TECHNICAL MEMORANDUM

To:	**Humboldt Bay Harbor, Recreation, and Conservation District**
From:	**Moffatt & Nichol**
Date:	**April 30, 2024**
Subject:	**Redwood Marine Multipurpose Terminal Replacement Project - Coastal Hazards Analysis**
M&N Job No.:	**212991-03**

Disclaimer:

This draft technical memorandum is a work-in-progress and is intended to be an internal document for use by the Humboldt Bay Offshore Wind Heavy Lift Marine Terminal Project Team as a part of the conceptual design process and the ongoing permitting process. This memorandum is meant to be read as part of a comprehensive packet of technical analyses. It is not written to be a standalone document and it is assumed that the reader has substantial project knowledge and context to understand the memorandum's content. All aspects of this memorandum are subject to change and may become less accurate over time. To better understand the project, please review the more comprehensive and up to date documents posted to the Humboldt Bay Harbor District's website at https://humboldtbay.org/humboldt-bay-offshore-wind-heavy-lift-marine-terminal-project-3

1. Introduction

The Humboldt Bay Harbor, Recreation and Conservation District (Harbor District) is proposing to redevelop an approximately 180-acre site the Humboldt Bay Offshore Wind Heavy Lift Marine Terminal Project (Project) at the Port of Humboldt Bay, California, on the Samoa Peninsula. The Project would provide a new multi-purpose, heavy-lift marine terminal facility to support the offshore wind energy industry and other potential, future, coastal-dependent industries. The new marine facility would include both landside and waterside components as part of the redevelopment of the existing Redwood Marine Terminal 1 (RMT1) and would serve as a facility for the vertical integration, launching, and long-term maintenance of fully assembled wind turbine generators (WTGs). The Project does not include the planning, design, construction, or operation of offshore wind farms.

The proposed project includes two wharves and a wet storage tie-up pier to meet the operational needs of a heavy-lift marine terminal facility to support the offshore wind energy industry and other coastal-dependent industries. The project has a minimum service life of 50 years and needs to be resilient against sea level rise (SLR) within the project planning horizon.

Moffatt & Nichol (M&N) has analyzed coastal hazards to develop design recommendations in terms of minimum elevation for top of pier/wharf deck for use in future phases of design. M&N conducted this study by reviewing coastal hazards and exposure of the new terminal as well as available science on climate change implications for coastal hazards. This technical memorandum summarizes the findings of this study.

2. Site Setting

The Project is located in relatively low-lying areas of Samoa Peninsula along the west shoreline of Samoa Channel on the north side of Humboldt Bay. The proposed marine terminal will be sheltered from energetic waves (both wind waves and swell). As a result, the primary coastal hazards for the site include coastal flooding associated with extreme water levels (EWLs), as opposed to coastal flooding resulting from wave runup and overtopping. EWLs are driven by strong tidal forces (which occur during full or new moon) and prevailing winds generating storm surge. Rising sea levels will increase the frequency and intensity of extreme water level events along the low-lying coastal areas.

2.1. Tidal Datums and Water Levels

Astronomical tides in the Humboldt Bay are mixed semi-diurnal, with two high and two low tides of unequal height occurring daily. Tidal datums from NOAA CO-OPS for Samoa and North Spit, CA closest tide stations to the site, are listed in Table 2-1. The greater daily tidal range (MHHW to MLLW) increases from 6.85 feet near the Bay entrance to 7.37 feet near RMT1.

TABLE 2-1: TIDAL DATUMS AT NOAA SAMOA, CA AND NORTH SPIT, CA TIDE STATIONS

	Samoa, CA (NOAA 9418817)		North Spit, CA (NOAA 9418767)	
Tidal Datum	**FEET, MLLW**	**FEET, NAVD88**	**FEET, MLLW**	**FEET, NAVD88**
Highest Observed Tide (HOT)	N/A	N/A	9.88	9.54
Highest Astronomical Tide (HAT)	9.36	8.64	8.84	8.5
Mean Higher High Water (MHHW)	7.37	6.65	6.85	6.51
Mean Sea Level (MSL)	3.99	3.27	3.70	3.36
North American Vertical Datum 1988 (NAVD88)	0.72	0.0	0.34	0.0
Mean Lower Low Water (MLLW)	0.0	-0.72	0.0	-0.34
Lowest Astronomical Tide (LAT)	-2.43	-3.15	-2.4	-2.74

Baseline hazard conditions at the site are evaluated using the NOAA North Spit, CA station (9418767), given its longer period of observed tides. The highest astronomical tide at this station is 9.88 feet MLLW (9.54 feet NAVD88), which acts as the baseline hazard condition.

