national design standards. Design and Construction **$450,000.**

Shoreline Protection:

- Raising Riprap to an appropriated elevation (approximate 4 – 5 ft) based on the design water levels and increased wave heights. Design and construction: **$250,000.**

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 all aspects of the work and site conditions, based on information made available to us at this stage of the project. Costs will be modified during subsequent stages of project execution, as the level of project definition increases. 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.

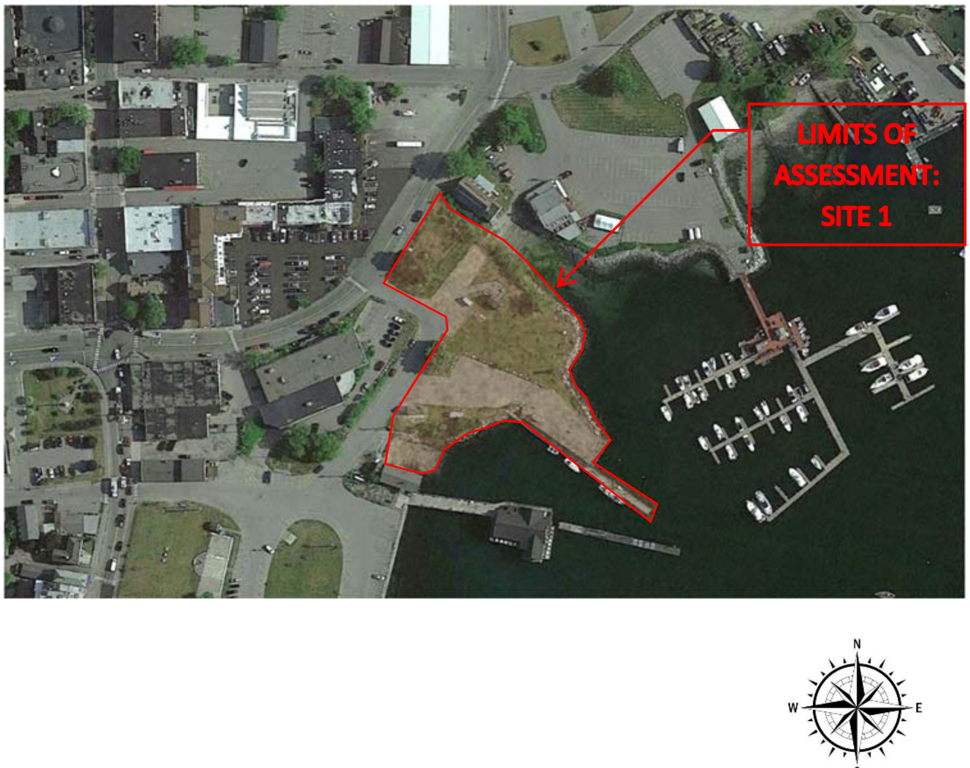
Tirrell Day, PE
Senior Structural Engineer

D. Todd Coffin
Associate Project Manager

Attachments: Appendix A - Photolog
Appendix B – Inundation Maps and Cross Sections

Appendix A - Photolog for Middle Pier, Rockland ME

By: *T. Day* ***Date:*** *03SEPT2019* ***Reviewed:*** *K. Sun* ***Date:*** *05DEC2019*

Photograph	Comment
Photograph No. 1: 	**Comment:** **Overview of Site 1.**
Photograph No. 2: 	**Comment:** **Overview of Site 2.**

By: T. Day Date: 03SEPT2019 Reviewed: K. Sun Date: 05DEC2019

Photograph No. 3:	Comment:
	View of parking area near park.

Photograph No. 4:	Comment:
	View of parking area near park.

By: *T. Day* *Date:* *03SEPT2019* *Reviewed:* *K. Sun* *Date:* *05DEC2019*

Photograph No. 5:

Comment:

View of wharf from above.

