Garden Street Hotel Development Project
Sea Level Rise Hazard Analysis
And Adaptation Plan

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DUDEK

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Glossary

Abbreviation	Term
BFE	Base Flood Elevation
CCC	State of California Coastal Commission
CDP	Coastal Development Permit
CoSMoS	Coastal Storm and Modeling System
DFE	Design Flood Elevation
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Association
OPC	Ocean Protection Council
SLR	sea level rise
USGS	U.S. Geological Survey

Executive Summary

Garden Palms, LLC is in the process of obtaining a Coastal Development Permit (CDP) for the proposed hotel development located at 101 Garden Street Santa Barbara, CA (Project). Moffatt & Nichol has been commissioned by Garden Palms, LLC, as a subconsultant to Dudek, to prepare a sea level rise (SLR) hazard analysis (study) specific to the Project site and design life that is consistent with the *California Coastal Commission Sea Level Rise Policy Guidance* originally adopted in August 2015 and updated in November 2018 to incorporate SLR projections released by the California Ocean Protection Council (OPC) in 2018:

The Coastal Act (Pub. Res. Code Section 30253) requires that "*new development shall (a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard; and (b) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.*"

The sea level rise projections used for analysis of coastal hazards and development of adaptation strategies were based on a Project design life of 75 to 100 years, corresponding to a time horizon near the end of the century (2100) or later. Sea level rise projections in 2100 would likely remain below 3.1 feet (low-risk aversion) but could reach 6.6 feet (medium-high risk aversion), or as much as 9.8 feet (extreme risk aversion) in a worst-case scenario.

Rather than focus on sea level rise projected for this single time horizon, multiple scenarios were selected to account for the uncertainty of sea level rise projections. This iterative approach will provide a basis for understanding how coastal hazards and impacts change during the Project's design life. Sea level rise scenarios of 2.5 to 6.6 feet (75-200 cm), at increments of 0.8 feet (25 cm), were selected based on the coastal storm and modeling system (CoSMoS) hazard data available to portray how coastal hazards evolve and potentially impact the Project site. The range of scenarios used in the analysis and probabilities associated with each are indicated in Table 1.

Table 1: Sea Level Rise Scenarios

SLR scenario analyzed feet (cm)	Probability and Timing for each Risk Aversion Profile		
	Low Risk Aversion (17% probability)	Medium-High Risk Aversion (0.5% probability)	Extreme Risk Aversion (H++ scenario)
2.5 (75)	2090±	2060	2050±
3.3 (100)	2110±	2070	2060±
4.1 (125)	2130±	2080±	2065±
4.9 (150)	2140±	2085±	2070
5.7 (175)	> 2150	2095±	2075±
6.6 (200)	> 2150	2100	2080±

Given the proposed development is a commercial structure that poses very low risk to public health, safety, natural resources and critical infrastructure, the "medium-high" risk aversion profile is assumed to be most representative of the Project's risk tolerance. Based on the "medium-high" risk aversion profile, the 5.7-foot and 6.6-foot scenarios provide a conservative indication of potential flood hazards near the end of the Project design life. According to the OPC guidance, there is a 99% probability sea level rise will not exceed 6 feet by 2100.

The coastal hazards evaluated in this study include shoreline erosion and storm related flooding from coastal and fluvial events. Site location and elevation are key factors in assessing coastal hazards at the Project site. The Project site is located more than 1,000 feet from the active shoreline; therefore, the site has a very low vulnerability to coastal erosion and wave hazard zones over the life of the Project.

The results presented in Section 3 indicate that the site has a high adaptive capacity for sea level rise and associated coastal storm flooding hazards. The proposed hotels, with a finish floor elevation of 13 feet-NAVD88, are not exposed to any coastal hazards, including annual, 20- and 100- year storms, until SLR exceeds 4.9 feet, which is unlikely to occur in this century. However, portions of the Project site that remain at existing grade and low-lying areas adjacent to the project could experience flooding during these events, resulting in some indirect impacts to site accessibility. According to OPC guidance, there is a 98% probability that SLR will not exceed 5 feet in this century, which suggests the Project is unlikely to experience coastal flooding before 2100. An SLR scenario of 5.7 feet seems to be a tipping point at which 100-year coastal storm events could result in flood elevations higher than the proposed minimum finish floor elevation of 13 feet NAVD88.

The highest SLR scenario evaluated, 6.6 feet, is representative of the medium-high risk aversion projection for 2100. A 100-year coastal storm event in combination with a 6.6 feet SLR scenario would result in additional flooding around the Project site, with flood elevations about 2 feet higher than the finish floor elevation of 13 feet. The best available science indicates there is an approximate 99.5% probability that SLR will not exceed 6.6 feet this century, making this a very conservative scenario for the 2100 time horizon. The combined probability of this level of SLR in combination with a 100-year storm event in the year 2100 is about 1 in 20,000 (P = 0.01 x 0.005 = 0.00005).

The Project site seems to be more sensitive to fluvial hazards because it is within the present day 100-year floodplain of Mission Creek and in close proximity to the Laguna Channel. The lower reaches of both channel systems are limited in capacity and unable to convey the base flood level, resulting in widespread urban flooding during a 100-year event. The lagoon at the mouth of Mission Creek and just north of the Laguna Channel typically breaches when flood levels exceed the beach berm, which is typically between +8-9 feet NAVD (ESA PWA, 2014). Flood levels in the lower creek channels are often highest before the beach berm is breached. Therefore, this breach flood level can be used as a simple proxy for fluvial and SLR hazards. For example, 4.1 feet of SLR (corresponding to ~2080) is assumed to increase the beach berm elevation by the same amount. The beach flood level under this SLR scenario would be ~13 feet and could possibly result in flooding at the Project site if no adaptation measures are implemented to mitigate this flood risk. However, the actual flood risk for the project under this scenario would depend on the more complicated interaction of the stage-storage relationship in each creek/channel and the runoff response (timing) of each watershed.

In the event SLR accelerates faster than current projections, or in-line with the H++ scenario, adaptation strategies could be implemented to reduce the risk of damage to the facility at the end of the Project design life. The following adaptation strategies can be developed to mitigate for known hazards in design of the facility:

- Raise the finish floor elevation of sensitive facilities to reduce potential damages from flooding. Elevating critical facilities such as electrical system buildings, backup power generators etc. can help reduce/minimize the damage during extreme storm events.
- If raising the finish floor elevation of sensitive structures is not feasible beyond a certain point, then deploying removable flood barriers in various building structures such as entrances and parking lots can provide additional protection against extreme events. This type of protection can provide several feet of additional capacity to reduce damage from flooding and generally are more affordable than permanent barriers.
- The City could reduce widespread coastal and fluvial flooding potential by implementing techniques described in the Mission Lagoon – Laguna Creek Restoration Project Conceptual Project Plan (ESA PWA, 2014), such as inlet management to lower lagoon breach elevation, Laguna Channel widening, implementation of detention basin, and increasing pumping capacity.
- At the Project site scale, check valves or tide gates could be installed to reduce potential for backflow from the Laguna Channel into the Project site. Over the long term, additional on-site flood storage and protection features could be integrated with the landscape surrounding the proposed development to supplement any regional adaptation strategies pursued by the City or County.

