APPENDIX H

SEA LEVEL RISE ANALYSIS

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Irvine, California 92618
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Memorandum

January 7, 2021

To: Anthony Wrzosek, R.D. Olson Development

From: Alyssa Cannon, Anchor QEA, LLC

cc: Josh Burnam, MPH, D.Env. and Adam Gale, Anchor QEA, LLC

Re: Dana Point Harbor Hotels Development Coastal Hazards

As directed by R.D. Olson Development, in lieu of developing a new coastal hazards analysis for the hotel component of the Dana Point Harbor Revitalization Plan, Anchor QEA, LLC, has prepared this memorandum to address additional comments provided by the City of Dana Point specific to the hotel development. The August 2019 Dana Point Harbor coastal hazards analysis, prepared for that separate revitalization project, is also included as Attachment 1.

This technical memorandum presents the analysis and results of the additional coastal hazards evaluation that was conducted for the proposed development at the hotel Site, including the following:

- Summary of the August 2019 Dana Point Harbor Coastal Hazards Analysis
- Coastal Storm Modeling System (CoSMoS) wave data
- Summary of project coastal hazards

Based on initial concepts for the hotel development (dated October 21, 2020), the proposed finished floor elevation of the development is +15 feet North American Vertical Datum of 1988 (NAVD88) for Surf Lodge, and +12.5 feet NAVD88 for the lowest occupied level at Dana House.

For the purposes of this evaluation, a design life of 75 years for the development has been assumed.

Summary of August 2019 Dana Point Harbor Coastal Hazards Analysis

This section summarizes the data and results of the August 2019 Dana Point Harbor Coastal Hazards analysis, as relevant to the proposed hotel development.

Tidal Levels

Tidal datums for the area (Table 1) were sourced from the National Oceanic and Atmospheric Administration (NOAA) Tides and Currents database, tidal station 9410660: Los Angeles, California (NOAA 2019a).

Table 1
Tidal Datums: Los Angeles NOAA Station No. 9410660

Tidal Datum	Elevation Relative to MLLW at Gage Location (feet)	Elevations Relative to NAVD88 (feet)
HAT	7.3	7.1
MHHW	5.5	5.3
Mean High Water	4.8	4.6
MSL	2.8	2.6
Mean Low Water	0.9	0.7
NAVD88	0.2	0.0
MLLW	0.0	-0.2
LAT	-2.0	-2.2

Notes:
HAT: highest astronomical tide
LAT: lowest astronomical tide
MHHW: mean higher high water
MLLW: mean lower low water
MSL: mean sea level

Sea Level Rise and Coastal Flooding

Sea level rise (SLR) estimates for the Site were taken from the California Coastal Commission's *Sea Level Rise Policy Guidance* (CCC 2018) for Los Angeles (the closest station). For the Site, California Coastal Commission guidance recommends the medium-high risk aversion (a 0.5% probability SLR exceeds) based on the project type. The medium-high risk aversion scenario should be used for projects with greater consequences and/or a lower ability to adapt, such as residential and commercial structures. The time frame used to evaluate impacts to the Site due to predicted SLR is based on the design life of the proposed structures (CCC 2018). As stated previously, the design life of the development is expected to be approximately 75 years. Therefore, a medium-high risk aversion SLR estimate for 2100 should be used for design, which is based on a 0.5 % probability SLR will exceed +6.7 feet. The projected tidal elevations at the Site based on the projected SLR estimate for 2100 are summarized in Table 2.

Table 2
Potential 2100 Tidal Levels at the Site

Tidal Level	Current Conditions[1]	2100 Conditions[2]
HAT	7.1	13.8
MHHW	5.3	12.0
MSL	2.6	9.3
NAVD88	0.0	6.7
MLLW	-0.2	6.5

Notes:
All elevations are in feet, relative to NAVD88.
1. Existing tidal datums are provided in Table 1.
2. 2100 conditions are based on medium-high risk aversion (+6.7 feet).

In addition to SLR, existing and future storms can result in coastal flooding. The Federal Emergency Management Agency's (FEMA's) Flood Insurance Study for Orange County (FEMA 2019) divides Dana Point Harbor into various zones. Just within the breakwaters, the 100-year runup elevation is +17 feet NAVD88 and drops to +8 feet NAVD88 within the marina.

Wind Data

Minimal wind data were available for the local area; therefore, wave data were used to more accurately represent storm conditions.

Wave Data and Offshore Storm Waves

Wave data were collected from NOAA's National Data Buoy Center (NOAA 2019b) for two buoys: San Pedro South, California, Station 46253 (approximately 29 miles west-northwest of the Site) and San Pedro, California, Station 46222 (approximately 37 miles west-northwest of the Site). The farther afield station (46222) is a longer established station and was used for an extreme offshore wave analysis, as the closer station had insufficient data for an extreme analysis. The results of the extreme value analysis are shown in Table 3. These values represent offshore, deep-water waves and do not necessarily reflect heights at the Site as waves will reduce based on depths and shoreline geometry, resulting in wave shoaling, refraction, diffraction, and reflection.