2.2. Sea Level Rise Projections

Comprehensive guidance of sea-level rise (SLR) for California was first developed by the National Research Council (2012). The guidance relied on the best available science at the time to identify a range of SLR scenarios including low, intermediate, and high projections, considering regional factors such as El Niño and extreme storm events that affect ocean levels, precipitation, and storm surge.

Current guidance for California is provided in Ocean Protection Council or OPC (2018) which recommends evaluation of SLR impacts using a scenario-based approach to recommend evaluation of SLR impacts and is identified as the best available source for SLR scenarios according to the California Coastal Commission.

The OPC provides SLR projection values for various emission and risk aversion scenarios at North Spit. The high emission condition is considered with both the low-risk aversion (likely range) and medium-high risk aversion (1-in-200 chance) scenarios. For 2080, under the high emission scenario, the low-risk aversion SLR projection is 2.9 feet and the medium-high risk aversion SLR projection is 5.1 feet.

3. Coastal Hazards

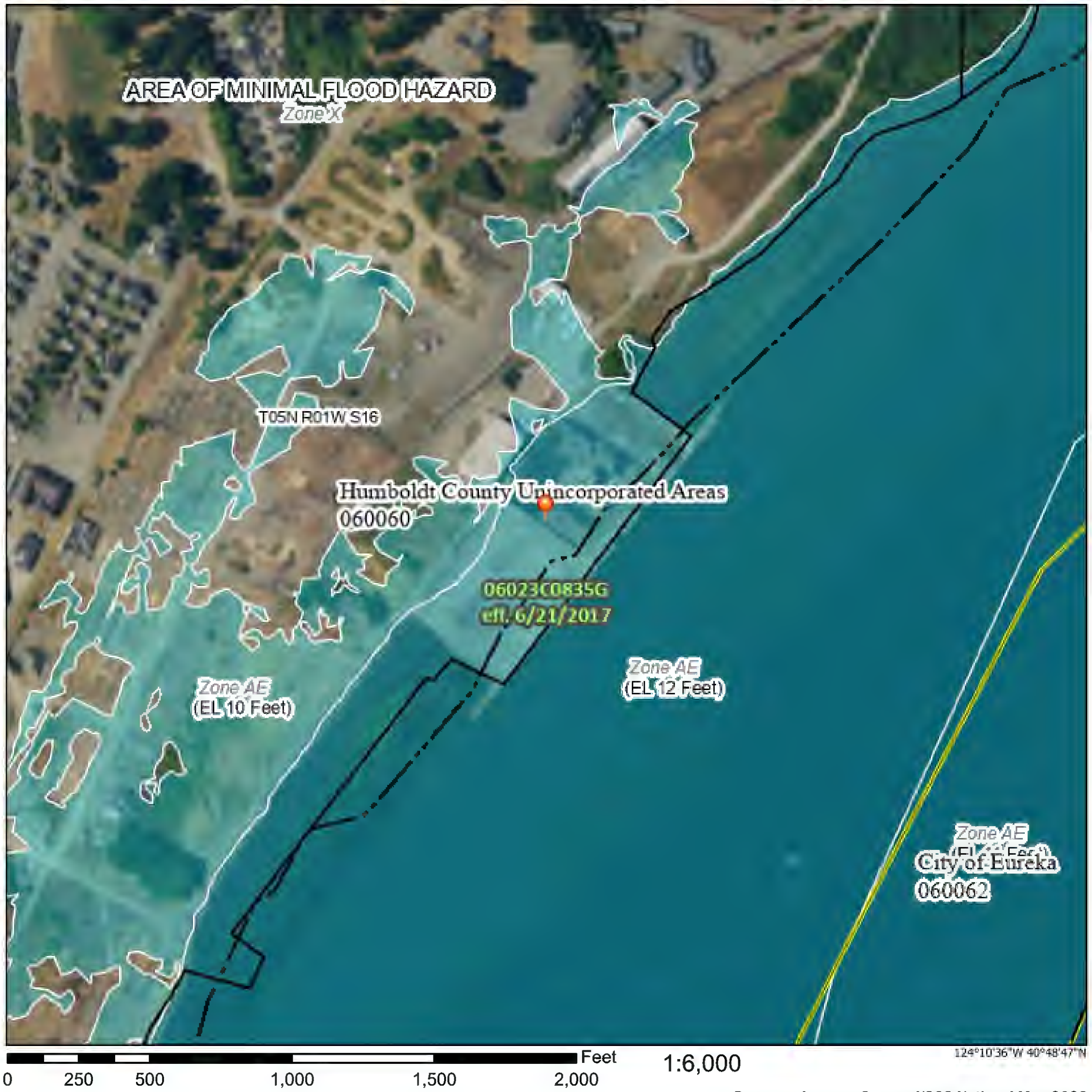
3.1. Flood Hazards

The Federal Emergency Management Administration (FEMA) develops Flood Insurance Rate Maps (FIRMs) to identify riverine and coastal flood hazards. These maps identify the BFE to which flood water is anticipated to rise during the 1% annual chance flood event. Wave runup is included within BFE calculations per the FEMA Flood Insurance Study (FIS) published in conjunction with flood mapping results for the Project site.