1. Introduction

Garden Palms, LLC is in the process of obtaining a Coastal Development Permit (CDP) for the proposed hotel development located at 101 Garden Street, Santa Barbara, California (Project) and commissioned Moffatt & Nichol to prepare a sea level rise hazard analysis (study) specific to the Project site and design life that is consistent with the *California Coastal Commission Sea Level Rise Policy Guidance* (2018 Update). This study involves gathering publicly available information and data on potential coastal hazards influenced by sea level rise, mapping and evaluating the projected hazards with respect to various sea level rise scenarios, assessing the degree to which the Project is impacted by these hazards, and describing adaptation measures to avoid or minimize impacts related to sea level rise during the Project design.

1.1 Purpose of Study and Methodology

The purpose of this study is to provide a *Sea Level Rise Hazard Analysis* and adaptation strategies for the Project to meet the applicable objectives described in Chapter 6 of the CCC SLR Policy Guidance. An iterative approach using multiple scenarios is provided as a basis for understanding how hazards and impacts change under different sea level rise projections. The project life and sea level rise projection range are defined based on CCC Sea Level Rise Policy Guidance (2018) and the Ocean Protection Council (OPC) State of California Sea Level Rise Guidance (2018). Various tools and sources are implemented to identify, evaluate and compile the related coastal hazards such as coastal storm erosion and flooding, and fluvial flooding as follow:

- City of Santa Barbara Sea Level Rise Vulnerability Assessment and Adaptation Plan
- County of Santa Barbara Sea Level Rise Vulnerability Assessment
- Coastal hazards published by USGS as part of the Coastal Storm Modeling System (CoSMoS) 3.0
- FEMA Flood Insurance Rate Maps (FIRM) and Flood Insurance Studies (FIS)
- Mission Lagoon – Laguna Creek Restoration Project, Conceptual Project Plan (ESA PWA, 2014)

The coastal hazard data including annual, 20- and 100- year storm flooding depths and durations and non-storm coastal erosions with respect to sea level rises ranging from 2.5 feet (75 cm) up to 6.6 feet (200 cm) with 0.82 feet (25 cm) increment is extracted from the *Coastal Storm and Modeling System (CoSMoS) 3.0,* Phase 2 results published by the United States Geological Survey[1] (USGS). Also, FEMA FIS report and FIRM for the City of Santa Barbara are downloaded from FEMA[2] and utilized to study the fluvial flooding. The FIS report provides floodplain data, which includes 1 %annual chance flood elevations (referred to as the Base Flood Elevation [BFE]) and delineations of the 1% annual chance floodplains and floodway.

Evaluated coastal hazards provide the basis for adaptation strategies to be implemented to minimize potential impacts throughout the project life.

[1] https://www.usgs.gov
[2] https://www.fema.gov

1.2 Site Location

The Project is a proposed hotel development within the jurisdiction of City of Santa Barbara and it is surrounded by U.S. Highway 101, the Laguna Channel, Mission Creek, and the Pacific Ocean. The site specifically is bounded by East Yanonali Street and the Union Pacific railway in a northeast-southwest direction, and by Santa Barbara Street and Garden Street in northwest-southeast direction, as shown in Figure 1. The Project is located within the coastal zone and, therefore, requires a coastal development permit (CDP).

Figure 1: Location Map

According to FEMA Flood Insurance Rate Maps (FIRMs) (Figure 2), the Project site is located in Zone AH, which is defined as an area subject to shallow flooding in a 100-year storm event on Mission Creek where average depths are between 1 and 3 feet. Also, the Project site is adjacent to, but outside of, the Laguna Channel 100-year floodplain (Zone AE) east of the project. The effective base flood elevation (BFE) in the project area is 12 feet (Figure 2). BFE is a computed elevation (rounded to the nearest foot) to which floodwater is expected to rise during a 100-year storm event. The Building and Safety Division of the City of Santa Barbara determined the design flood elevation (DFE) to be 13 feet, based on the mapped BFE plus one foot of freeboard. The finish floor elevation for the hotel, and other habitable spaces are required to be at or above the DFE of 13 feet.