Table 3
Extreme Deep-Water Wave Heights

2-Year	5-Year	10-Year	25-Year	50-Year	75-Year	100-Year
12.9 feet	14.8 feet	16.0 feet	17.5 feet	18.6 feet	19.1 feet	19.6 feet

Note:
Wave data are dated September 8, 2004, to December 31, 2018 (National Data Buoy Center Station 46222).

Data Summary

The expected lifetime of the development is 75 years; therefore, the costal hazards are based on a similar return period. Specific coastal hazards for this project are summarized in Table 4. As the finished floor elevation for Surf Lodge is to be +15 feet NAVD88, neither existing nor future flood elevations are expected to impact that part of the development. However, the lowest occupied level of Dana House is to have a finished floor elevation of +12.5 feet NAVD88 and will therefore have potential future flooding due to SLR. The 2100 Highest Astronomical Tide estimate of +13.8 feet NAVD88 is based on a 0.5% probability SLR will exceed +6.7 feet by 2100.

Table 4
Summary of Existing Coastal Hazards

Coastal Hazard	Existing (2020) Conditions	Future (2100) Conditions
MSL	+2.6 feet NAVD88	+9.3 feet NAVD88
MHHW	+5.3 feet NAVD88	+12.0 feet NAVD88
HAT	+7.1 feet NAVD88	+13.8 feet NAVD88
FEMA 100-year runup elevation	+8 feet NAVD88	+14.7 feet NAVD88
75-year significant deep-water wave height[1]	19.1 feet	19.1 feet

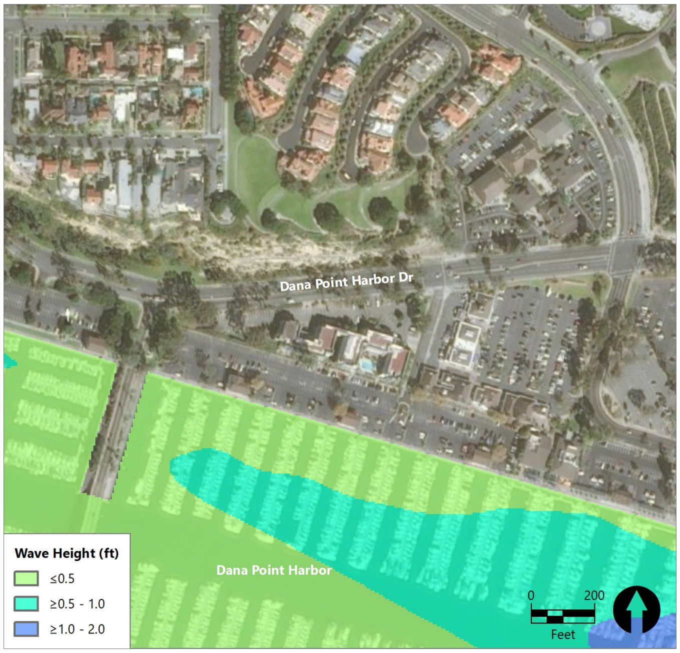
Note:
1. Deep-water wave height is based on offshore buoy data and does not represent nearshore wave heights.

CoSMoS Wave Data

The U.S. Geological Survey CoSMoS (Barnard et al. 2018) was used to further evaluate potential local flooding and wave impacts at the Site. CoSMoS makes detailed predictions over large geographic scales of storm-induced coastal flooding and erosion for both current and future SLR scenarios. As Dana Point Harbor has a hard shoreline (i.e., seawall), there are no estimates for shoreline erosion at the Site. However, there are flood depth and wave height estimates for Dana Point Harbor (see Figures 1 through 6). Conditions for both the 20-year and 100-year wave events are summarized as follows:

- With no SLR, wave heights can reach approximately 1 foot within the marina (Figures 1 and 2).
- No flooding is expected without SLR.
- With 6.6 feet of SLR, wave heights can reach approximately 2 feet within the marina (Figures 3 and 4).
- Flooding is expected for existing conditions, as depths are predominately between 2 and 3 feet; however, flood depths could exceed 3 feet in areas near the seawall, based on LiDAR data used by CoSMoS for the area.

