Appendix K-2

Coastal Hazard and Sea Level Rise Vulnerability Assessment (April 30, 2025)

moffatt & nichol

1660 Hotel Circle North, Suite 500
San Diego, CA 92108

(619) 220-6050
www.moffattnichol.com

MEMORANDUM

To: City of Oceanside

From: Moffatt & Nichol

Date: April 30, 2025

Subject: Pier View Way Bridge – Coastal Hazard and Sea Level Rise Vulnerability Assessment

M&N Job No.: 11151

1 Introduction

The Pier View Way Bridge is located at the terminus of Pier View Way in Oceanside, California. It is the primary entrance and exit to the Oceanside Municipal Pier and encompasses the local Lifeguard Headquarters Building (hereafter Lifeguard Building), which is situated beneath the bridge span at its western end. An existing rock revetment in front of the Lifeguard Building protects the structure from direct wave impacts and coastal erosion. Figure 1 and Figure 2 illustrate the location of the Pier View Way Bridge, Lifeguard Building, and existing revetment. Originally constructed in 1927, the nearly century-old bridge is approaching the end of its service life and requires major repair or reconstruction. The Lifeguard Building, constructed in 1987, is integrated under the bridge and is also deteriorating. The project proposes improvements to the Pier View Way Bridge and Lifeguard Building. The Lifeguard Building and its fronting revetment are considered a coastal dependent essential public works facility and are a focus in this coastal hazard study (M&N, 2023).

As highlighted by a previous Coastal Hazard Vulnerability Assessment (ESA, 2018), the project site faces increased flood frequency and associated risks due to future sea level rise (SLR). To address this vulnerability and inform the proposed project repair/reconstruction, the City of Oceanside contracted Moffatt & Nichol (M&N) to perform a detailed coastal hazard and SLR assessment for the Pier View Way Bridge and Lifeguard Building. The scope of this assessment, as presented herein, included the following:

- Review of the project site's coastal setting.
- Review of the latest California SLR guidance and selection of appropriate SLR scenarios for the project.
- Review of USGS Coastal Storm Modeling System (CoSMoS) results and FEMA Flood Insurance Rate Maps (FIRM).
- A site-specific wave runup analysis, using data from the FEMA California Coastal Analysis and Mapping Project/Open Pacific Coast (CCAMP/OPC) study, for both the existing and proposed structures.
- Determination of flood zones at the project site and their associated flood elevations.
- An evaluation of SLR-related vulnerabilities at the project site, including coastal flooding, erosion, currents, groundwater changes, and tsunami risks.

Figure 1: Location of Pier View Way Bridge and Lifeguard Building

Figure 2: Historical Photo of Lifeguard Building and Rock Revetment

2 Coastal Settings

The following sections describe the coastal settings of the project site as relevant to potential flooding risks. The discussion focuses on astronomical tides and waves, which are key components of coastal flooding.

2.1 Tides

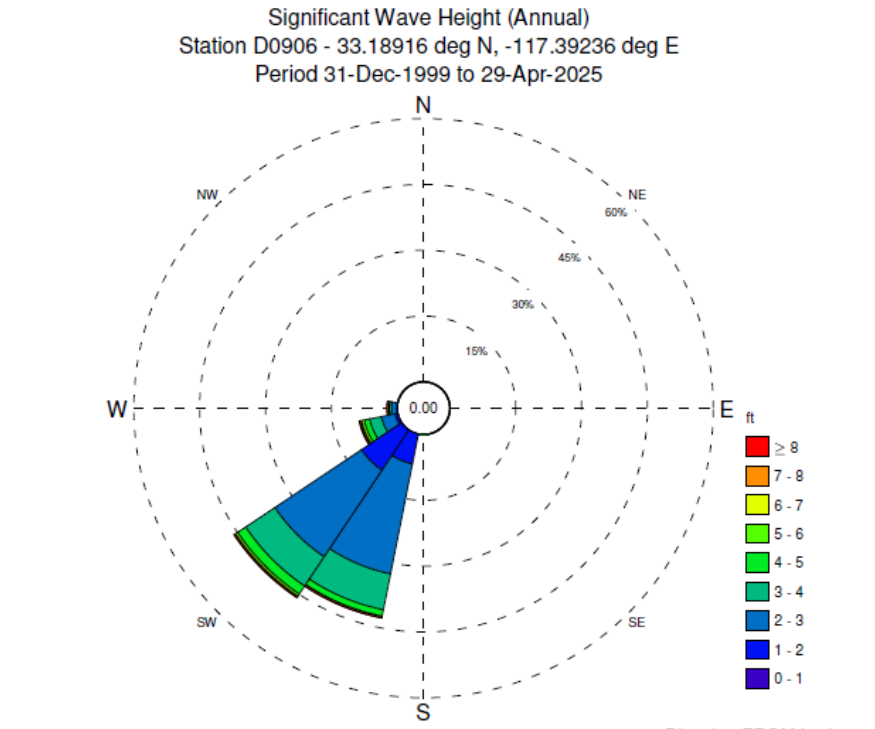
Tides on the Southern California coast have a semi-diurnal pattern, with two high tides and two low tides every day. The nearest tide gauge to the Pier View Way Bridge is National Oceanic and Atmospheric Administration (NOAA) La Jolla tide gauge (ID#9410230). Table 1 lists tidal datums published at this station for the 1983-2001 epoch, referenced to the North American Vertical Datum of 1988 (NAVD88). The tidal range between Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) is 5.32ft. The historically observed highest water level is 7.62 feet (ft) NAVD88, which occurred on November 25, 2015.

Table 1: Tidal Datums at La Jolla (NOAA ID#9410230, 1983-2001 Epoch)

Description	Datum	Elevation (ft NAVD88)
Highest Observed Water Level (11/25/2015)	HOWL	7.62
Highest Astronomical Tide	HAT	7.01
Mean Higher-High Water	MHHW	5.13
Mean High Water	MHW	4.41
Mean Sea Level	MSL	2.54
Mean Low Water	MLW	0.71
North American Vertical Datum of 1988	NAVD88	0.00
Mean Lower-Low Water	MLLW	-0.19
Lowest Astronomical Tide	LAT	-2.20
Lowest Observed Water Level (12/17/1933)	LOWL	-3.06

2.2 Waves

The Coastal Data Information Program (CDIP) provides observation-driven wave hindcast and nowcast model data along the California coast through its Monitoring and Prediction (MOP) system. Data from January 2000 to April 2025 at MOP Station D0906, located at the Oceanside Pier at a 33-ft (10-m) water depth (33.1892N -117.3924W), was used to characterize typical nearshore wave conditions. The wave rose plot and joint probability table provided in Figure 3 show that waves are predominantly southwesterly and are typically (72% of the time based on MOP Station D0906 data) less than 3 ft. The peak wave period histogram in Figure 4 shows that 70% of the waves have a peak period between 12 to 16 seconds. An extreme value analysis of waves at the Oceanside Pier was also conducted using the same data. The resulting extreme wave conditions for various return periods are listed in Table 2. The 1-year and 100-year offshore significant wave heights are 8.8ft and 14.6ft, respectively.