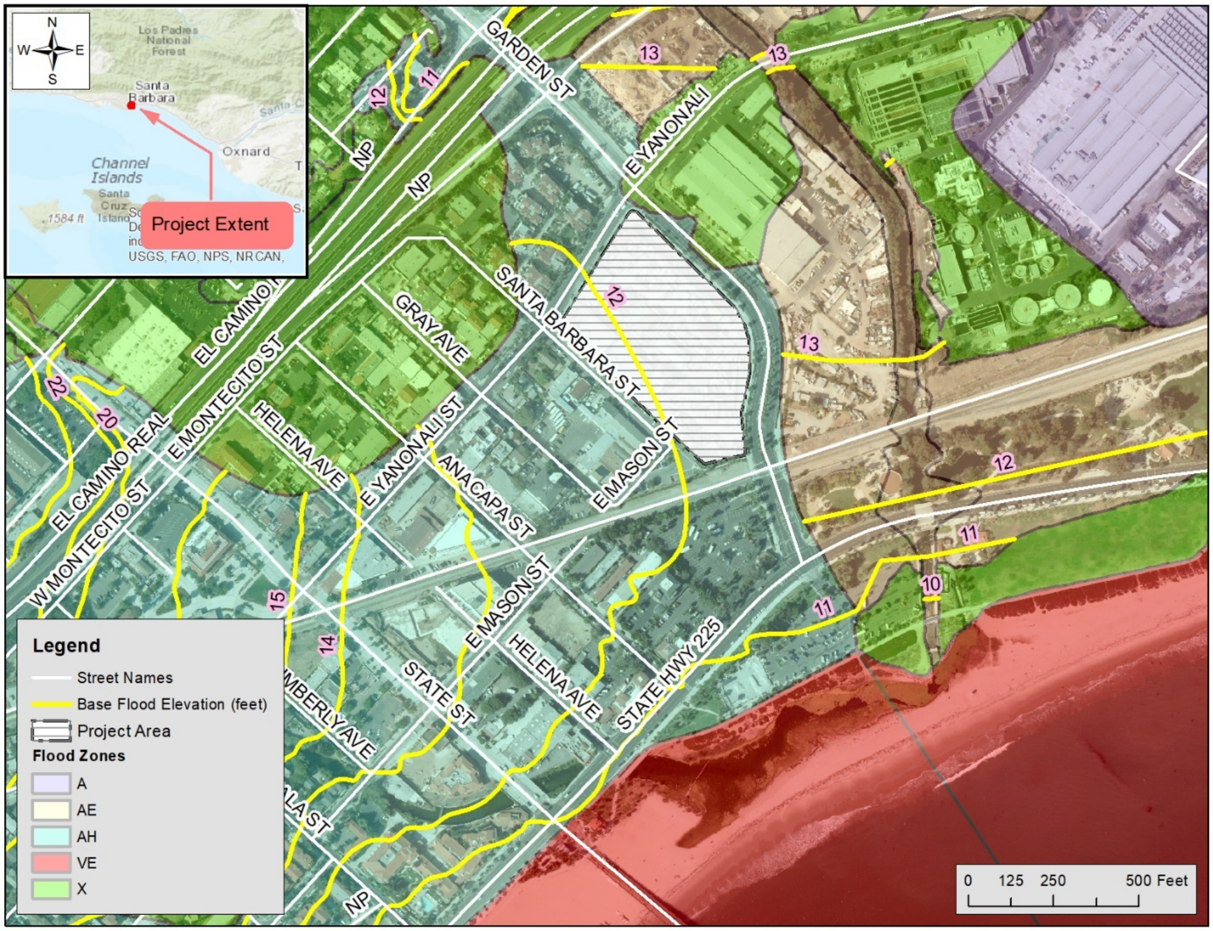

Figure 2: FEMA Flood Insurance Rate Map and Location of the Project Site in Relation to Flood Zones

1.3 Site Topography

Site location and elevation are key factors in assessing coastal hazards at the Project site. Figure 3 shows surface elevation implemented in CoSMoS, which is the primary tool for performing coastal hazards assessment. CoSMoS uses a seamless, 10-foot (3-meter) digital elevation model (DEM), which is the integration of high-resolution datasets available, such as light detection and ranging (Lidar) topography, multibeam and single beam sonar bathymetry, and interferometric synthetic aperture radar (IfSAR) topography, and matches well with the survey data provided by Garden Palms, LLC. The average site elevations are in range of 10 to12 feet (relative to the North American Vertical Datum of 1988 [NAVD]) which are lower than the adjacent areas west and east of the Project site (Figure 3).

The Project site is located about 1,000 feet away from a dynamic shoreline subject to seasonal, storm-related and long-term trends of shoreline change. According to a previous City of Santa Barbara Sea Level Rise vulnerability study (ESA, 2018), the shoreline is located within a long-term shoreline erosion zone and has also experienced severe erosion from coastal and fluvial storms. In addition to natural fluctuations in shoreline change driven by currents, waves, and water levels, the shoreline position is also affected by sediment management activities. The shoreline east of Stearns Wharf is designated as a receiver beach for sediment dredged from Santa Barbara Harbor on a regular basis (USACE, 2016).

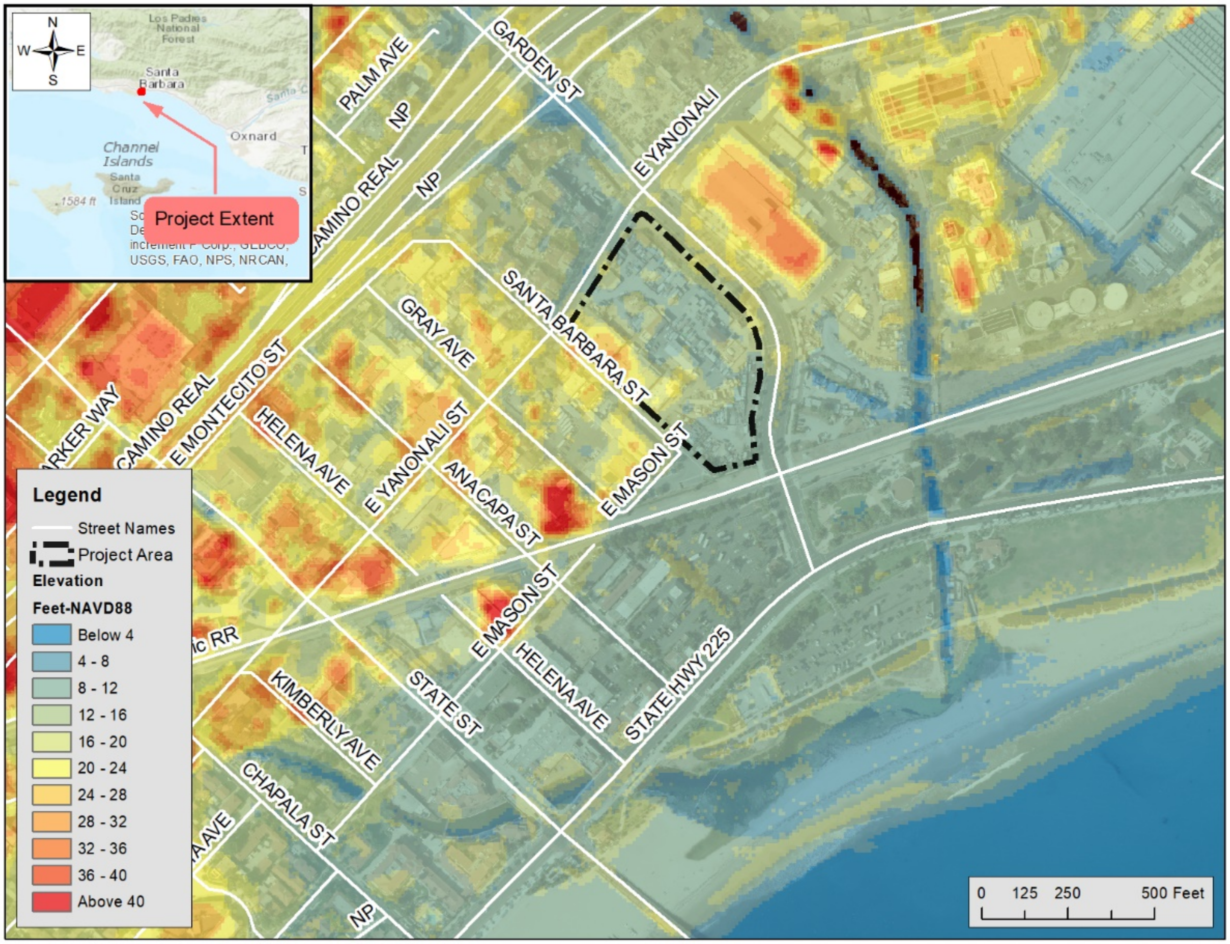

Figure 3: Existing Site Topography

2. Sea-Level Rise Scenarios

There is broad agreement in the scientific community that the earth is predicted to warm and that sea levels will rise as a result of the thermal expansion of water and increased contributions from melting glaciers (CCC, 2015). Although there is consensus among the scientific community on these concepts, the timing and severity of sea level rise is relatively uncertain, especially for planning horizons beyond 2050. The uncertainty in sea level rise projections is partially due to the range of future global emissions scenarios (a function of social and political behavior) and the non-linear ocean response to warmer temperatures and contributions from land-based ice sources.