Figure 1
20-Year Wave Heights, No Sea Level Rise



Note:
ft: feet

Figure 2
100-Year Wave Heights, No Sea Level Rise

Figure 3
20-Year Wave Heights, 6.6 Feet Sea Level Rise

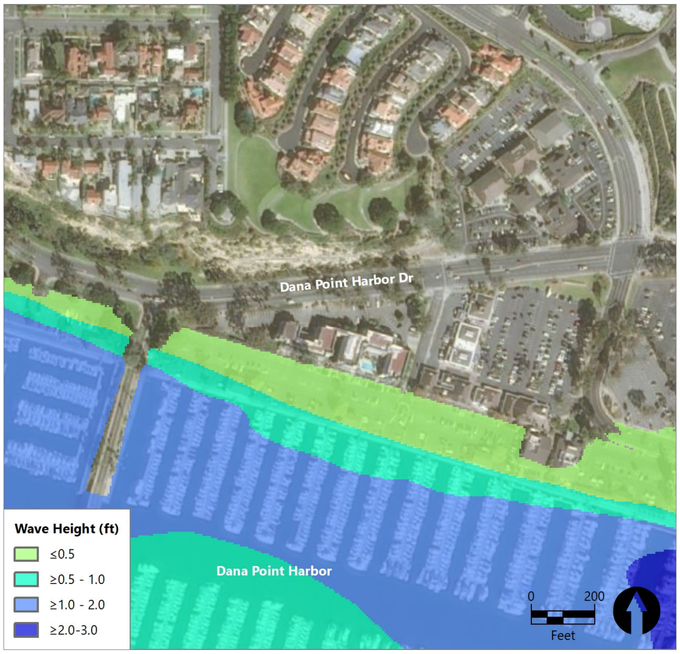


Figure 4
100-Year Wave Heights, 6.6 Feet Sea Level Rise

Figure 5
Flood Depths for 20-Year Waves, 6.6 Feet Sea Level Rise

Figure 6
Flood Depths for 100-Year Waves, 6.6 Feet Sea Level Rise

Summary of Project Coastal Hazards

A comprehensive table of coastal hazards is included in Table 5. For the Surf Lodge, the lowest proposed finished floor elevation is +15 feet NAVD88; as all current and future tidal levels, as well as the FEMA 100-year wave runup elevations, are below the proposed finished floor elevation, inundation of the Surf Lodge is not expected. However, the lowest occupied floor elevation for Dana House is +12.5 feet NAVD88; therefore, future SLR tidal elevations and storm flooding could inundate the area, based on a 0.5 % probability SLR will exceed +6.7 feet. To prevent potential future inundation, based on FEMA 100-year runup elevations and estimated 2100 SLR, the finished floor elevation should be above +14.7 feet NAVD88.

Table 5
Coastal Hazards Summary Table

Coastal Hazard	Existing (2020) Conditions	Future (2100) Conditions[2]
MST	+2.6 feet NAVD88	+9.3 feet NAVD88
MHHW	+5.3 feet NAVD88	+12.0 feet NAVD88
HAT	+7.1 feet NAVD88	+13.8 feet NAVD88
FEMA 100-year runup elevation	+8 feet NAVD88	+14.7 feet NAVD88
75-year significant deep-water wave height[1]	19.1 feet	19.1 feet
CoSMoS 20-year marina wave height	1 foot	2 feet
CoSMoS 100-year marina wave height	1 foot	2 feet

Note:
1. Deep-water wave height is based on offshore buoy data and does not represent nearshore wave heights.
2. A medium-high risk aversion SLR was used for the Future (2100) Conditions, which is based on a 0.5 % probability SLR will exceed +6.7 feet.

References

Barnard, P.L., L.H. Erikson, A.C. Foxgrover, P.W. Limber, A.C. O'Neill, and S. Vitousek, 2018. Coastal Storm Modeling System (CoSMoS) for Southern California, v3.0, Phase 2 (ver. 1g, May 2018): U.S. Geological Survey data release. Available at: https://doi.org/10.5066/F7T151Q4.

CCC (California Coastal Commission), 2018. *Sea Level Rise Policy Guidance. Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits*. Science Update unanimously adopted November 7, 2018.

FEMA (Federal Emergency Management Agency), 2019. *FEMA Flood Insurance Study: Orange County, California and Incorporated Areas.* Flood Insurance Study Number: 06059CV001C. Version Number 2.3.3.1. Revised March 21, 2019.

NOAA (National Oceanic and Atmospheric Administration), 2019a. NOAA Tides and Currents Database. Station ID 9410660. Accessed March 14, 2019. Available at: https://tidesandcurrents.noaa.gov/stationhome.html?id=9410660.

NOAA, 2019b. NOAA National Data Buoy Center. Available at: http://www.ndbc.noaa.gov.

Attachment 1
August 2019 Dana Point Harbor Coastal Hazards Analysis

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ANCHOR QEA

Memorandum

August 12, 2019

To: Joe Ueberroth, Dana Point Harbor Partners, LLC and Dana Point Harbor Partners Drystack, LLC

From: Alyssa Cannon and Adam Gale, Anchor QEA, LLC

cc: Randy Mason, PE, Anchor QEA, LLC

Re: Dana Point Harbor Revitalization – Coastal Hazards and Sea Level Rise Assessment

Anchor QEA, LLC, has completed a coastal hazards analysis for the Dana Point Marina to assist in the California Coastal Commission (CCC) permitting process. The proposed project includes reconfiguration, repair, and modernization throughout Dana Point Harbor with the following elements:

- Marina replacement and reconfiguration (Inner Basin and Outer Basin)
- Marina Drystack Area reconfiguration
- Seawall and revetment repair
- Upland boater service improvements such as replacing existing structures

The applicant has requested a coastal hazards and sea level rise (SLR) analysis/memorandum to aid in understanding potential long-term risks associated with the project and various environmental conditions, predictions, and impacts.

This technical memorandum presents the analysis and results of the coastal hazards evaluation that was conducted for the proposed development, including the following:

- Description of Dana Point Marina (Site) and coastal setting
- Identification of current coastal hazards at the Site, including high tides, storm waves, and wave overtopping
- Identification of potential future coastal hazards at the Site based on local predicted SLR estimates
- Discussion of minimization of impacts from both existing and future (potential) coastal hazards
- Potential future adaptative measures

A project lifetime of 75 years for the coastal structures is expected and was used for the coastal hazards analysis.