Percentage of Occurrence

Significant Wave Height, ft	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total										42.74	45.94	8.97	2.34				100.00
8												0.11					0.20
7											0.12	0.14					0.33
6											0.22	0.32					0.68
5										0.31	0.58	0.62	0.13				1.64
4										1.47	2.20	1.25	0.31				5.23
3										8.34	8.01	2.72	0.50				19.57
2										25.55	23.72	3.21	1.14				53.62
1										6.95	11.00	0.60	0.16				18.72
0																	

Figure 3:Wave Rose and Joint Probability Table at MOP Station D0906

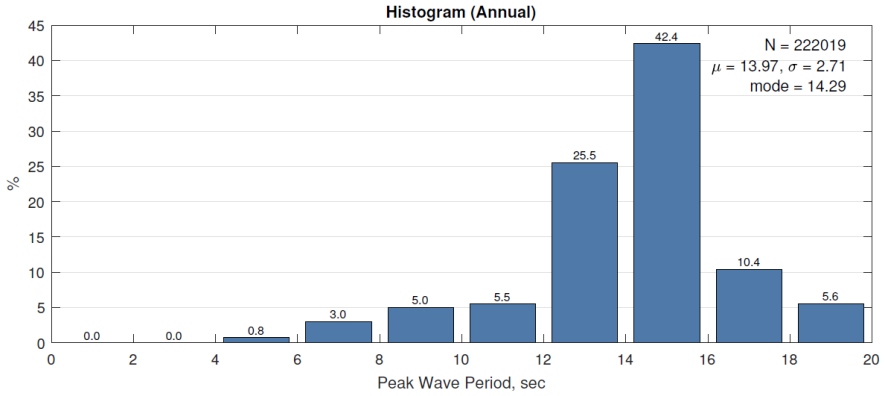


Figure 4:Histogram of Peak Wave Periods at MOP Station D0906 (2000/01-2025/04)

Table 2: Extreme Nearshore Wave Conditions at Oceanside Pier (MOP D0906, 33ft-depth)

Return Period (year)	Significant Wave Height (ft)
1	8.8
5	10.8
10	11.7
50	13.7
100	14.6

3 Sea Level Rise Projections

Construction of the proposed Pier View Way Bridge is expected to be completed by 2030. A 75-year minimum design life is assumed for the structure, consistent with the California Coastal Commission's (CCC's) recommended time frame of 75 to 100 years for residential and commercial structures (California Coastal Commission, 2024). Using a 75-year design life for project development, year 2105 is used as the time horizon for SLR scenarios. Table 3 lists the SLR projections at La Jolla (closest station to the project site), published in the 2024 Ocean Protection Council (OPC) SLR guidance (Ocean Protection Council, 2024) which has been adopted in the latest CCC SLR Policy Guidance. Table 3 does not provide a specific SLR projection for 2105, thus it was interpolated from 2100 and 2110 projections (highlighted in blue box).

SLR scenarios of 3.5ft and 5.3ft have been selected for analysis within this study to capture potential hazards at the end of the project design life under intermediate and intermediate-high scenarios. Per CCC 2024 SLR Guidance, CCC recommends the intermediate-high scenario for most development (California Coastal Commission, 2024)

- The 3.5ft SLR scenario is used to illustrate any potential hazards at the end of the 75-year project design life (by 2105) under the intermediate scenario, or at the middle of the design life (by 2085) under intermediate-high scenario.
- The 5.3ft SLR scenario represents potential hazards at the end of the 75-year project design life under the intermediate-high scenario.

The two SLR scenarios selected for this project and their projected time horizons are presented in Table 4. The evaluation of the two selected SLR scenarios will provide a good overall picture of the site's coastal vulnerability within a 75-year life span.

Table 3: Projected SLR at La Jolla (Ocean Protection Council, 2024)

YEAR	LOW	INT-LOW	INTERMEDIATE	INT-HIGH	HIGH
2020	0.2	0.2	0.3	0.3	0.3
2030	0.3	0.4	0.4	0.4	0.5
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.7	0.8	1.0	1.3
2060	0.6	0.8	1.1	1.6	2.0
2070	0.7	1.0	1.4	2.3	3.0
2080	0.8	1.2	1.8	3.1	4.1
2090	0.9	1.4	2.4	3.9	5.3
2100	0.9	1.6	3.1	4.8	6.6
2110	1.0	1.8	3.8	5.7	7.9
2120	1.1	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.1	9.9
2140	1.2	2.4	5.5	7.6	10.9
2150	1.3	2.6	6.0	8.2	11.8

2105 (75-year design life)

Table 4: Estimated Project Completion, Design Life and Proposed SLR Projections

Estimated Completion Year	Design Life	Year SLR Projection	SLR Guidance
2030	75 years	By 2105: 3.5' (intermediate)[1] By 2105: 5.3' (int-high)[1,2]	OPC 2024 & CCC 2024

Note:
[1] SLR projection interpolated between 2100 and 2110, as shown Table 3.
[2] SLR projection by 2130 with a 100-year design life is 4.9ft under the intermediate scenario. It is below the selected higher scenario of 5.3ft.

4 Coastal Hazards and Sea Level Rise Vulnerability Analysis

The following sections discuss the coastal hazards that are relevant to the Pier View Way Bridge, including coastal flooding caused by extreme water levels and wave runup, currents, erosion, tsunamis, and groundwater impacts. Potential hazards for both existing and proposed structures under existing and future SLR scenarios were assessed.

4.1 Coastal Flooding

4.1.1 Existing Sources of 100-year Extreme Water Levels

4.1.1.1 FEMA FIRM

Per FEMA FIRM Panel 06073C0734J, the Pier View Way Bridge and Lifeguard Building are located in the coastal VE zone with a base flood elevation (BFE) of 16ft NAVD88 (see Figure 5). FEMA Zone VE designates a Coastal High Hazard Area, specifically an area subject to high-velocity wave action from storms or seismic sources. This FIRM panel is effective on December 20, 2019. FEMA's BFE, also known as the 100-year flood elevation, defines the water elevation with a one percent chance of exceedance in any given year. The two bounding transects (shown as Transect #16 and Transect #17 in Figure 5) do not cross the pier structure; thus the revetment protection in front of the Lifeguard Building and its impact on wave runup are not included in FEMA BFE analysis. Additionally, no SLR was considered in FEMA's BFE analysis. Hence, a site-specific calculation of the 100-year flood elevation is required to consider the revetment impacts.

Figure 5: Excerpt of FEMA FIRM Panel 06073C0734J, Effective 12/20/2019.

4.1.1.2 CoSMoS

The CoSMoS model, developed by United States Geological Survey (USGS), provides estimates of coastal flooding due to future SLR and coastal storms along the California coast (Barnard, 2018). It integrates projections of SLR with models simulating tides, waves, and storm surge to estimate coastal hazards under various scenarios. For this study, modeled 100-year flood elevations and corresponding storm wave conditions on the beach at the pier were extracted from the CoSMoS database as provided in Table 5. As CoSMoS results are only available in 0.25m (0.8ft) SLR increments, the 1.0m (3.3ft) and 1.5m (4.9ft) SLR scenarios were selected as the closest available representatives of the target 3.5ft and 5.3ft SLR. The predicted 100-year coastal flooding elevations based on the maximum wave height are included in Table 5. The 100-year water elevations from CoSMoS do not include site-specific impacts from the pier and revetment structure.

Table 5: CoSMoS Predicted Flood Elevations under 100-year Coastal Storm at Various SLR Intervals

SLR Scenario	100-year Flood Elevation[1] (ft NAVD88)
No SLR	10.1
+1.0 m (+3.3ft) SLR[2]	13.2
+1.5 m (+4.9ft) SLR[2]	14.0

Note:

[1] The flood elevation extracted from CoSMoS includes all components of total water level: relative sea level rise, surge, seasonal effects and wave runup (CoSMoS, 2025).

[2] CoSMoS provides results in 0.25m SLE increments. The +1.0m (3.3ft) and +1.5m (4.9ft) SLRs are the closest SLR cases to the 3.5ft and 5.3ft SLR studied here.

4.1.2 Site-specific Wave Runup Analysis

As discussed in Section 4.1.1, FEMA FIRM does not include the revetment and building structure in the transect analysis and is only available for the existing No SLR condition. CoSMoS model simulated SLR impacts but also does not consider the structural impact. Upon review of the existing FEMA FIRM and CoSMoS extreme flood predictions, a site-specific wave runup analysis is required to account for structures and future

SLR. This section documents site-specific wave runup calculation inputs, methodology, and the resulting 100-year flood elevations at the Lifeguard Building.