2.1 Best Available Science for Sea Level Rise Projections

As a supporting study to a CDP application, the most relevant guidance to this analysis is the *California Coastal Commission Sea Level Rise Policy Guidance* (CCC, 2018). The original guidance document was adopted in 2015 and a science-focused update was adopted in November 2018. The purpose of the update was to incorporate recent publications by the Ocean Protection Council (OPC) titled *Rising Seas in California: An Update on Sea-Level Rise Science* (2017) and the *State of California Sea-Level Rise Guidance: 2018 Update* (2018). The 2018 OPC Sea Level Rise Guidance is now referenced as the best available science throughout the CCC Sea Level Rise Policy Guidance document.

The OPC (2018) Guidance projects sea level rise for multiple emissions scenarios and uses a probabilistic approach based on Kopp et al. 2014 to generate a range of projections at a given time horizon. For the 2060 time horizon the "likely range" of sea level rise is between 0.4 to 1.0 feet. Kopp et al. 2014 estimated there is a 66% probability that sea level rise will fall within this "likely range". The likely range of sea level rise at the 2070 time horizon is 0.7 - 1.7 feet for a high emissions scenario. The likely range of sea level rise at the 2100 time horizon is 1.2 – 3.1 feet for a high emissions scenario. The upper limit of the "likely range" is recommended for low-risk aversion situations where impacts from sea level rise greater than this amount would be insignificant, or easily mitigated. This "low risk aversion" curve is shown in orange in Figure 4. At any given time horizon there is a 17% chance that sea level rise will exceed this curve.

For medium-high risk aversion situations, more conservative (lower probability) projections for sea level rise are recommended by the OPC Guidance. These projections have a 1-in-200 chance (0.5% probability) of occurring at a given time horizon and would be appropriate for use on projects where damage from coastal hazards would carry a higher consequence and/or a lower ability to adapt such as residential and commercial structures. Based on the recommendations of the OPC and CCC guidance documents, the medium-high risk aversion is considered for the Project to evaluate the timing and probability of each sea level rise scenario. The medium-high risk aversion curve is shown in red in Figure 4.

The OPC guidance also includes a specific singular scenario (called H++), based on projections by Sweet et al 2017 which incorporates findings of DeConto and Pollard (2016) that predict Antarctic ice sheet instability could make extreme sea-level outcomes more likely than indicated by Kopp et al. 2014 (OPC, 2017). Because the H++ scenario is not a result of probabilistic modeling, the likelihood of this scenario cannot be determined. Due to the extreme and uncertain nature of the H++ scenario, it is most appropriate to consider when planning for development that poses a high risk to public health and safety, natural resources, and critical infrastructure (OPC 2018). The H++ extreme risk aversion curve is shown in purple in Figure 4.

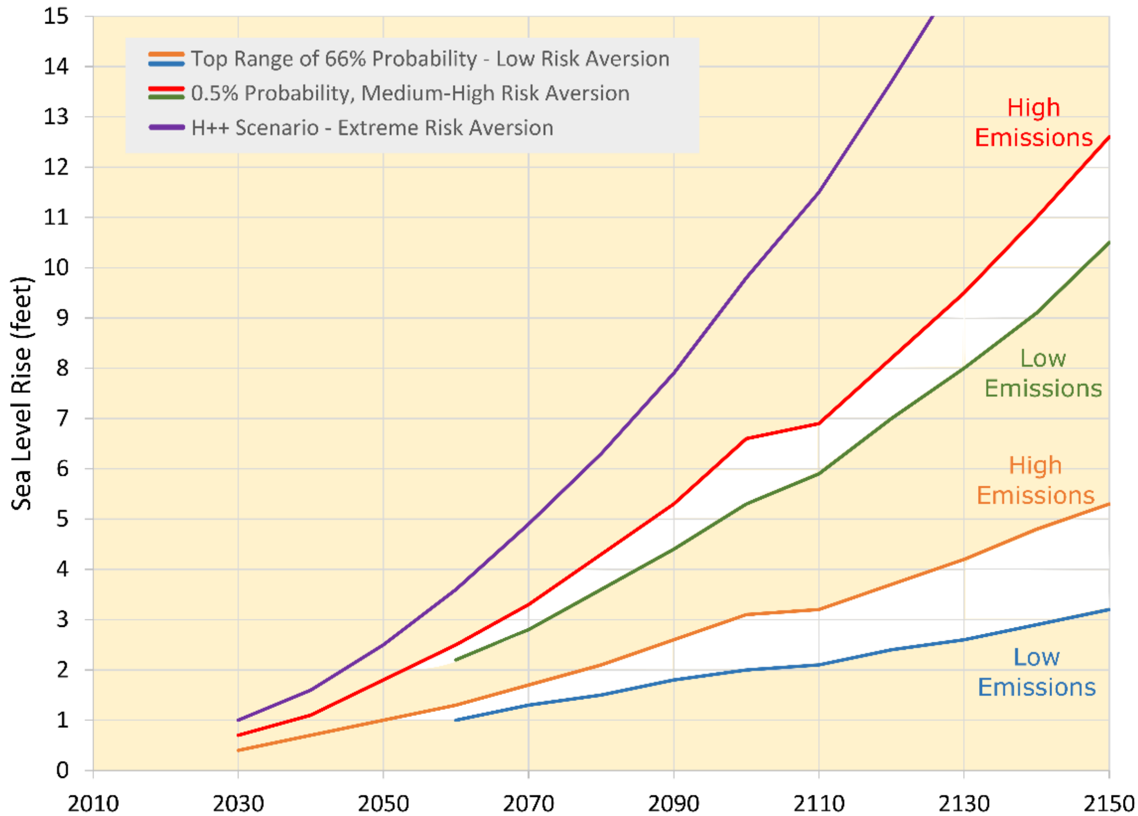

Figure 4: Sea Level Rise Projections for Three Risk Aversion Levels, Santa Barbara, CA (OPC, 2018)

2.2 Project Design Life and Sea Level Rise Scenarios

According to OPC, the design life of commercial structures, such as the proposed hotels, can range between 75 to 100 years. However, most of the available climate model experiments do not extend beyond 2100 and use of 2110 projections or beyond should be done with caution. This sea level rise hazard assessment report focuses on sea level rise projections up to 6.6 feet (200 cm) corresponding to a time horizon of 2100-2110. Sea level rise projections in 2100 range from 5.3 feet (low emissions) to 6.6 feet (high emissions) and in 2110 range from 5.9 feet (low emissions) to 6.9 feet (high emissions), for medium-high risk aversion. There is a 0.5% chance that sea level rise will exceed these scenarios at any given time horizon. This probability is lower (more conservative) than the typical 1 in 100 annual chance exceedance probability used in design of flood protection infrastructure. The joint probability of combining a medium-high risk aversion sea level rise scenario with an extreme event (e.g. 100-yr storm) becomes very low. The joint probability of a medium-high sea level rise scenario in 2100 occurring with a 100-yr event is P = 0.01 x 0.005 = 0.00005, or roughly a 1 in 20,000 chance.