Site Description and Coastal Setting

Dana Point Marina is located in Dana Point, California, in southern Orange County (Figure 1). The marina is protected from northerly waves by a natural shoreline headland to the northwest. Two large permeable breakwaters, one along the west/southwest and one along the eastern sides of the marina, protect the Site from westerly and southerly waves. While the outer breakwaters are semi-permeable, allowing some waves into the marina, the inner island (with parks and parking) adds a second layer of defense against waves for the Inner Basin.

A 75-year lifetime is assumed for the boat launch facility and for the other upland building pad elevations. See Attachments 1, 7, and 9 for design drawings. The boater service buildings, spaced around the marina, will have finished floor elevations ranging between 10.6 and 12.5 feet North American Vertical Datum of 1988 (NAVD88; 10.8 to 12.7 feet MLLW), and the boat launch and storage facilities will have a finished floor elevation of 10.6 feet NAVD88 (10.8 feet MLLW).

Figure 1
Vicinity Map

Tidal Information (Water Levels)

Tidal datums for the area (Table 1) were sourced from the National Oceanic and Atmospheric Administration (NOAA) Tides and Currents database, tidal station 9410660: Los Angeles, California (NOAA Tides and Currents 2019); see Figure 1 for the location.

Table 1
Tidal Datums: Los Angeles NOAA Station No. 9410660

Tidal Datum	Elevation Relative to MLLW at Gage Location (feet)[1]	Elevations Relative to NAVD88 (feet)[2]
HAT[1]	7.3	7.1
MHHW	5.5	5.3
Mean High Water	4.8	4.6
MSL	2.8	2.6
Mean Low Water	0.9	0.7
NAVD88[1]	0.2	0.0
MLLW	0.0	-0.2
LAT	-2.0	-2.2

Notes:
1. HAT and NAVD88 are based on the Santa Barbara Control Station No. 9411340.
2. Elevations relative to MLLW are based on the current (1983 to 2001) tidal epoch.
HAT: highest astronomical tide
LAT: lowest astronomical tide
MHHW: mean higher high water
MLLW: mean lower low water
MSL: mean sea level

Wind

Minimal wind data are available for the local area. The Dana Point station (U.S. Air Force 722859) has wind data from 1984 to 1996, taken irregularly only a few times a day; see Figure 1 for the location. Based on this minimal data, the storm return period is outlined in Table 2, but it is likely not fully representative of current storm conditions. Therefore, wave data were used to more accurately represent storm conditions.

Table 2
Storm Return Period Wind Speeds

2-Year	5-Year	10-Year	25-Year	50-Year	75-Year	100-Year
24 mph	27 mph	30 mph	32 mph	34 mph	35 mph	36 mph

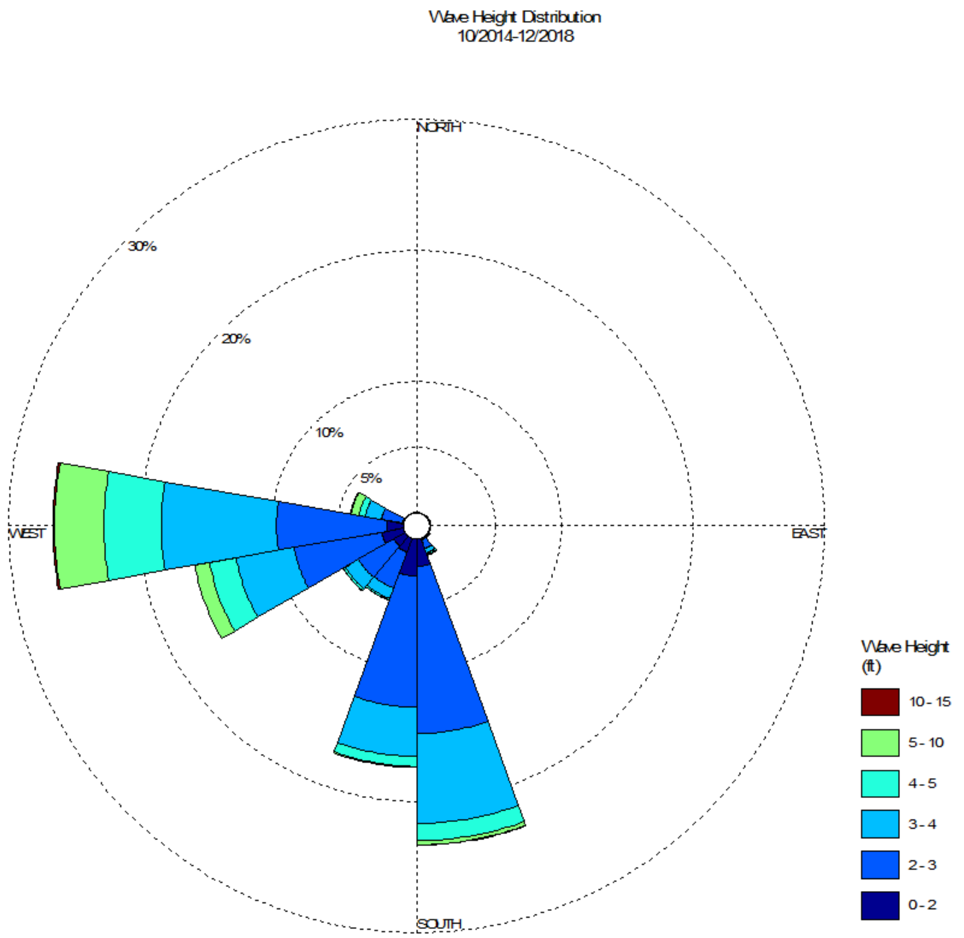
Notes:
Wind data dated 1984 to 1996, Dana Point, California (U.S. Air Force 722859)
Wind speeds are 2-minute averages
mph: miles per hour