Photograph No. 6:

Comment:

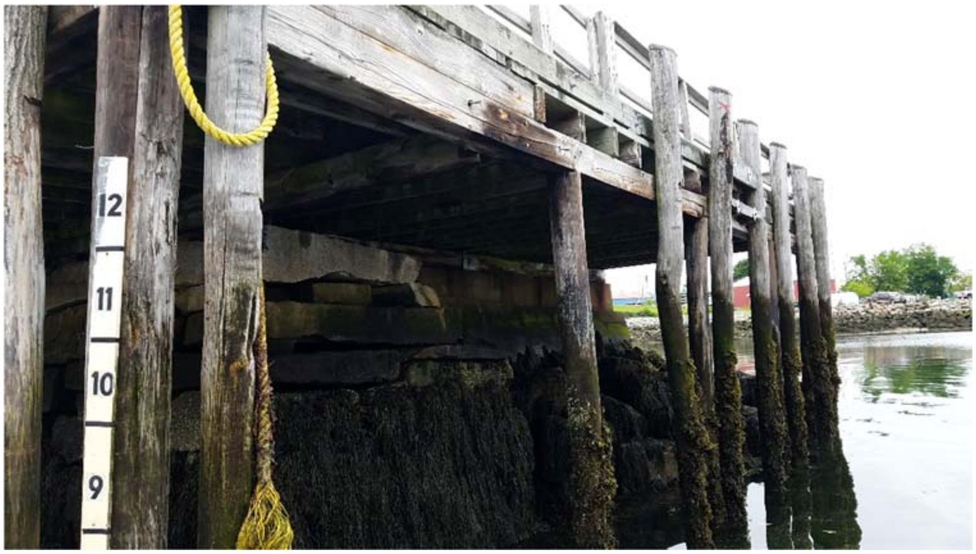
View of South Pier from above.

By: T. Day Date: 03SEPT2019 Reviewed: K. Sun Date: 05DEC2019

Photograph No. 7:	Comment:
	View of West Pier from above
Photograph No. 8:	Comment:
	Close-up of timber members at pier.

By: *T. Day* ***Date:*** *03SEPT2019* ***Reviewed:*** *K. Sun* ***Date:*** *05DEC2019*

Photograph No. 9:



Comment:

View facing northeast at front of pier and wharf.

Photograph No. 10:

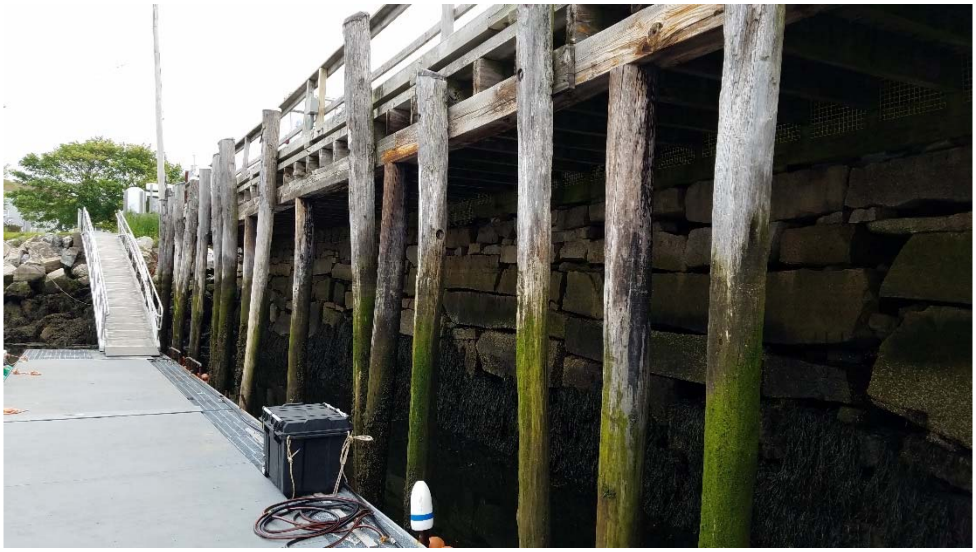
Comment:

View facing north at south side of wharf and pier.

View of typical construction.

1. **Possible bearing element missing for transfer of loading to subsequent support member.**

By: T. Day Date: 03SEPT2019 Reviewed: K. Sun Date: 05DEC2019

Photograph No. 11:	Comment:
	View of south pier at wharf and floating dock.
Photograph No. 12:	**Comment:**
	View of floating dock gang way attachment to concrete footing.