Rather than focus on sea level rise projected for this single time horizon, multiple scenarios were selected to account for the uncertainty of sea level rise projections. This iterative approach will provide a basis for understanding how coastal hazards and impacts change during the Project's design life. Given the uncertainty in sea level rise projections, the precise value selected for each scenario is not as important as selecting a range of values that can help identify impact thresholds. The sea level rise scenarios used in this analysis and potential timing of each are listed below. The probabilities that sea level rise will meet or exceed a particular height over a given time horizon are shown in Figure 5 and based on Kopp et al. 2014.

1. Sea level rise of 2.5 feet (75 cm) represents the medium-high risk aversion projection for 2060, considering a high emission scenario. There is a 99.5% probability that sea level rise will not exceed this amount before 2060. This sea level rise scenario also represents the low risk aversion for 2090, which means there is 17% probability that this scenario will happen by that time.
2. Sea level rise of 3.3 feet (100 cm) represents year 2070 for high emissions scenario and medium-high risk aversion projection, which means there is a 99.5% probability sea level rise will not exceed this amount by 2070.
3. Sea level rise of 4.1 feet (125 cm) is within the low and high emissions scenarios for 2080 and is representative of the medium-high risk aversion projection for this time horizon. However, there is a 95% chance this amount of sea level rise doesn't occur this century.
4. Sea level rise of 4.9 feet (150 cm) represents the medium-high risk aversion projection for the 2090 time horizon. This scenario can also be used to evaluate the extreme risk aversion (H++) projection for year 2070.
5. Sea level rise of 5.7 feet (175 cm) represents the medium-high risk aversion projection between low and high emissions scenarios for 2100. There is a ~99% probability that sea level rise of this magnitude will not occur this century.
6. Sea level rise of 6.6 feet (200 cm) represents the high emissions, medium-high risk aversion projection for 2100. Under a worst-case (H++) scenario, this amount of sea level rise could occur in the 2080-2090 time horizon.

There is 99% chance that sea level rise will not exceed 6 feet by 2100 for a high emissions scenario. This gives us high confidence that the scenarios used in this analysis adequately characterize potential impacts over the Project design life, which is estimated to be between 75-100 years.

SANTA BARBARA - High emissions (RCP 8.5)

	Probability that sea-level rise will meet or exceed... (excludes H++)									
	1 FT.	**2 FT.**	**3 FT.**	**4 FT.**	**5 FT.**	**6 FT.**	**7 FT.**	**8 FT.**	**9 FT.**	**10 FT.**
2030										
2040	1.3%									
2050	14%	0.2%								
2060	40%	2%	0.2%							
2070	64%	7%	0.8%	0.2%	0.1%					
2080	78%	20%	3%	0.7%	0.2%	0.1%	0.1%			
2090	86%	37%	8%	2%	0.7%	0.3%	0.1%	0.1%	0.1%	
2100	89%	53%	19%	6%	2%	1%	0.3%	0.2%	0.1%	0.1%
2150	98%	87%	63%	38%	20%	11%	6%	3%	2%	1%

Figure 5: Sea Level Rise Probabilities at Different Time Frames (from OPC, 2018)

3. Coastal Hazards

Coastal hazards influenced by sea level rise, such as shoreline erosion, extreme wave events and fluvial storm events, are discussed in this section. The hazard information is compiled from several reference documents, and no additional numerical modeling was performed as part of this study. The resources used and assumptions made for each hazard type are described in each section along with maps illustrating the proximity of each hazard to the Project site. The hazard maps are presented solely on the basis of the assumptions accompanying the referenced information utilized at the time of the Study.

3.1 Shoreline Erosion

Shoreline erosion is a widely accepted consequence of sea level rise and the subject of several news articles that have cited a 67% loss of beaches in California by the end of the century. However, there are many factors that will influence how much shoreline retreat occurs in a given area. The proposed Project site is located more than 1,000 feet away from the shoreline. Historical Google Earth photos show that the shoreline position has not moved significantly in the past decade, during which the beach has been nourished through a hydraulic cutterhead dredge and pipeline system repeatedly as part of the Santa Barbara Harbor maintenance program.

CoSMoS 3.0 results are the best available predictor of shoreline retreat due to sea level rise and offer the ability to evaluate future shoreline position with and without beach nourishment. However, there is very little difference between these predictions indicating that no significant beach nourishment program was included in the CoSMoS-COAST model at this location. In both cases, the CoSMoS results indicate a shoreline retreat of 270 feet if the sea level rises 2.5 feet (75 cm) by ~2060. If the sea level rises 6.6 feet, the CoSMoS results predict another ~130 feet of shoreline retreat (see Figure 6). The project's setback of 600 feet from the active shoreline, even under an extreme sea level rise scenario, indicates the site has a good adaptive capacity in the form of a horizontal setback from littoral processes and hazards, throughout the Project design life.