4.1.2.1 Analysis Transect

Figure 6 presents the location of a new transect for site-specific wave runup analysis (labeled as Pier Transect), passing adjacent to the pier and Lifeguard Building, together with the two bounding FEMA FIRM panel transects (#16 and #17). Detailed bathymetric and topographic data along this transect line were compiled using historical elevation profiles from the SANDAG Regional Beach Monitoring Program (1997-2021) (Coastal Frontiers Corporation, 2021). Figure 7 presents all historical beach profiles from the adjacent SANDAG transect, OS-1000, as shown in Figure 6.

Analysis of this data revealed that the Spring 2016 profile represented the most eroded beach condition observed during the monitoring period. This profile was selected as the most likely winter eroded profile for the runup analysis to provide a conservative assessment of wave impacts under potentially vulnerable beach states. To create a complete nearshore profile for analysis, the landward portion of the SANDAG OS-1000 2016 data was combined with offshore data (elevations below 0ft NAVD88) derived from the 2016 USGS West Coast El-Nino Lidar DEM (Office for Coastal Management, 2022). The existing revetment and Lifeguard Building features, based on a May 2021 topographic survey (Figure 8), were then incorporated into the composite Pier Transect. This survey indicated the existing revetment has an approximate 2.5H:1V slope, a crest at +13.5ft NAVD88, and a toe around +5.5ft NAVD88 (Figure 9 illustrates the resulting existing condition profile).

For the proposed condition, which includes adding a lifeguard observation sidewalk and seawall atop the existing revetment footprint. A “bullnose” feature on the seawall is proposed to reduce overtopping and redirect waves and up-rushing water seaward. Per EurOtop, long period large waves tend to fill the space underneath the bullnose, and the waves observe the structure as a normal vertical wall (EurOtop, 2018). Therefore, two profiles were developed for the analysis while discarding the proposed bullnose. The first (Figure 10) assumes the existing revetment toe elevation (+5.5ft NAVD88, based on 2021 survey) for direct comparison and impact analysis. The second, termed the 'proposed design profile' (Figure 11), incorporates an eroded revetment toe at -0.5ft NAVD88, reflecting the 2016 eroded conditions. Since the restoration/reconstruction design is based on the 100-year coastal storm, the revetment was assumed to be intact in the runup calculations. The bridge soffit was estimated at +26.15ft NAVD88 (assuming 2ft below the pier deck elevation of +28.15ft NAVD88). Future beach profiles under 3.5ft and 5.3ft SLR were developed assuming the beach berm accretes vertically with SLR while maintaining a foreshore slope similar to existing conditions.

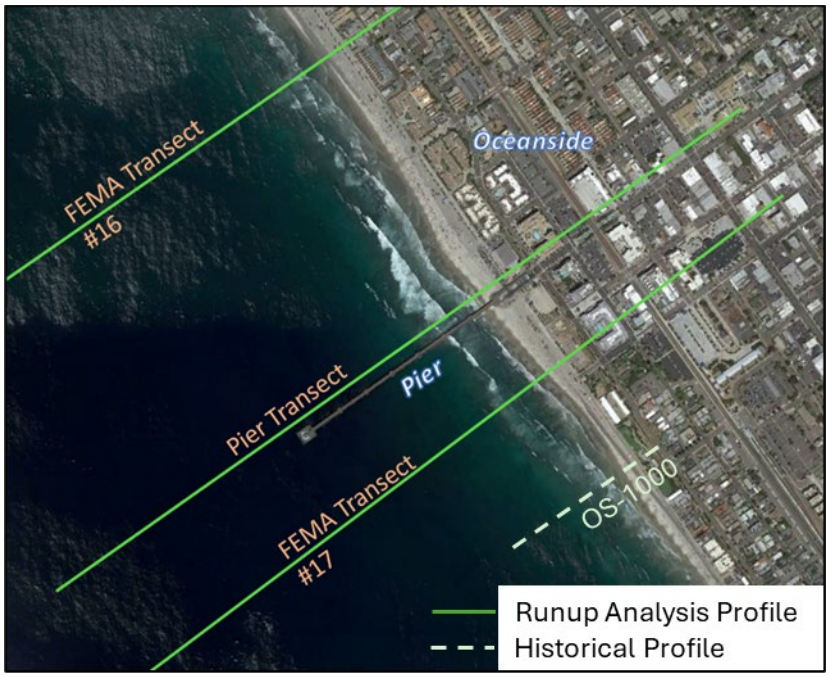


Figure 6: Transect Locations at Pier View Way Bridge

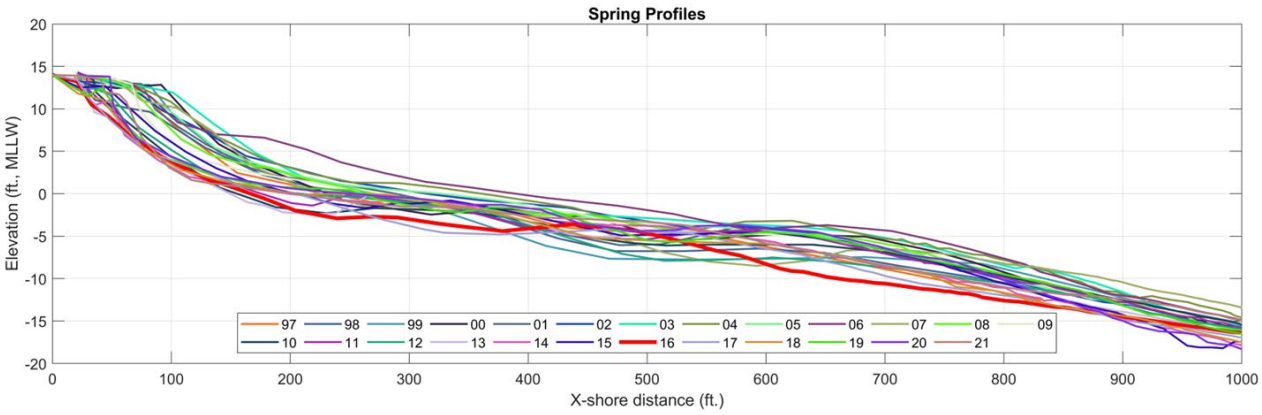


Figure 7: Spring Profile Plot at SANDAG Profile OS-1000 (Coastal Frontiers Corporation, 2021)

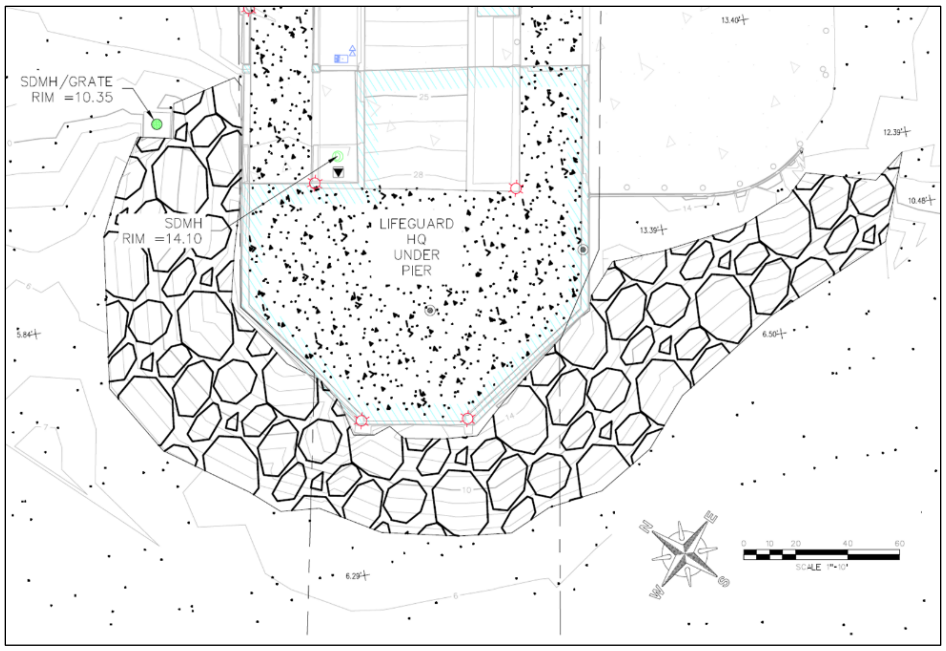


Figure 8:Topographic Survey of the Existing Rock Revetment (NV5, 2021)