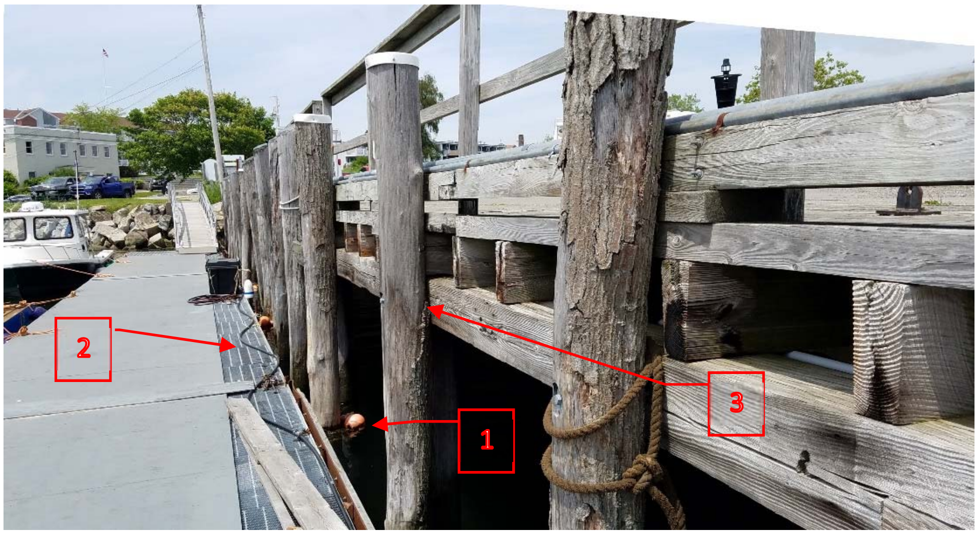
By: *T. Day* ***Date:*** *03SEPT2019* ***Reviewed:*** *K. Sun* ***Date:*** *05DEC2019*

Photograph No. 13:	Comment:
	View from above at location in Photograph 12. Attachment of sill and cover plate.

Photograph No. 14:	Comment:
	Side view of gang way attachment facing north.

By: *T. Day* *Date:* *03SEPT2019* *Reviewed:* *K. Sun* *Date:* *05DEC2019*

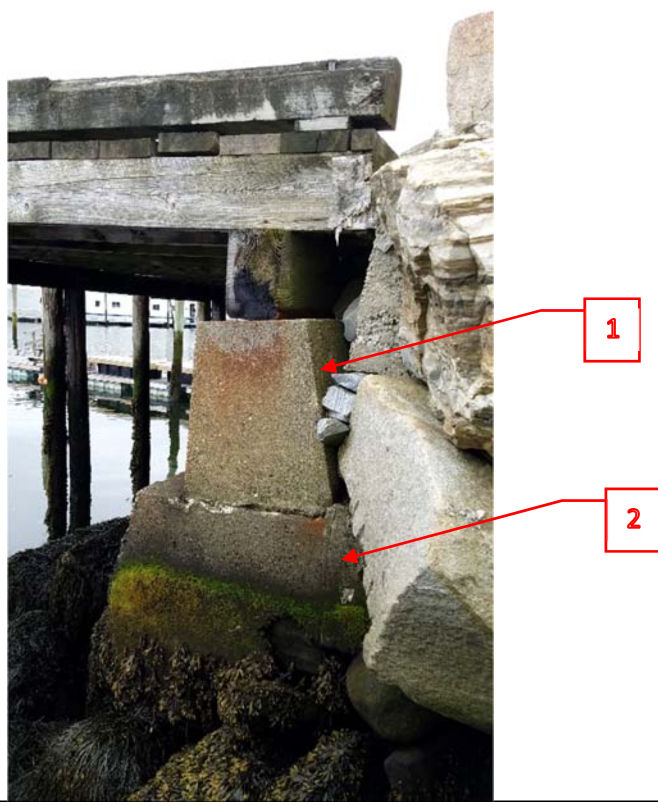
Photograph No. 15:



Comment:

1. **Mooring Chain attachment at float.**
2. **Floating deck water supply line.**
3. **Limits of floating dock mooring chain at high water level.**

Photograph No. 16:



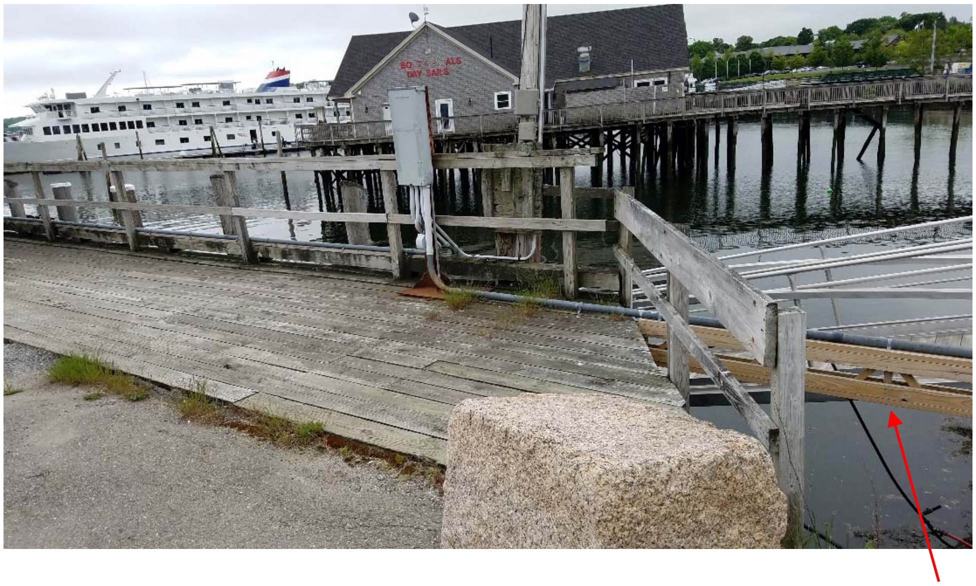
Comment:

View of abutment support of pier at north side.

1. **Stem support**
2. **Footing**

By: *T. Day* ***Date:*** *03SEPT2019* ***Reviewed:*** *K. Sun* ***Date:*** *05DEC2019*

Photograph No. 17:



Comment:

View of pier and pipe bridge for electrical conduit which is vulnerable to wave action.

Photograph No. 18:

Comment:

Close-up of electrical conduit and pipe bridge attachment to pier as noted in previous photo.

By: *T. Day* *Date:* *03SEPT2019* *Reviewed:* *K. Sun* *Date:* *05DEC2019*

Photograph No. 19:	Comment:
	View of sewer pump station and wet well cover.
Photograph No. 20:	**Comment:**
	Rear view of sewer pump station building.

By: *T. Day* ***Date:*** *03SEPT2019* ***Reviewed:*** *K. Sun* ***Date:*** *05DEC2019*

Photograph No. 21:

Comment:

View of lobster cooking station near entrance of property.

Photograph No. 22:

Comments:

View of roof structure; open gable.

By: T. Day Date: 03SEPT2019 Reviewed: K. Sun Date: 05DEC2019

Photograph No. 23:	Comments:
	View at open side of lobster cooking station.
Photograph No. 24:	**Comments:**
	View of revetment at south side of property.

By: *T. Day* *Date:* *03SEPT2019* *Reviewed:* *K. Sun* *Date:* *05DEC2019*

Photograph No. 25:	Comments:
	**View of riprap revetment at north side of property.**
Photograph No. 26:	**Comments:**
	**View of sea wall at harbor park near Harbormaster’s office.**

By: T. Day Date: 03SEPT2019 Reviewed: K. Sun Date: 05DEC2019

Photograph No. 27: 	**Comments:** View facing north at series of docks for large carriers.
Photograph No. 28: 	**Comments:** View of Harbormaster office.