Wave

Wave data were collected from NOAA's National Data Buoy Center for the closest wave buoy, San Pedro South, California Buoy, Station 46253 from 2014 through 2018 (NOAA NDBC 2019). The buoy is located approximately 29 miles west-northwest of the Site in the San Pedro Channel. The wave rose in Figure 2 depicts the distribution of waves by height and direction. While the buoy is far from the Site, it is expected that the wave rose is representative of directional distribution based on similar positioning, with an open southerly fetch and some protection from westerly waves from Santa Catalina Island (see Figure 1).

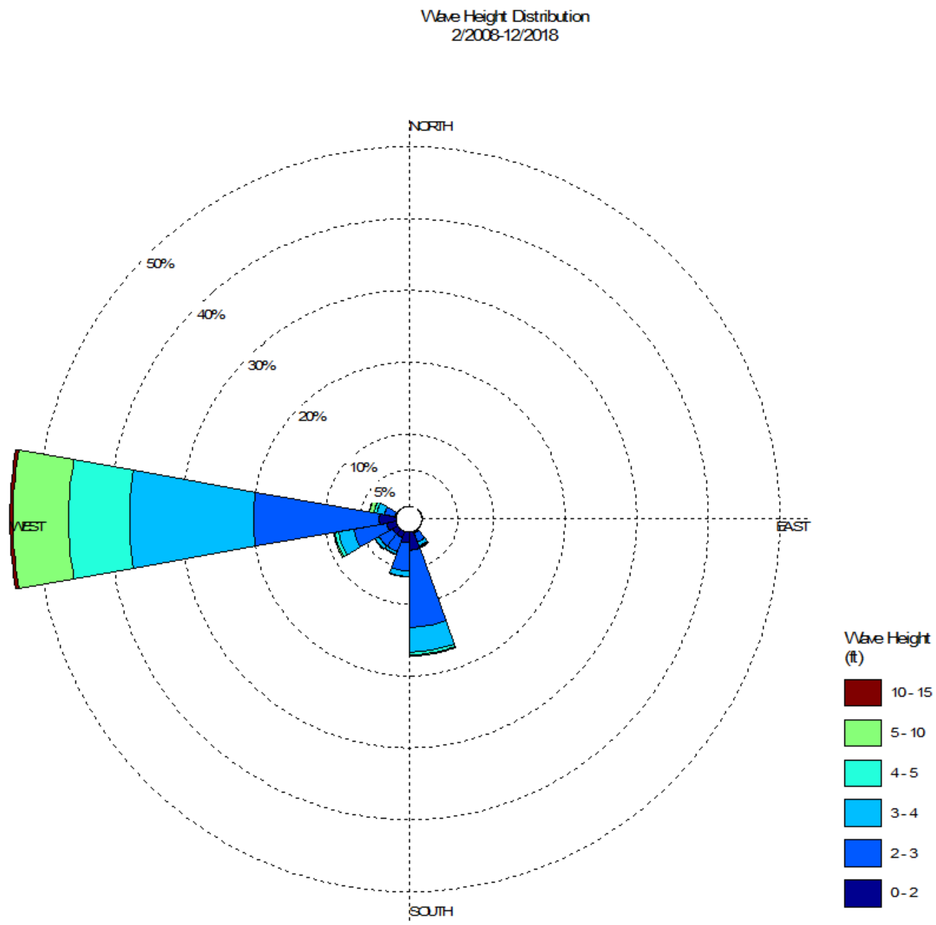
Additionally, wave buoy data from farther afield with a longer record was evaluated as well (the San Pedro, California, Station 46222 from 2004 to 2018 [NOAA NDBC 2019]). The buoy is located approximately 37 miles west-northwest of the Site in the San Pedro Channel (see Figure 1). The wave rose in Figure 3 depicts the distribution of waves by height and direction. This longer-established station has more exposure to waves from the west from the open Pacific Ocean and is more protected from southerly waves by Santa Catalina Island. However, both stations have wave heights of similar magnitude.

Figure 2
Wave Height Distribution: Buoy Station 46253



Wave data from October 20, 2014 to December 31, 2018.

Figure 3
Wave Height Distribution: Buoy Station 46222



Wave data from February 7, 2008 to December 31, 2018.

Existing Coastal Hazards

Existing coastal hazards that can impact the Site include extreme astronomical tides, storm waves, and storm surge (due to wind and wave set up during storms).