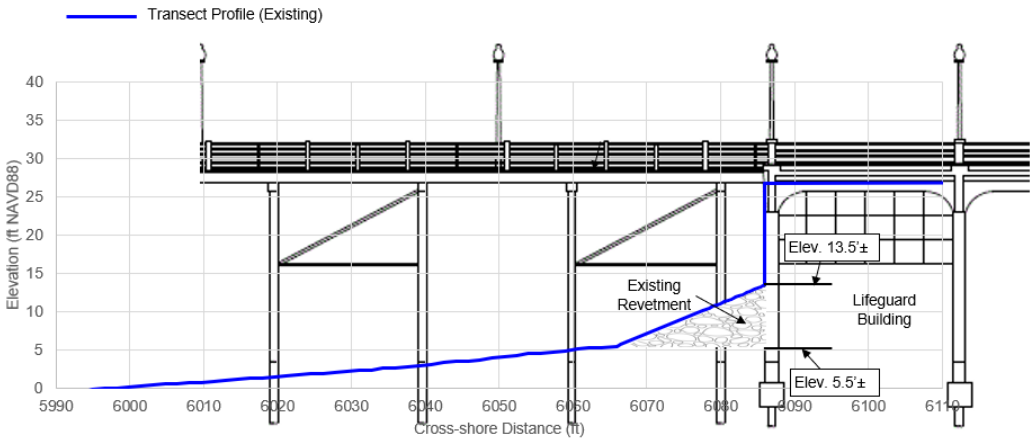


Figure 9: Pier View Way Bridge Transect Profile of Existing Condition

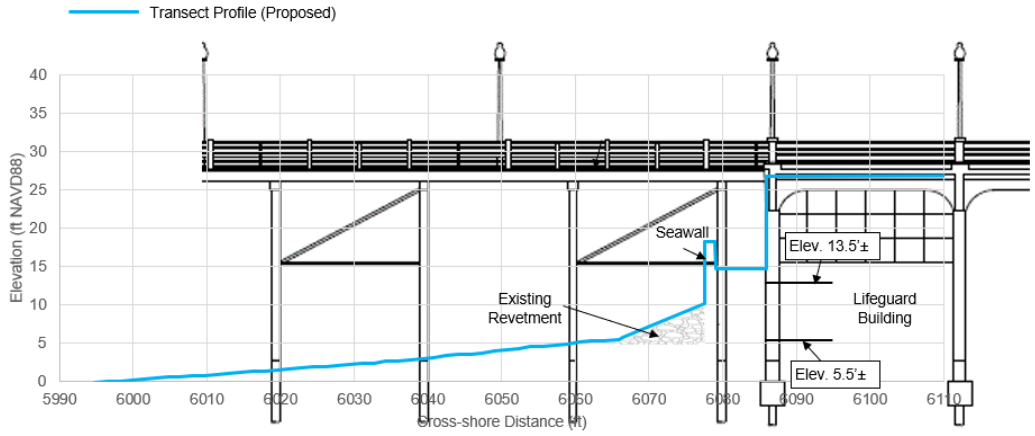


Figure 10: Pier View Way Bridge Transect Profile of Proposed Condition

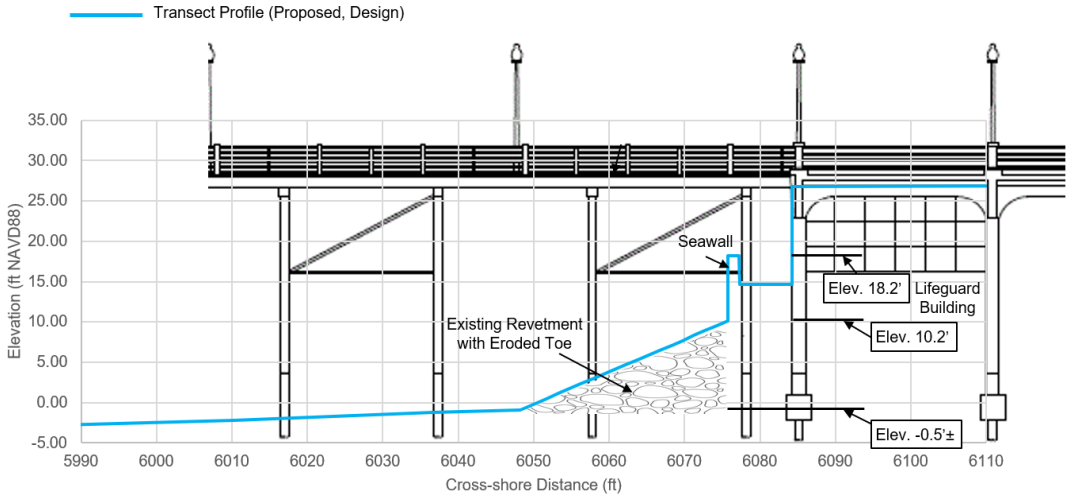


Figure 11: Pier View Way Bridge Transect Profile of Proposed Design Condition (with Eroded Revetment Toe)

4.1.2.2 Methodology

Runup analysis employed methodologies documented in CCAMP/OPC Intermediate Data Submittal Reports (BakerAECOM, 2016) prepared for the recent FEMA mapping analysis in San Diego County. Figure 12 depicts the flowchart of the technical approach adopted here. Nearshore wave parameters and water levels at a depth of 49.2ft (15m) for 155 selected peak events are available from the FEMA CCAMP/OPC study at the nearest transect (#17). The wave setup, runup, and overtopping of these peak events were re-analyzed using the site-specific nearshore bathymetric and topographic conditions at the Pier Transect, incorporating relevant SLR scenarios. The site-specific analysis conducted by M&N can be summarized in the following steps:

- Construct transect topographic profiles at the pier and Lifeguard Building, including both the existing revetment and proposed structures.
- Extract extreme wave parameters at FEMA Transect #17 to be used in 1-D wave setup and runup analysis.
- Calculate total wave levels (including stillwater elevation, wave setup and runup) for the extreme events at the pier transect under +0.0ft, 3.5ft and +5.3ft SLR scenarios.

- Conduct extreme value analysis to determine the 100-year design water elevation at the site for all scenarios.