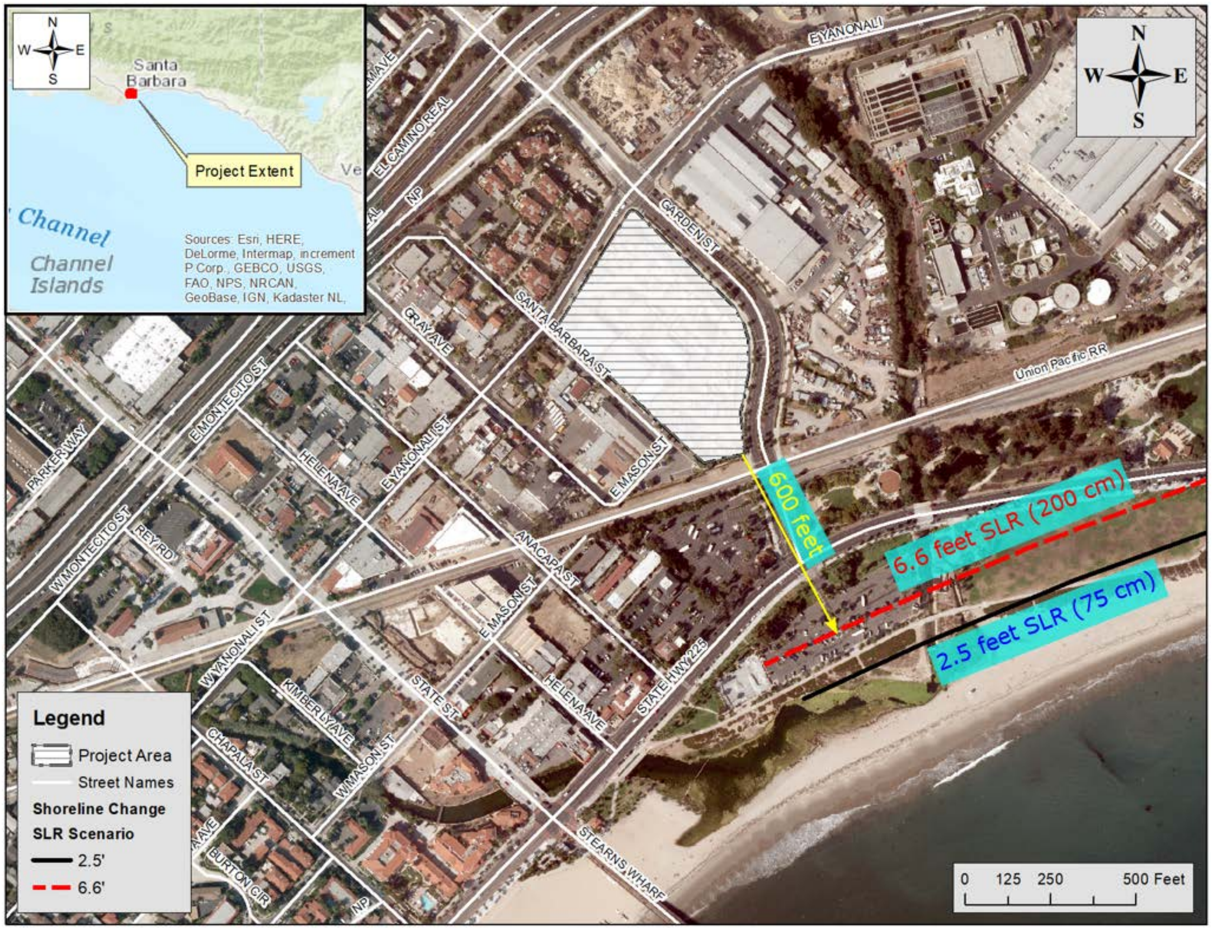

Figure 6: CoSMoS Shoreline Erosion Projections (Without Future Beach Nourishment)

3.2 Coastal Storms

The Project site is located about 1,000 feet inland of the active shoreline, behind two public parking lots, and a sandy beach about 200 feet wide. In general, the beach provides some buffer against erosion and flooding during coastal storm events. However, a widely acknowledged impact of sea level rise is a landward and upward shift in the beach profile and shoreline position. This long-term shoreline change combined with sea level rise and an extreme wave event will result in the coastal storm hazard area moving further landward.

Results from CoSMoS 3.0 were used to evaluate how these hazards may affect the Project site. CoSMoS is a multi-agency effort led by the USGS to make detailed predictions of coastal flooding and erosion based on existing and future climate scenarios for Southern California. The modeling system incorporates state-of-the-art physical process models to enable detailed prediction of currents, wave height, wave runup, and total water levels (Barnard, P.L. et al, 2009). The storm-related water levels are then projected onto a digital elevation model to estimate the extent of flooding. The coastal flooding extents are available for three storm event return periods including annual, 20- and 100- year wave event in combination with various rates of sea level rise.

For this study, CoSMoS 3.0 preliminary results indicate that coastal hazards for sea level rise scenarios below 2.5 feet (75 cm) are largely confined to the beach areas and do not pose a threat to the Project site. Therefore coastal hazards for sea level rise scenarios less than 2.5 feet were not evaluated in detail for this study. Sea level rise scenarios of 2.5 to 6.6 feet (75-200 cm), at increments of 0.8 feet (25 cm), portray how coastal hazards evolve and potentially impact the Project site and therefore were used in the analysis. Maps showing how the coastal flood hazard changes with each sea level rise scenario are provided in Figures 8 to 10. The maps and analyses in the following sections are based on CoSMoS 3.0 results at existing grade and their relation to the proposed minimum design floor elevation of 13 feet.

3.2.1 Project Exposure to Coastal Storms

Annual coastal storm event

The CoSMoS 3.0 results indicate that the Project site (at existing grade) would experience shallow flooding of ~1-foot depth (Figure 8.C) with sea level rise of 4.1 feet. However, after construction, the finish floor elevation of the hotel would not be exposed to flooding during annual coastal storm event until sea level rise reaches 5.7 feet, corresponding to the "medium-high" risk aversion projection for ~2090 (Figure 7). Therefore, flooding from an annual coastal storm event is not a concern until the end of the century or later. According to Figure 7 and the flooding maps shown in Figure 8, sea level rise of 5.7 feet seems to be a tipping point for the Project site and surrounding area in terms of flooding. For sea level rise of 5.7 feet (Figure 8.E), most of the project area experiences some flooding with a duration of about 18 hours. Site accessibility would also be a concern as the U.S. 101 underpass and Cabrillo Boulevard south of the Project site experience prolonged flooding (Figure 11.E). With 6.6 feet of sea level rise, the entire Project site becomes exposed to a flooding depth of up to 1 foot above FFE (Figure 8.F) for a long duration (Figure 11.F). Also, flooding in the adjacent areas is widespread for higher sea level rise scenarios (4.9-6.6 feet), impacting adjacent roads and development, except for a segment of Garden Street and Yanonali Street northwest of the Project. It should be noted that the best available sea level rise projections indicate that there is a 98% chance that sea level rise will not exceed 5 feet in this century (OPC, 2018).

20-year coastal storm event

The 20-year coastal storm flooding map (Figure 9) shows similar results compared to annual storm events (Figure 9). A 20-year coastal storm event combined with 4.1-foot sea level rise scenario (Figure 9.C) would make the Project site a flood-prone low-lying area. A higher sea level rise scenario, such as 5.7 feet (Figure 9.E), would flood the entire Project site by several feet above the existing grade. This appears to be a tipping point when flooding from adjacent areas would encroach into the Project site in higher sea level rise scenarios. A higher sea level rise scenario (i.e. sea level rise of 6.6 feet) expands the coastal flooding area beyond the Project site into adjacent streets and causes considerable road access issues for the entire region, with widespread flooding for a long duration.