Current FEMA FIRM panel 6023C0835G, effective date of June 21, 2017, show AE[1] zone flood elevations of 10.34 ft MLLW (+10 ft NAVD88) in upland areas and 12.34 ft MLLW (+12 ft NAVD88) along the shoreline of the Project site and applicable to the wharves/pier, see Figure 2-1.

[1] Zone AE indicates areas that have at least a 1%-annual-chance of being flooded, but where wave heights are less than 3 feet.

FIGURE 2-1: SNAPSHOT OF FEMA FIRM NO. 06023C0835G TAKEN AT THE PROPOSED RMT1.



Basemap Imagery Source: USGS National Map 2023

3.2. Wave Hazards

Wave environment along the Project site shoreline has been characterized by Northern Hydrology & Engineering (NHE 2022). This characterization showed that prevailing wind-waves at the site are from east-northeast to south directions. The predicted peak wave heights and periods for the four longest fetch lengths and adjusted wind speeds are listed in Table 2-1.

TABLE 3-1: ESTIMATED WIND-WAVE CHARACTRISTICS ALONG THE PROJECT SITE SHORELINE

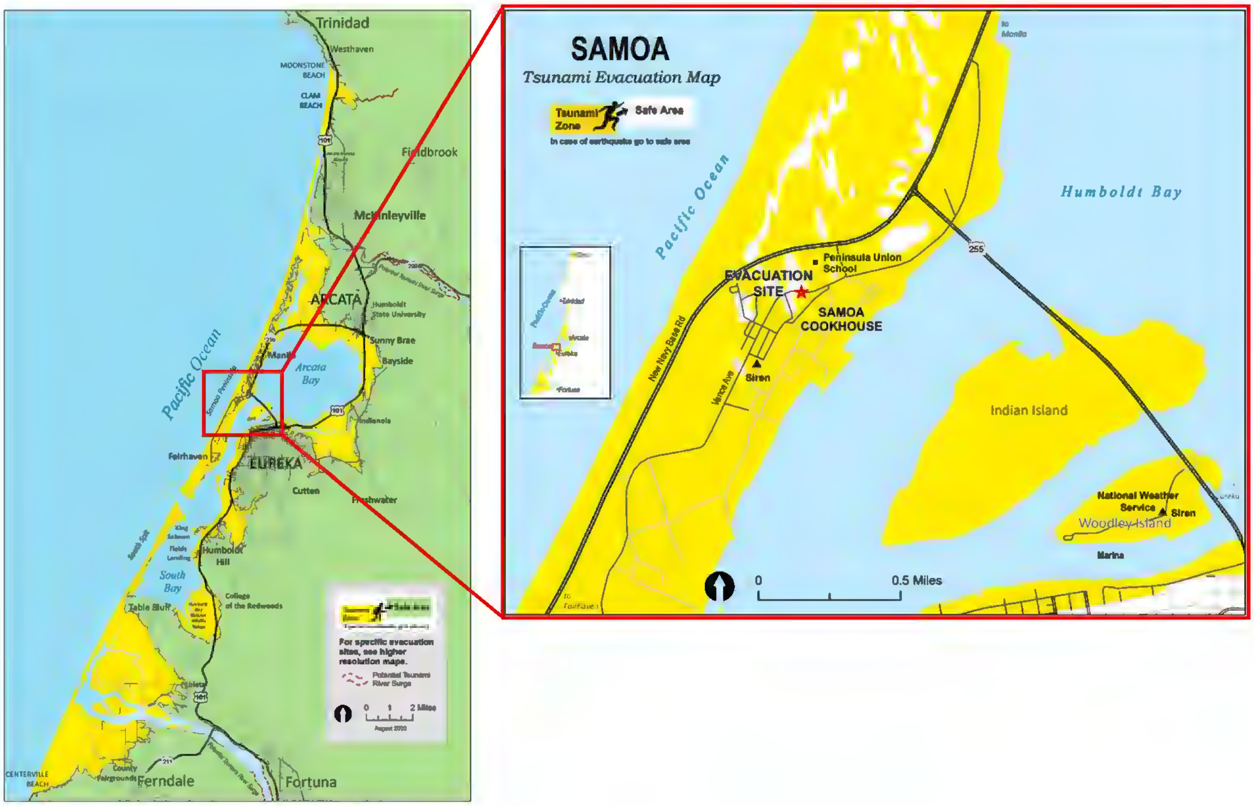
Wind Direction (from)	Fetch Length (km)	Adjusted Wind Speed (mps)	Adjusted Wind Speed (mph)	1% Peak Wave Height (m)	1% Peak Wave Height (ft)	1% Wave Period, Tp (s)
East-Northeast	67.5	11.5	25.7	0.54	1.8	2.6
East	90.0	14.98	33.5	0.68	2.2	2.7
Southeast	135.0	22.46	50.2	0.41	1.3	1.6
South	180.0	22.21	49.7	0.57	1.9	2.0