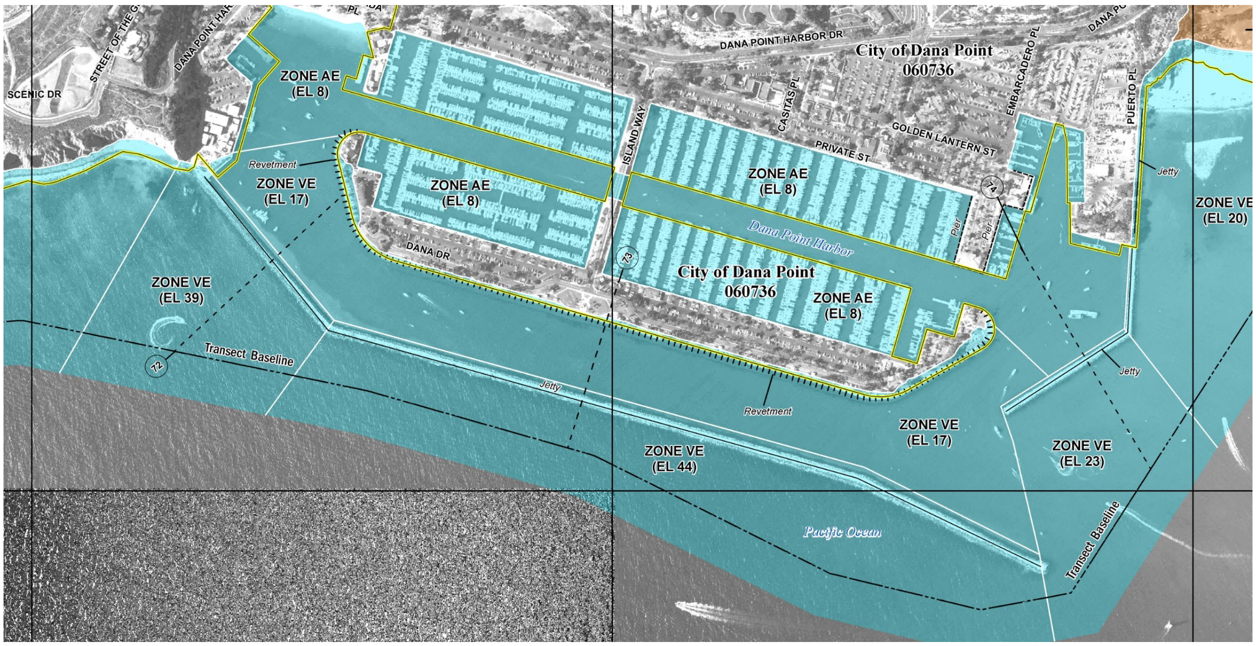
Extreme Tidal Levels

Highest astronomical tide (HAT) at the Los Angeles station is 7.3 feet above mean lower low water (MLLW) (NOAA Tides and Currents 2019; 7.1 feet above NAVD88), which is almost 2 feet above MHHW. The HAT elevation is 3.5 feet below the lowest finished floor elevation (10.8 feet MLLW; 10.6 feet NAVD88).

FEMA Coastal Flooding

FEMA's Flood Insurance Study for Orange County (FEMA 2019) divides the Dana Point Harbor into various zones (see Figure 4). Just outside the breakwaters, the 100-year coastal wave runup elevation is 43.8 feet NAVD88 (44 feet MLLW; FEMA 2019, Table 26). However, within the breakwaters, the 100-year runup elevation drops to 17 feet NAVD88 and down to 8 feet NAVD88 within the marina.

Figure 4
FEMA Flood Insurance Rate Map



FEMA Flood Insurance Rate Map, Orange County, California; panel 504 of 539

Waves and Currents

Offshore Extreme Waves

Wave data from Station 46222[1] (Figure 3) was used to estimate extreme wave heights for return periods of 2, 5, 10, 25, 50, and 100 years. The results of the extreme value analysis are shown in Table 3. These values represent offshore, deep-water waves and do not necessarily reflect heights at the Site, as waves will reduce based on depths and shoreline geometry resulting in wave shoaling, refraction, diffraction, and reflection.

[1] Station 46253, while closer to the Site, was not used, as there are insufficient data for an extreme analysis.

Table 3
Extreme Deep-Water Wave Heights

2-Year	5-Year	10-Year	25-Year	50-Year	75-Year	100-Year
12.9 feet	14.8 feet	16.0 feet	17.5 feet	18.6 feet	19.1 feet	19.6 feet

Note:
Wave data dated September 8, 2004, to December 31, 2018 (National Data Buoy Center Station 46222)

Marina Waves, Wind Setup, and Currents

"Modeling Study of Dana Point Harbor, California: littoral sediment transport around a semi-permeable breakwater" (Li et al. 2015) presents wave and current transmission through the western breakwater. A significant wave height of 0.6 to 0.7 meter (2 to 2.3 feet) outside of the breakwater can equate to a 0.05- to 0.07-meter (0.16- to 0.23-foot) wave on the harbor side. However, the marinas are more protected from waves by the inner island housing, parking, and parks (see Figure 1).