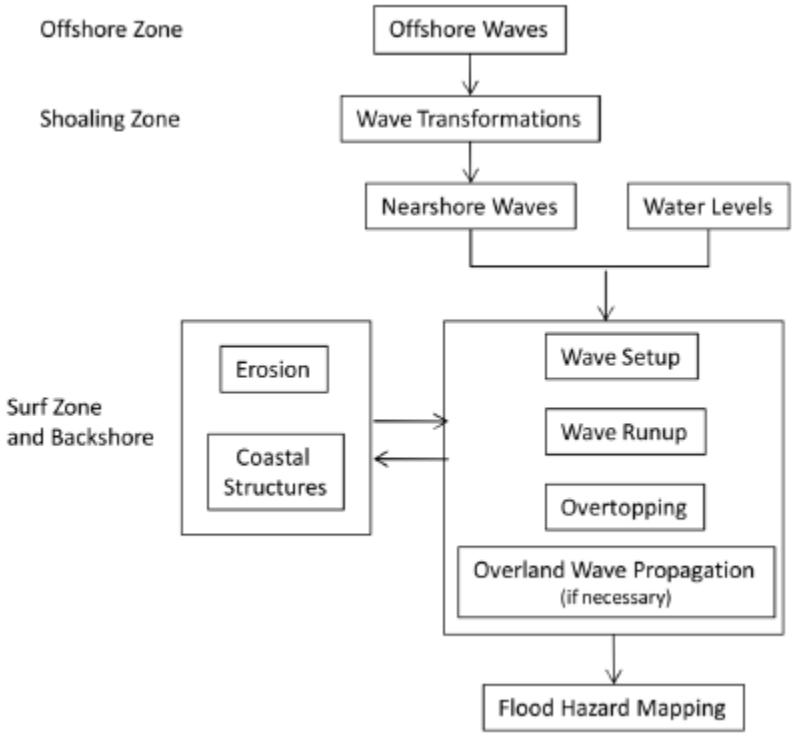


Figure 12: Summary of Technical Approach Adapted from Pacific Guidelines (BakerAECOM, 2016)

As illustrated in the profile plots (Figure 9 through Figure 11), the site-specific Pier Transect is composed of three shoreline features progressing from offshore to inland: a sandy beach, a rock revetment and a vertical wall (Lifeguard Building in existing condition in addition to seawall in proposed condition). The specific methodology for calculating wave setup and runup was adapted based on the profile configuration and water level conditions, following FEMA guidance.

For the existing condition profile, characterized by a foreshore slope less than 0.11, the calculation method depended on the water level relative to the structure toe. The Stockdon method was applied when the revetment toe was above the stillwater level. If the water level inundated the revetment toe (+5.5ft NAVD88) but remained below the base of the vertical wall (+13.5ft NAVD88), the TAW method was used instead. If the entire revetment was inundated (above +13.5ft NAVD88) for a given SLR scenario, potentially allowing direct wave impact to the building, the TAW method was adjusted to reflect the influence of the vertical wall. In this case, the wall base was set to +13.5ft NAVD88, with the crest defined by the bridge soffit at approximately +26.15ft NAVD88 (assuming a 2ft deck thickness).

The proposed condition profile (shown in Figure 10) has the same revetment and seawall features as the existing profile, but the proposed seawall along the sidewalk perimeter has a lower base (approximately +10.1ft NAVD88). The same runup approach as the existing condition was therefore adopted for the proposed profile, with geometry updated to reflect geometry of the new vertical wall component.

The 'proposed design profile' (Figure 11) considers an eroded revetment toe (approximately -0.5ft NAVD88), which results in a steeper foreshore slope. The Stockdon method does not apply in this steeper foreshore

condition. Consequently, only the TAW method was used to compute the runup on either the revetment or the seawall depending on whether the water level reached the seawall base (above +10.1ft NAVD88).

In a few extreme events where the dynamic water level exceeds the proposed seawall crest along the sidewalk (+18.2ft NAVD88), the runup elevation was computed assuming the seawall was not in place and the wave runup occurs directly on the Lifeguard building. This assumption was verified using computational fluid dynamics modeling which indicated that the relatively short seawall and narrow sidewalk offer minimal resistance to runup from longer period waves (12 to 16 seconds) characteristic of more extreme events. Therefore, ignoring the seawall along the sidewalk for these specific events, which control the design, provides a reasonably conservative estimate for the Total Water Levels (TWLs).

4.1.2.3 Results

The 100-year TWLs computed at the Lifeguard Building for the three profiles (existing, proposed, and proposed design conditions) are provided in Table 6. Each profile condition has three SLR scenarios: No SLR, 3.5ft and 5.3ft SLR. Due to the presence of the revetment and seawall, the TWL is higher than the adjacent beach with FEMA BFE of 16ft NAVD88. The TWL increases with SLR. The proposed condition also shows increases in TWL under 3.5ft and 5.3ft SLR. This is because the toe of the seawall is lowered with the proposed sidewalk. Compared to the proposed conditions, the 'proposed design condition' has a higher TWL under the present sea level due to eroded beach conditions, exposing a lower revetment toe. With consideration for SLR, the seawall toe becomes inundated more frequently during peak events and the two proposed conditions become more similar, thus there are less differences in TWL.

Table 6: 100-year Total Water Levels[1] at the Lifeguard Building (in ft NAVD88)

Sea Level Rise	Existing Condition	Proposed Condition[2]	Proposed Design Condition[3]
Present (No SLR)	21.2	20.4	22.6
+3.5ft	23.8	25.0	26.1
+5.3ft	24.7	28.8	29.2

Note:
[1] Total water level anticipated during 100-year storm event. It includes stillwater level, wave setup and runup per FEMA CCAMP/OPC study (BakerAECOM, 2016).
[2] Runup computed at the proposed vertical seawall along the sidewalk of the Lifeguard Building.
[3] Design condition was developed with the most eroded condition as posted in 2016 with an estimated revetment toe elevation at -0.5ft NAVD88.

4.1.3 Flood Zones and Flood Elevations

For flood elevation determination, the project area was divided into two flood zones with a transition zone in between. As shown in Figure 13, the zones progressing from coastal to inland are named: Zone 1, Transition Zone and Zone 2. Zone 1 is the area subjected to direct wave impacts and its TWL includes stillwater level, wave setup and runup on the structures. Zone 2 is not subjected to direct wave impacts, but will is exposed to flooding due to wave runup on the beach and the Lifeguard Building. A small transition area is provided between the two zones due to the inherent uncertainty associated with flooding hazards.

The calculated site-specific TWLs in Section 4.1.2 includes the impacts of the existing and proposed structures, marked as the flood elevations in Zone 1. Due to the presence of the revetment and the proposed seawall, the wave runup elevation (hence TWL) is higher than that of adjacent beaches with FEMA BFE of 16ft NAVD88. Zone 2 is impacted by wave runup and overtopping on beaches north and south of the Pier View Way Bridge. The flood elevation under No SLR in this zone is conservatively assumed to be the same as the adjacent beach areas per FEMA BFE. Figure 14 and Figure 15 illustrate the flood zones and the associated flood elevations

for both existing and proposed structure conditions. Under 5.3ft SLR, the TWL at Zone 1 of +28.8ft NAVD88 exceeds the bridge soffit of +26.15ft NAVD88. Under such circumstances, the pier deck is exposed to uplift forces by waves.