3.3. Tsunami Hazards

Tsunamis are most commonly generated by earthquakes in marine and coastal regions. Submarine (underwater) landslides and underwater volcanic eruptions are also capable of generating destructive tsunamis. Major tsunamis are produced by large earthquakes associated with the movement of oceanic and continental plates. The circumstances that characterize tsunami-genic earthquakes are greater than magnitude 7 on the Richter scale and shallow focus (< 30km depth in the earth).

The Project site is highly exposed to tsunami hazards due to its proximity to the Cascadia Subduction Zone (CSZ). CSZ is a tectonic plate boundary known for its potential to generate massive undersea earthquakes. When a large-scale seismic event occurs along this subduction zone, it can displace a vast amount of ocean water, triggering a tsunami. The resulting wave could potentially over-wash the Samoa Peninsula and inundate the Project site as shown in Figure 2-2. The projected inundation is expected to be 3 feet or less. It is estimated that it would take between 10 to 20 minutes after the earthquake for the tsunami to reach the shore. However, the real tsunami travel time will depend on the location of the triggering earthquake.

FIGURE 2-2: TSUNAMI HAZARD AND EVACUATION MAP (CALIFORNIA GEOLOGICAL SURVEY 2021)



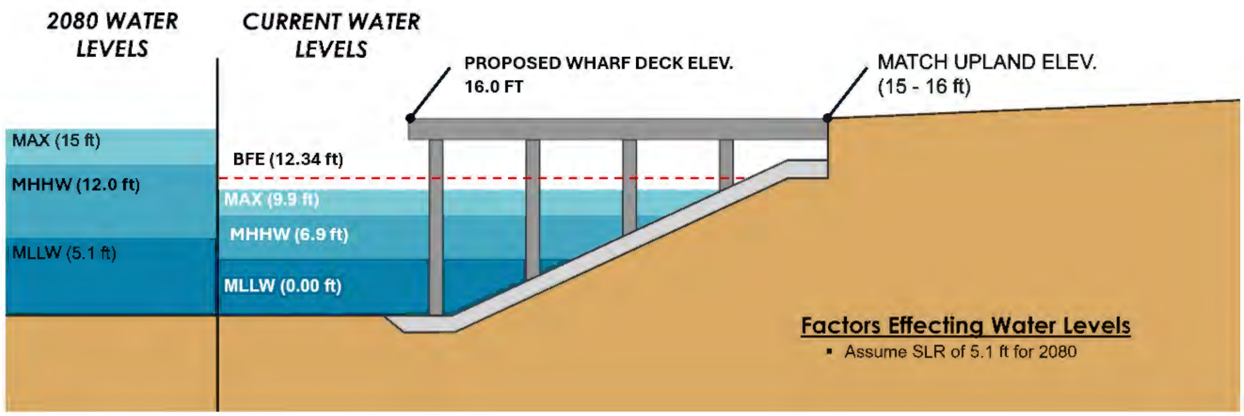
4. Design Recommendations

This coastal hazard analysis uses the 50-year (2080) horizon to develop recommendations for minimum elevation for top of wharf/pier deck at the newly proposed marine terminal.