100-year coastal storm event

The CoSMoS 3.0 results show that the Project site would be exposed to flooding with sea level rise of 3.3 feet at existing grade (Figure 10.B). However, after hotel construction, the hotel would not experience flooding in a 100-year coastal storm event until sea level rise exceeds 4.9 feet, which is unlikely (2% chance) to occur this century (Figure 10.C). A sea level rise of 4.9 feet (Figure 10.D) would result in several feet of regional flooding with a duration of about 18 hours. The results indicate that an extreme coastal storm event combined with ~4.9 feet of sea level rise could be a tipping point for flooding of the Project site after construction (Figure 7), as well as the regions located seaward of it including the two public parking lots, portions of the residential and commercial development, the railroad, and Cabrillo Boulevard. A sea level rise of 5.7 feet (Figure 10.E) intensifies the flooding, and depth of flooding increases to about 1 foot above the Project FFE with duration of more than 18 hours (Figure 13.E) in the project area. Higher sea level rise scenarios (such as sea level rise of 6.6 feet) worsen the onsite and regional flooding with a projected flood elevation about 2 feet above the Project FFE and about 4 to 8 feet higher than low-lying areas adjacent to the site.

Since the hotel buildings will be constructed with finish floor elevation of 13 feet, it will be exposed to flooding in the following scenarios (Figure 7):

a) An annual coastal storm and sea level rise of 5.7 feet
b) A 20-year coastal storm and sea level rise of 5.7 feet
c) A 100-year coastal storm and sea level rise of 4.9 feet

These sea level rise values represent thresholds at which the flooding predicted by CoSMoS would exceed the finish floor elevation of the proposed hotel buildings. However, there could be indirect impacts to the Project from sea level rise scenarios of 3.3 to 4.1 feet due to flooding of the surrounding roads and buildings. The 100-year coastal storm elevation for the 3.3-foot sea level rise scenario is about 12 feet NAVD, which is equivalent to the present day 100-year base flood elevation on Mission Creek. This is an indication that fluvial flooding hazards pose a greater risk to the development that coastal hazards, at least over the next ~50 years.

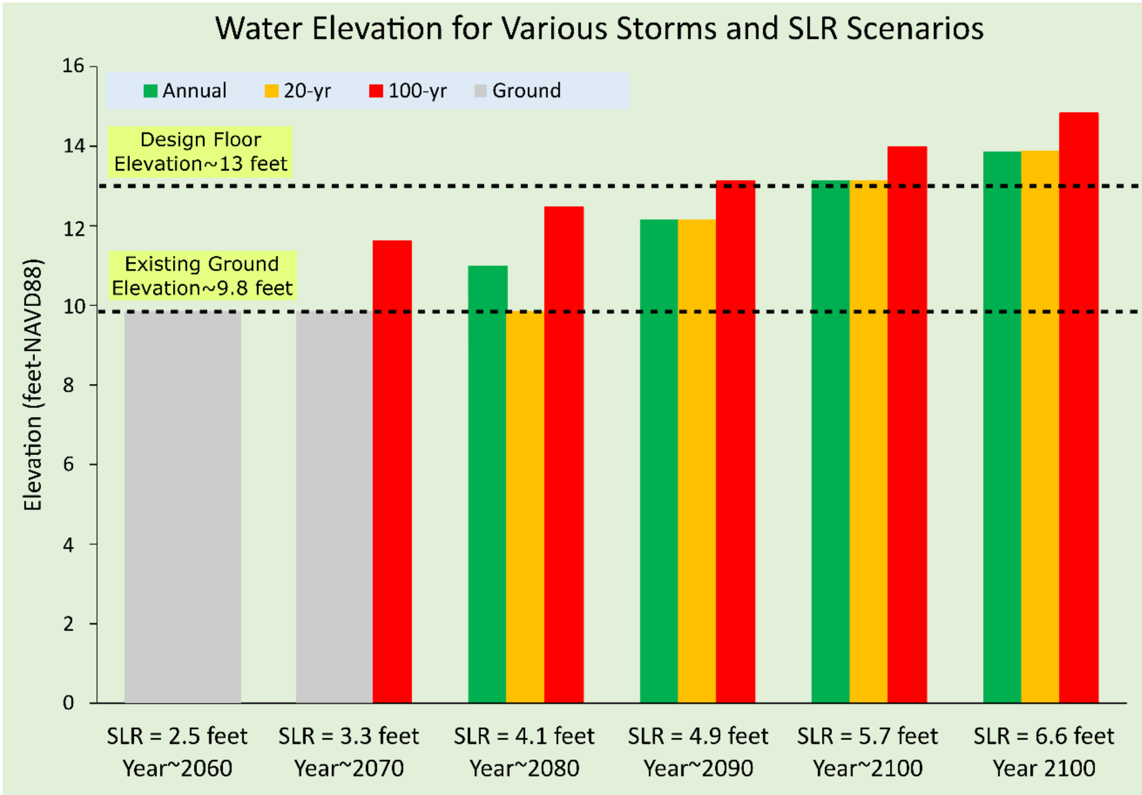

Figure 7: CoSMoS Flood Elevations for Each Sea Level Rise Scenario Compared to Proposed Finish Floor Elevation