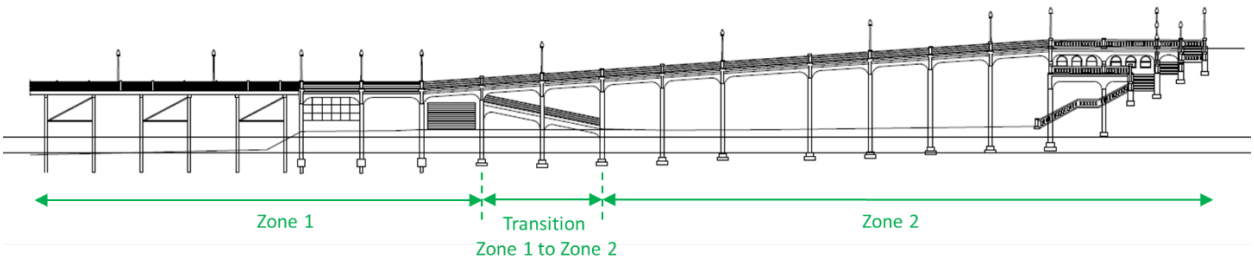


Figure 13: Definition of Flood Zones along Pier View Way Bridge

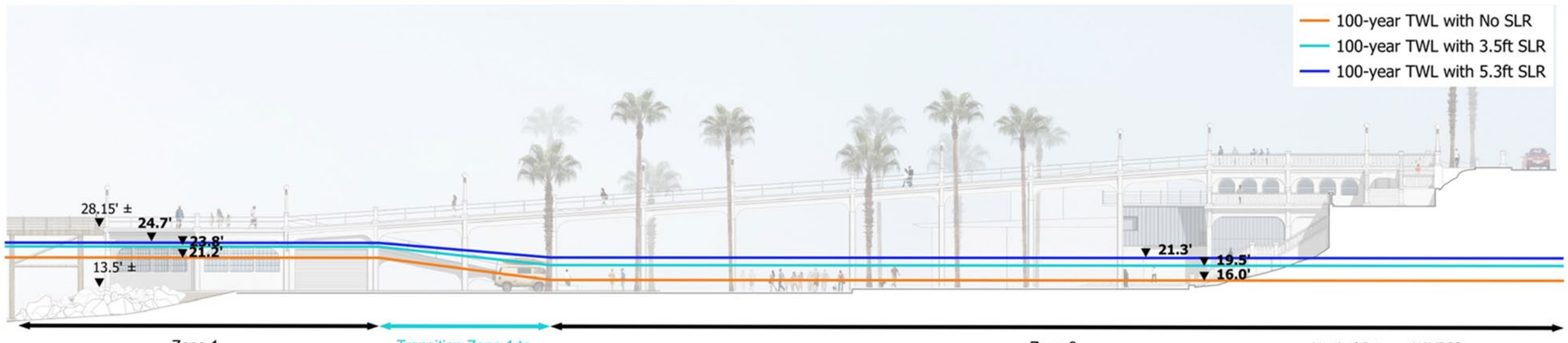
moffatt & nichol

1660 Hotel Circle North, Suite 500
San Diego, CA 92108

(619) 220-6050
www.moffattnichol.com

PIER VIEW WAY BRIDGE & LIFEGUARD HEADQUARTERS

100-Year Storm Condition (Existing Structure)



DEFINITIONS

SLR = Sea Level Rise

NAVD88 = North American Vertical Datum of 1988

TWL = Total Water Level
(Maximum water level anticipated during 100-year storm event
Σ Stillwater + Wave Setup + Wave Runup)

Total Water Level During 100-year Storm Condition

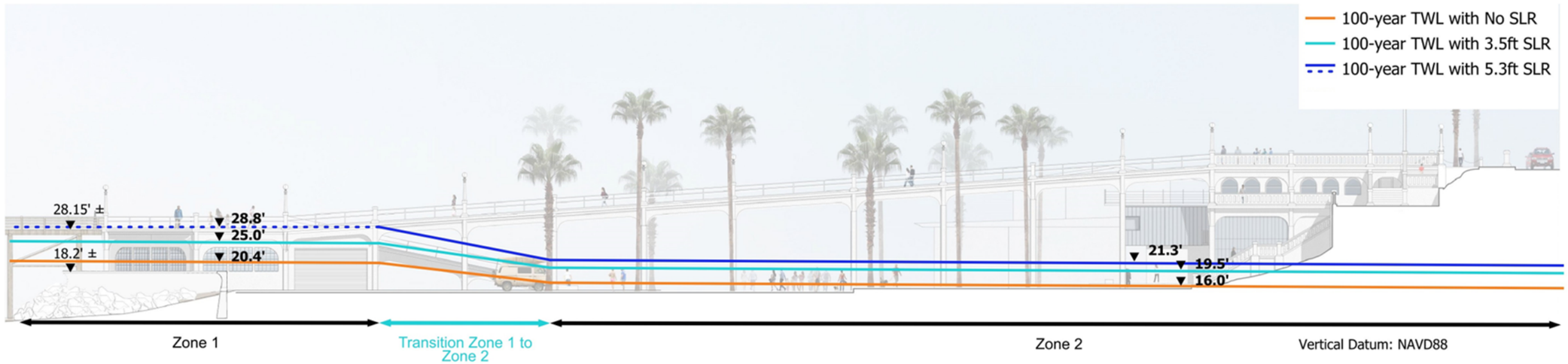
Location	Present Day (0.0ft SLR)	2105 - Intermediate SLR (3.5ft SLR)	2105 - Int-High SLR (5.3ft SLR)
Zone 1	21.2ft	23.8ft	24.7ft
Zone 2	16.0ft	19.5ft	21.3ft

Notes:
1. Sea level rise projections are based on Ocean Protection Council 2024 Sea Level Rise Guidance.
2. Zone 1 – Area surrounding the lifeguard building.
3. Zone 2 – Area landward of the lifeguard building.

Figure 14: Flood Zones and 100-year Flood Elevations – Existing Structure

PIER VIEW WAY BRIDGE & LIFEGUARD HEADQUARTERS

100-Year Storm Condition (Proposed Structure)



DEFINITIONS

SLR = Sea Level Rise

NAVD88 = North American Vertical Datum of 1988

TWL = Total Water Level
(Maximum water level anticipated during 100-year storm event
Σ Stillwater + Wave Setup + Wave Runup)

Total Water Level During 100-year Storm Condition

Location	Present Day (0.0ft SLR)	2105 - Intermediate SLR (3.5ft SLR)	2105 - Int-High SLR (5.3ft SLR)
Zone 1	20.4ft	25.0ft	28.8ft
Zone 2	16.0ft	19.5ft	21.3ft

Notes:
1. Sea level rise projections are based on Ocean Protection Council 2024 Sea Level Rise Guidance.
2. Zone 1 – Area surrounding the lifeguard building. The TWL is higher than the bridge soffit under 5.3ft SLR (shown as blue dash line). Under such circumstances, the pier deck will be exposed to uplift wave forces.
3. Zone 2 – Area landward of the lifeguard building.

Figure 15: Flood Zones and 100-year Flood Elevations – Proposed Structure

moffatt & nichol

1660 Hotel Circle North, Suite 500
San Diego, CA 92108

(619) 220-6050
www.moffattnichol.com

4.2 Currents

The USGS CoSMoS model provides estimates of maximum depth-averaged current velocities along the California coastline under various SLR scenarios and storm conditions. Figure 16 illustrates the maximum predicted velocity magnitudes at the project site under typical (non-storm) conditions with 1.5m SLR. As shown, typical maximum velocities are less than 3.3ft/s (1m/s) except within the wave breaking zone where they reach 3.3 to 6.6ft/s (1 to 2m/s). Table 7 summarizes maximum current velocities extracted near the Oceanside Pier for both existing and design SLR scenarios, comparing typical (non-storm) and 100-year storm conditions. Notably, predicted maximum currents even under typical conditions exceed 2ft/s, indicating a dynamic environment for sediment transport and potential scour risks.

It is important to recognize that CoSMoS does not incorporate any localized structure-induced effects on currents. However, the proposed new Lifeguard Building will be protected by the properly sized revetment within its current revetment footprint to against the wave impact. Also, the proposed project does not change its project footprint, hence, it will not change the current conditions or the long-shore sediment process.

Figure 16: CoSMoS Maximum Current Velocity under 4.9ft (1.5m) SLR at Pier View Way Bridge (No Storm Condition)

Table 7: Maximum Depth-averaged Current Velocity at Oceanside Pier (CoSMoS)

SLR Scenario	Max Current Velocity – Tides, No Storm (ft/s)	Max Current Velocity – 100-year Storm (ft/s)
No SLR	4.5	0.7
+1.0 m SLR	3.0	1.4
+1.5 m SLR	4.0	1.8

4.3 Erosion

As illustrated in the historical beach profile plots in Figure 7, the beachfront near the Pier View Way Bridge experiences seasonal coastal erosion. While seasonal variability and periodic sand nourishment temporarily restore sand levels and beach width, historical aerial photographs offer additional evidence of long-term erosion. Specifically, Figure 17 compares a photograph of the existing revetment in January 2016 and April 2021. A white arrow marks the toe of the revetement in each image. These images reveal that the revetment toe was more exposed, suggesting a larger footprint due to greater winter erosion in 2016 compared to 2021. This observation aligns with the historical profile data, which identified 2016 as having the most significantly eroded beach conditions recorded at the bridge.