Beginning with the baseline high water elevation of 9.9 feet MLLW (9.5 feet NAVD88) and adding the listed SLR projections, the total water elevation for the low-risk and medium-high risk aversion scenarios are 12.8 feet MLLW (12.46 feet NAVD88) and 15.0 feet MLLW (14.66 feet NAVD88) respectively.

The proposed wharf elevation (for top of deck) with respect to MLLW as well as current and projected tidal datums are shown in Figure 3-1. The figure indicates that the proposed top of deck elevation of 16.0 feet MLLW (15.66 feet NAVD88) would accommodate both the low-risk (2.9 feet) and medium-high risk (5.1 feet) aversion SLR projections at a 50-year time horizon. Using the maximum observed water level of 9.9 feet MLLW with the medium-high risk aversion scenario (5.1 feet), the water level would be 1.0 feet below the proposed deck elevation of 16.0 feet MLLW.

FIGURE 3-1: WHARF ELEVATION RELATIVE TO TIDAL DATUMS IN FEET REFERENCED TO MLLW.



The proposed minimum deck elevation of 16 feet MLLW (16.34 feet NAVD88) would allow the wharf deck to avoid flooding caused by a EWLs under the low-medium and medium-high risk aversion scenarios for 2080. Figure 2 illustrates the proposed wharf deck elevation in relation to current water levels, future water levels under the medium-high risk aversion scenario for 2080 and a FEMA BFE of 12.34 feet MLLW (12 feet, NAVD88).

5. Summary of Findings and Recommendations for Next Steps

M&N analyzed coastal hazards to develop design recommendations in terms of minimum elevation for top of pier/wharf deck to be resilient against sea level rise (SLR) within the project planning horizon.

The proposed marine terminal will be sheltered from energetic waves (both wind waves and swell) and the primary coastal hazards for the site include coastal flooding associated with extreme water levels (EWLs), as opposed to coastal flooding resulting from wave runup and overtopping.

The proposed minimum deck elevation of 16 feet MLLW would allow the wharf deck to avoid flooding caused by future EWLs under the medium-high risk aversion scenario for 2080, the maximum observed water level from North Spit, and future FEMA BFE of 15.6 feet MLLW under the low-medium risk aversion scenario for 2080.

5.1. Design Considerations – Adaptive Measures

Raising elevation of assets would reduce exposure and risks from coastal flooding and the higher the design flood elevations, the lower the exposure and risks associated with coastal flooding. A benefit cost analysis based on these factors could inform selection of any final design elevations beyond minimum requirements. Additionally, given inherent uncertainty in long-term projections of SLR, the design should incorporate adaptation measures that can be implemented over time if certain thresholds of SLR are exceeded. Example adaptation measures include elevating the site where feasible, building flood barriers around the site perimeter, or installing floodproofing retrofits to protect infrastructure.

Additionally, connectivity and interdependencies between the physical infrastructure and operations should be considered as a factor in setting the minimum elevations for various Project elements. Future impacts to the Project from coastal hazards will depend not only on the design of Project elements, but also supporting infrastructure essential to Project function. For example, major roadways that provide access to the Project site, may experience a greater risk of flooding due to SLR, impacting access to Project facilities if not designed for future SLR.

5.2. Recommendations for Next Steps

It is recommended to update this analysis at the next phase of design and identify adaptation pathways to accommodate a phased plan for increasing resiliency of the new infrastructure against sea level rise.

5.3. Study Limitations

There is inherent uncertainty in projections of future change in sea level. Accordingly, M&N makes no warranty or representation that any of the projected values or results contained in this study will be achieved. Resilience of the new infrastructure against coastal hazards should be monitored and evaluated if actual SLR exceeds projected rates used in this study.

6. References

Northern Hydrology & Engineering (NHE), 2022. Humboldt Bay Hydrodynamic Modeling Study.

Ocean Protection Council (OPC), 2018. The State of California Sea-Level Rise Guidance 2018 Update.

Federal Emergency Management Administration (FEMA), 2017. *Flood Insurance Study for Humboldt County, California and Incorporated Areas, Flood Insurance Study Number 06023CV000A.*