Wind setup within the marina was estimated using the procedure outlined in *Estuary and Coastline Hydrodynamics* (Ippen 1966) and resulted in setup of less than 0.1 foot for the 100-year return period.

Currents inside the harbor are mainly wind- and tide-driven with small magnitudes of less than 4 centimeters per second (cm/s), compared to outside the harbor, where currents can be greater than 10 cm/s regularly and greater than 50 cm/s under storm conditions (Li et al. 2015).

As waves within the marinas are likely to be locally generated wind-driven waves (or wakes[2]), a fetch limited wave analysis was conducted assuming the largest potential fetches of the marina. Table 4 shows the potential wave heights using the 35-mph 75-year wind potential (Table 2).

Table 4
Potential in Marina Wind-Waves

Location	Fetch	Depth	Wave
East Marina	0.5 mile	11 feet	1.0 foot; 1.6 seconds
West Marina	0.4 mile	11 feet	0.9 foot; 1.5 seconds
Boat Launch	0.4 mile	15 feet	0.9 foot; 1.5 seconds

Note:
All scenarios assume a 75-year wind speed of 35 mph (Table 2).

Outer Basin Waves

In extreme storm conditions, the eastern breakwater can be overtopped, resulting in waves in the Outer Basin that could affect the proposed marina floats in that area. The eastern breakwater has a

[2] Not reviewed in this analysis, as vessels should be operating under no wake conditions

crest elevation of approximately +14 feet MLLW. A depth of approximately 30 feet outside of the breakwater could potentially allow a 75-year deep-water wave of more than 19 feet to reach the breakwater and cause overtopping, resulting in waves in the Outer Basin.

Everest International Consultants, Inc. (Everest), prepared a Wave Uprush Analysis for the Harbor Revitalization effort, concluding that the 100-year return period wave conditions at the Outer Basin have a significant wave height of 2.1 to 2.3 feet and a peak period of 15.5 seconds (Everest 2014).

Overtopping

Overtopping was estimated using the *Manual on Wave Overtopping of Sea Defences and Related Structures* (EurOtop2018).

While the marina seawalls will be repaired where needed, they will not be extended. The seawalls currently have a top elevation of +10 feet MLLW. Given the highest astronomical tide of +7.3 feet MLLW, and a potential in-marina wind-wave of 1 foot, no overtopping is expected.

The potential Outer Basin 100-year wave of 2.3 feet results in approximately 6 liters per second per linear meter (l/s/m) of overtopping, which has the potential to cause damage to seawalls if the crest is not protected (USACE 2008, Table VI-5-6).

Summary

The expected lifetime of the coastal structures is 75 years. Therefore, the existing coastal hazards are based on a similar return period. The specific coastal hazards for this project are summarized in Table 5.

Table 5
Summary of Existing Coastal Hazards

Existing Coastal Hazard	Value
MSL	+2.8 feet MLLW
MHHW	+5.5 feet MLLW
HAT	+7.3 feet MLLW
75-year significant deep-water wave height[1]	19.1 feet
75-year significant marina wave height[2]	1 foot
75-year marina wave on HAT	+7.8 feet MLLW
HAT marina overtopping	None

Notes:
1. Based on wave buoy data analysis (Table 3)
2. Based on fetch limited wave data (Table 4)

As Table 5 shows, tidal events and a 75-year wave event will not impact the uplands, as the seawall crest is at an elevation of +10 feet MLLW and finished floor elevations range from 10.6 to 12.5 feet NAVD88 (10.8 to 12.7 feet MLLW) behind the protective seawall.

Additionally, a 100-year significant wave height of 2.3 feet (75-year not included in referenced material; Everest 2014) can be expected within the Outer Basin, resulting in a 100-year Outer Basin wave elevation on the HAT of +8.5 feet MLLW. This elevation is below the boating service facilities, drystack, and seawall; however, as the Overtopping section outlines, it can result in overtopping of approximately 6 l/s/m, which has the potential to cause damage to seawalls if the crest is not protected.

Future Coastal Hazards

Future coastal hazards that may impact the Site include the current coastal hazards identified above, with the addition of increased water levels due to predicted SLR. SLR estimates for the Site were taken from CCC's *Sea Level Rise Policy Guidance* (CCC 2018) for Los Angeles (the closest station). The various ranges of SLR estimates are outlined in Table 6.

Uncertainties exist in estimates for SLR due to numerous issues related to understanding the physics and assumptions associated with predictive modeling (NRC 2012). These uncertainties increase as the projection period increases, with large uncertainties in predictions of SLR at 2100 and beyond.

For the Site, CCC guidance recommends the medium-high risk aversion (a 0.5% probability SLR exceeds) based on the project type. The medium-high risk aversion scenario should be used for projects with greater consequences and/or a lower ability to adapt, such as residential and commercial structures. The time frame used to evaluate impacts to the Site due to predicted SLR is based on the design life of the proposed structures (CCC 2018). As discussed above, the design life of the coastal facilities is expected to be approximately 75 years. Therefore, a medium-high risk aversion SLR estimate for 2100 should be used for design: +6.7 feet.