For the site-specific runup analysis, the most eroded condition/revetment toe was considered for the proposed design condition (approximately 6ft below the toe surveyed in the 2021 (NV5, 2021)). Despite using this worst-case scenario for analysis, the actual proposed project involves no modifications to the existing toe elevation with the revetment remaining within its existing footprint. Consequently, the proposed project is not expected to alter the alongshore sediment transport within the sediment littoral cell, and there are no expected impacts to coastal erosion and longshore sediment transport.

Figure 17: Comparison of Historical Aerial Images at Revetment – Changes in Exposed Revetment Extent indicate Sand Level Change

4.4 Tsunami

Southern California is exposed to potential tsunami risks, primarily due to distant sources such as the Aleutian Trench. As shown in Figure 18, the Pier View Way Bridge lies within the Tsunami Design Zone per the ASCE 7-22 Tsunami Geodatabase. Furthermore, the ASCE geodatabase specifies the 2475-year tsunami inundation elevation at the Pier View Way Bridge as 25.16ft NAVD88. Separately, the California Geological Survey and the California Governor's Office of Emergency Services (Cal OES) provides stateside tsunami inundation/hazard area maps for San Diego County based on a 1000-year return period event (California Geological Survey, 2019). Figure 19 shows that this tsunami hazard area is consistent with the ASCE 7-22 hazard boundary, with both indicating that the bridge is at risk of tsunami inundation. Based on the ASCE tsunami geodatabase and California Geological Survey maps, the proposed project is within the tsunami inundation hazard zone, but the project is not anticipated to impact the tsunami risk of the adjacent areas.

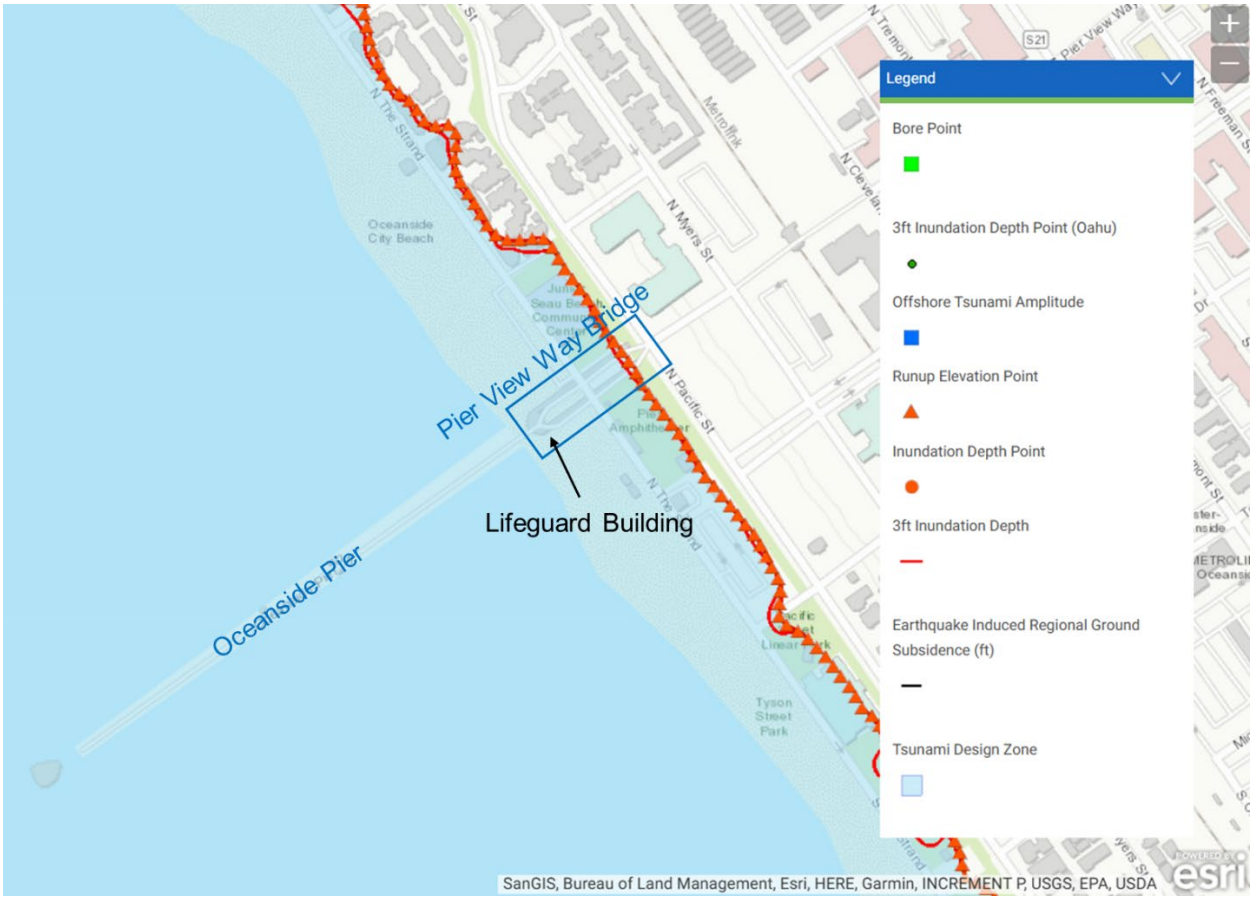


Figure 18: Tsunami Design Zone and Inundation Depth for Existing Structure Under a 2475-year Tsunami Event (ASCE, 2025)

Figure 19: Tsunami Hazard Area Map (California Geological Survey, 2019)

4.5 Groundwater

As illustrated in Figure 20, rising sea levels can push groundwater tables higher in coastal areas, increasing the risk of flooding and saltwater intrusion into freshwater supplies. The USGS CoSMoS-Groundwater model uses the software MODFLOW to simulate changes in the water table and groundwater flow for coastal California under all SLR scenarios examined (Befus, Hoover, Barnard, & Erikson, 2020). The model takes account of the current topography and allows the rising groundwater discharge to the drainage system rather than uniformly rising the groundwater table. Groundwater hazards can be influenced by a number of local factors that may not be captured in regional modeling efforts, so the CoSMoS results are intended to be used as an initial screening tool to identify potential hazard areas.

Figure 21 and Figure 22 show CoSMoS model groundwater table depths at the proposed project site under existing conditions (no SLR) and a 4.9ft (1.5m) SLR scenario, respectively. The CoSMoS model uses surface water level at MHHW as the boundary condition and provides modeling results at 0.8ft (0.25 m) SLR increments. With 1.5m SLR (the CoSMos results most representative of the higher 5.3ft design SLR scenario recommended for this study), the depth to groundwater under the existing topography (the pier structure is likely not included) reduces from 3.3 to 6.6ft (1 to 2m) to less than 3.3ft (1m) at the beachfront and at the landward side shrinks from 6.6 to 16.4ft (2 to 5m) to 3.3 to 6.6ft (1 to 2m). The proposed sidewalk structure

does not lower the elevation, and thus will not result in any negative impacts to the groundwater depth. In addition, no groundwater emergence is anticipated during the pier's service life.