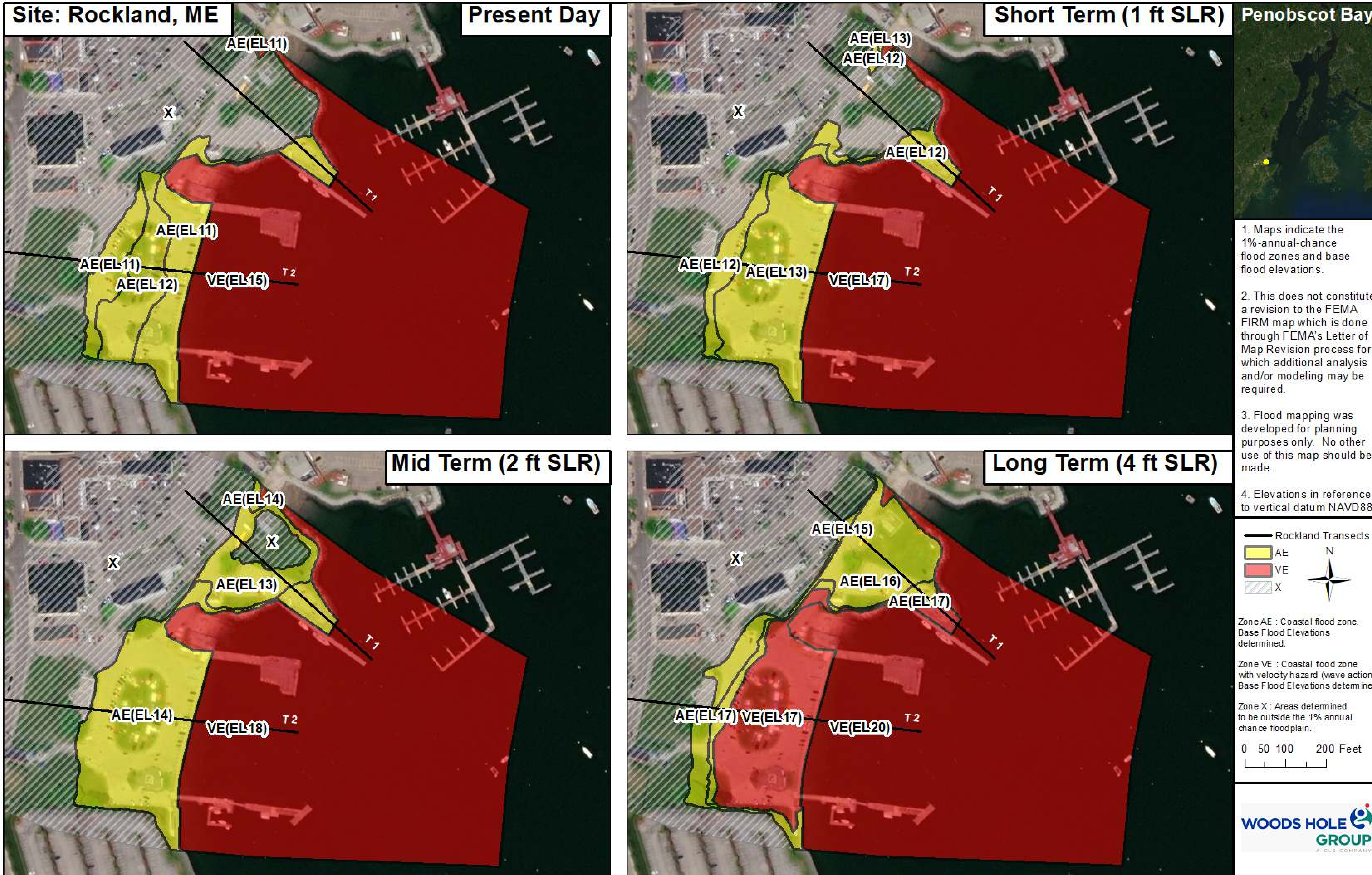
***By:* T. Day *Date:* 03SEPT2019 *Reviewed:* K. Sun *Date:* 05DEC2019**

Photograph	Comments
Photograph No. 29: 	**Comments:** View of building housing the yacht club and public restrooms.
Photograph No. 30: 	**Comments:** View of paved area above wharf. Close-up of deflection cracking.

By: *T. Day* *Date:* *03SEPT2019* *Reviewed:* *K. Sun* *Date:* *05DEC2019*

Photograph No. 31:	**Comments:**
	**View of cracks and surface delamination at pavement for wharf.**
Photograph No. 32:	**Comments:**
	**Additional signs of failing at paved area.** **Signs of previous repair work.**

Appendix B – Inundation Maps


Site: Rockland, ME
Present Day
AE(EL11)
X
AE(EL11)
AE(EL11)
AE(EL12)
VE(EL15)
T1
T2
Short Term (1 ft SLR)
AE(EL13)
AE(EL12)
X
AE(EL12)
AE(EL12)
AE(EL13)
VE(EL17)
T1
T2
Mid Term (2 ft SLR)
AE(EL14)
X
X
AE(EL13)
AE(EL14)
VE(EL18)
T1
T2
Long Term (4 ft SLR)
AE(EL15)
X
AE(EL16)
AE(EL17)
AE(EL17)
VE(EL17)
VE(EL20)
T1
T2
Penobscot Bay
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
Rockland Transects
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 50 100 200 Feet
WOODS HOLE GROUP
A CLS COMPANY