Table 6
Projected Sea Level Rise (feet) for Los Angeles

Year	Low Risk Aversion	Medium-High Risk Aversion	Extreme Risk Aversion
2030	0.5	0.7	1.0
2040	0.7	1.2	1.7
2050	1.0	1.8	2.6
2060	1.3	2.5	3.7
2070	1.7	3.3	5.0
2080	2.2	4.3	6.4
2090	2.7	5.3	8.0
2100	3.2	**6.7**	9.9
2110*	3.3	7.1	11.5
2120*	3.8	8.3	13.8
2130*	4.3	9.7	16.1

Notes:
* Most climate model experiments do not extend beyond 2100. Use of projects beyond 2100 should be done with caution and acknowledgement of increased uncertainty around these projects (CCC 2018).

Low Risk Aversion: Upper limit of "likely range" (approximately 17% probability SLR exceeds)
Medium-High Risk Aversion: 1-in-200 chance (0.5% probability SLR exceeds)
Extreme Risk Aversion: Single scenario (no associated probability)

The projected tidal elevations at the Site based on the projected SLR estimates for 2100 are summarized in Table 7. For comparison, the range of projected tidal elevations based on the low risk aversion and extreme risk aversion SLR estimates are also provided.

Table 7
Potential 2100 Tidal Levels at the Site[1]

Tidal Level	Current Conditions[2]	Low Risk Aversion	Medium-High Risk Aversion	Extreme Risk Aversion
HAT	7.3	10.5	14.0	17.2
MHHW	5.5	8.7	12.2	15.4
MSL	2.8	6.0	9.5	12.7
NAVD88	0.2	3.4	6.9	10.1
MLLW	0.0	3.2	6.7	9.9

Notes:
1. All elevations are in feet, relative to the current tidal epoch (1983 to 2001) MLLW elevation.
2. Existing tidal datums are provided in Table 1.

Future coastal hazards for the Site combine current coastal hazards due to storm events and increases in water level due to projected SLR. The deep-water wave heights are considered to be the same for existing and future conditions. As shown in Table 7, inundation, even at low risk aversion, is possible, and for medium-high risk aversion inundation could occur above mean sea level.

Table 8 outlines the predicted future coastal hazards for the Site.

Table 8
Summary of Future Coastal Hazards

Future Coastal Hazard	Value[1]
2100 MSL	9.5 feet MLLW
2100 MHHW	12.2 feet MLLW
2100 HAT	14.0 feet MLLW
75-year significant deep-water wave height[1]	19.1 feet
75-year significant marina wave height[2]	1 foot
75-year marina wave on 2100 HAT	14.5 feet MLLW
2100 HAT marina overtopping	Inundated

Notes:
1. All elevations are in feet, relative to the current tidal epoch (1983 to 2001) MLLW elevation
2. Based on wave buoy data analysis (Table 3)

As Table 8 shows, with the addition of SLR, the current +10 feet MLLW seawall crest elevation will be inundated by 2100 MHHW (12.2 feet MLLW; 12 feet NAVD88). With storm waves (75-year of 1 foot and 100-year of 2.3 feet) on top of the higher water levels with SLR (reaching elevations of 14.5 to 15.2 feet MLLW [14.3 to 15 feet NAVD88] on HAT), the potential wave damage to the buildings is increased.

Because inundation beyond the seawall is predicted with the 2100 SLR (and as early as 2070), future adaptive measures must be considered (see the Future Adaptive Measures section).

Comparison to Previous Studies

As mentioned in the Outer Basin Waves section, previous studies have been conducted for the area. Table 9 compares the updated analysis to the 2014 *Coastal Engineering Support Services – Wave Uprush Analysis* prepared by Everest. The 2014 study references 100-year wave heights versus the 75-year wave heights used in the updated study.

Table 9
Comparison of Coastal Hazards: 2014 and Updated Analysis

Future Coastal Hazard	2014 Everest Analysis[1,2]	Updated Analysis[1,3]
2100 SLR	16.5 to 66 inches (1.4 to 5.5 feet)	6.7 feet
2100 MHHW	6.8 to 10.9 feet MLLW	12.2 feet MLLW
2100 HAT	9.0 to 13.2 feet MLLW[4]	14.0 feet MLLW
75-year significant marina wave height[3]	--	1 foot
100-year significant Outer Basin wave height[2]	2.3 feet	--
75-year marina wave on 2100 HAT	--	14.5 feet MLLW
100-year Outer Basin wave on 2100 HAT	10.2 to 14.3 feet MLLW[4]	--
2100 HAT marina overtopping	Inundated	Inundated

Notes:
1. All elevations are in feet, relative to the current tidal epoch (1983 to 2001) MLLW elevation
2. Wave Uprush Analysis (Everest 2014)
3. Table 8
4. Everest used highest observed water level (7.7 feet MLLW) versus HAT (7.3 feet).

--: not applicable

Future Adaptive Measures

With increased water levels due to SLR, the existing seawall (+10 feet MLLW) is expected to be inundated (Table 8); therefore, future adaptations will be required to prevent flooding and damage to the buildings.

Potential adaptive measures include raising the buildings’ finished floor elevations or extend the seawall.

SLR effects should be continually monitored to ensure the seawall is extended before inundation can result in flooding of the facilities.

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