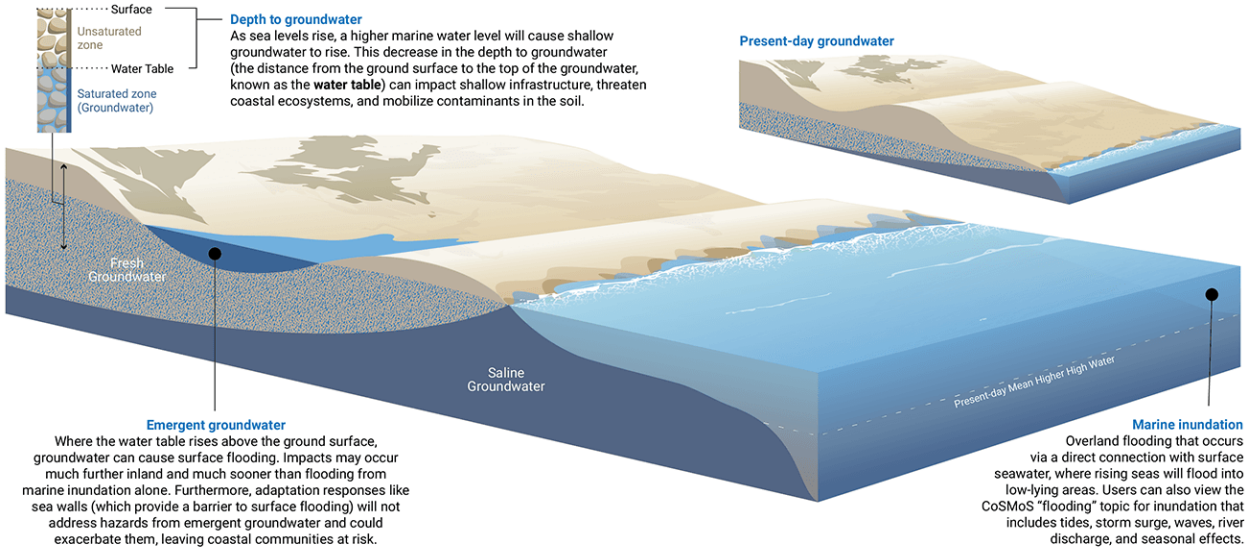


Figure 20: Illustration of Groundwater Level Changes due to SLR (Barnard, 2018)

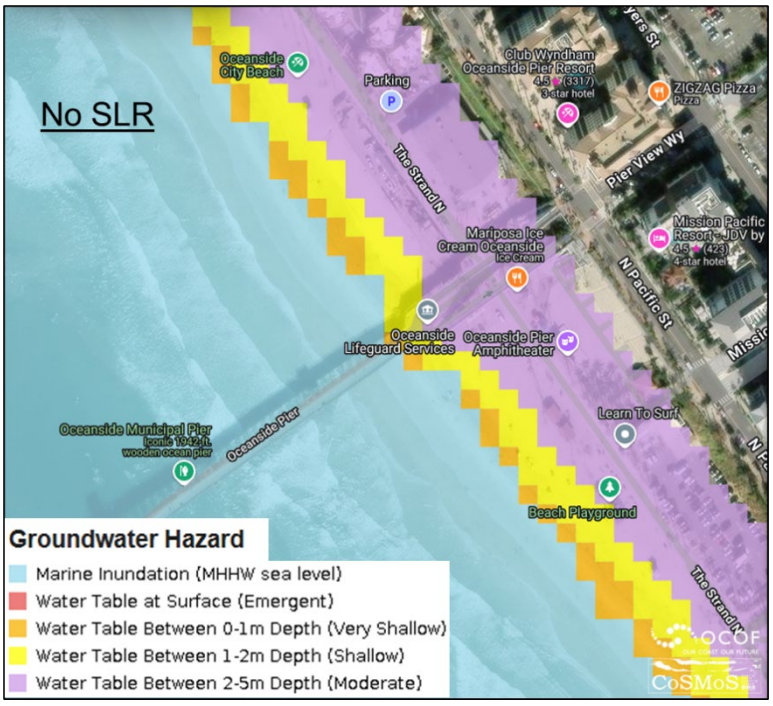


Figure 21: CoSMoS Groundwater Hazard Map under No SLR Condition

Figure 22: CoSMoS Groundwater Hazard Map under 4.9ft (1.5m) SLR Condition

5 Conclusions and Recommendations

This analysis assessed coastal hazards and SLR vulnerability of the proposed Pier View Way Bridge project. The assessment included reviewing available public information on coastal flooding and conducting a site-specific wave runup analysis for both existing and proposed site conditions. The runup analysis incorporated a conservative design scenario representing the most historically eroded beach condition. Potential impacts from other coastal hazards, including currents, erosion, tsunami inundation, and groundwater changes, were also evaluated.

These risks are generally expected to increase with SLR. The proposed project includes a new sidewalk structure in front of the Lifeguard Building but does not alter the existing revetment's footprint or slope. Therefore, it is not expected to change alongshore sediment transport patterns or negatively impact the adjacent areas. However, under future SLR conditions, higher water levels will allow waves to break closer to the shore, potentially increasing wave runup on the Lifeguard Building wall. The proposed sidewalk will provide some near-term protection but will only offer limited effectiveness in reducing wave runup during extreme wave events with future SLR since its size is small relative to the wavelengths.

Coastal hazard

Analysis confirmed that the existing Pier View Way Bridge, Lifeguard Building, and revetment are exposed to risks from coastal flooding, erosion, and tsunamis. Key findings on coastal hazards at the site are summarized below for existing and proposed conditions.

- Coastal Flooding:
    - The site-specific runup analysis on both existing and proposed structures indicates that the site is susceptible to coastal flooding under both conditions. Table 8 compares the 100-year TWL between the existing and the proposed with sidewalk conditions under three sea level scenarios. With SLR, the vulnerability to flood risk at the existing structure increases. However, these TWLs don't reach the pier soffit. With the proposed structure, the current sea

level results in a lower flood elevation compared to the existing site; however, the risks of coastal flooding increase under SLR.

Table 8: 100-year TWLs (in ft NAVD88) at Lifeguard Building

Sea Level Rise	Existing Condition[1]	Proposed Condition[1]
Present (No SLR)	21.2	20.4
+3.5ft	23.8	25.0
+5.3ft	24.7	28.8

Note: [1] For comparison purposes, the same revetment toe elevation and beach slope were applied in the analysis. See the analysis profiles for the existing and proposed condition in Figure 9 and Figure 10, respectively.

  - Eroded beach profile condition based on the Spring 2016 profile, representing the most eroded beach condition, was analyzed for the proposed structure to meet design needs. The 'proposed design condition' has a TWL of 22.6ft NAVD88 for current sea level; and 26.1ft and 29.2ft NAVD88 for 3.5ft and 5.3ft SLR, respectively. The TWLs for design are higher due to eroded beach conditions, allowing waves to break closer to the structure and exposing a lower revetment toe.
- Coastal Erosion: Historical beach profile data demonstrate seasonal coastal erosion at the site, although the changes are dynamic rather than continuous. The predicted maximum currents from USGS CoSMoS also indicated potential for erosion.
- Tsunami: The site is located within the tsunami hazard zone, exposed to risks of tsunami inundation and runup.
- Groundwater: Groundwater emergence is not expected, but rising groundwater level with SLR presents a potential hazard to underground utilities if present, and reduces the strength of the supporting structure.

Impact Assessment

The proposed project includes a new sidewalk structure in front of the Lifeguard Building but does not alter the existing revetment's footprint or slope. Therefore, it is not expected to change alongshore sediment transport patterns or negatively impact the adjacent areas. Key findings on impact assessment due to the proposed project include:

- No impacts to erosion, longshore transport, tsunami inundation, or groundwater are expected due to the proposed project.
- No impacts to surrounding areas are expected, as the proposed modifications to the structure are confined to the top of the revetment, with no alterations to the overall revetment footprint or structure footprint.

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