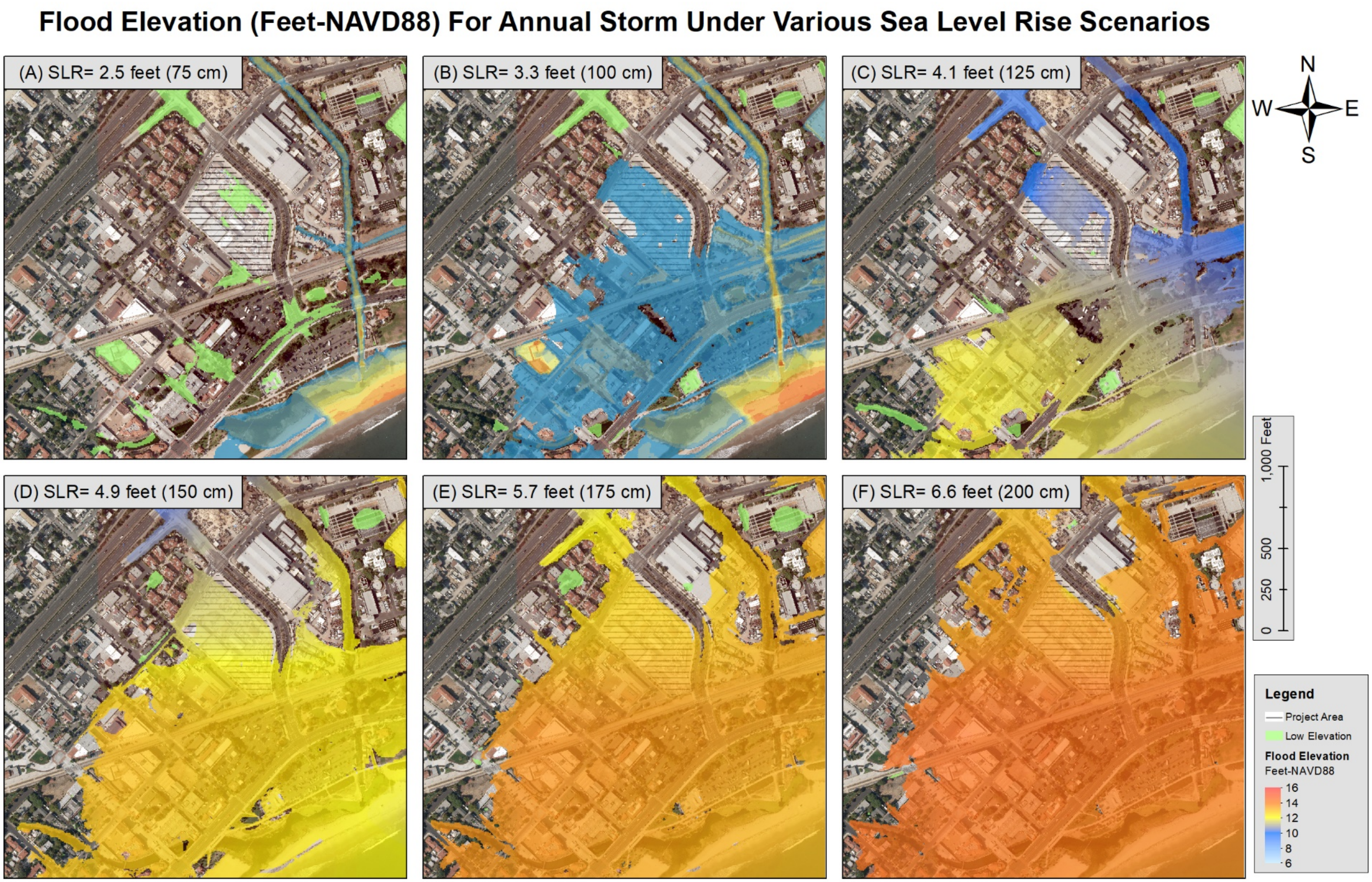

Figure 8: Annual Coastal Storm Flood Hazard Map at Existing Grade

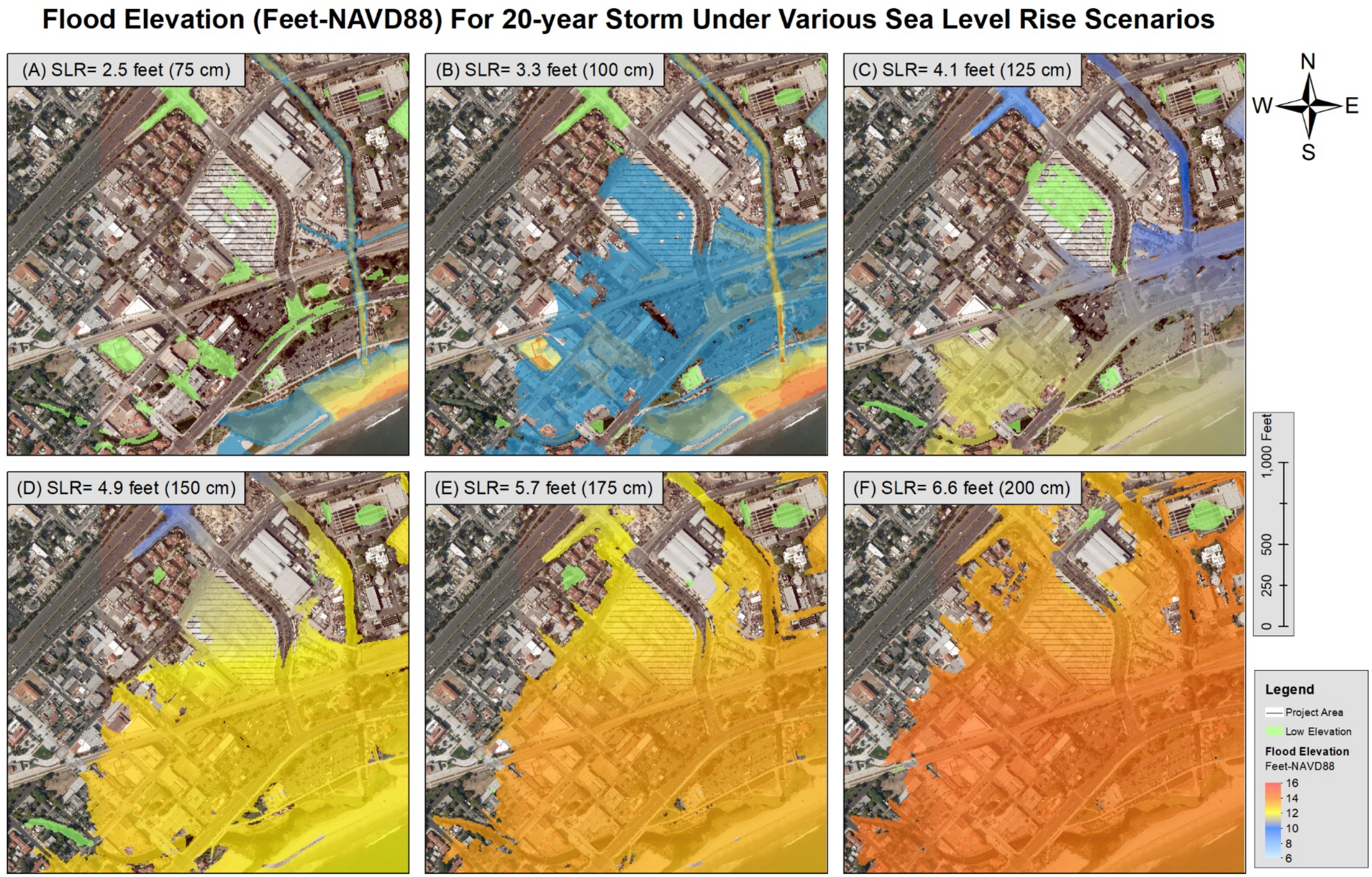

Figure 9: 20-year Coastal Storm Flood Hazard Map at Existing Grade

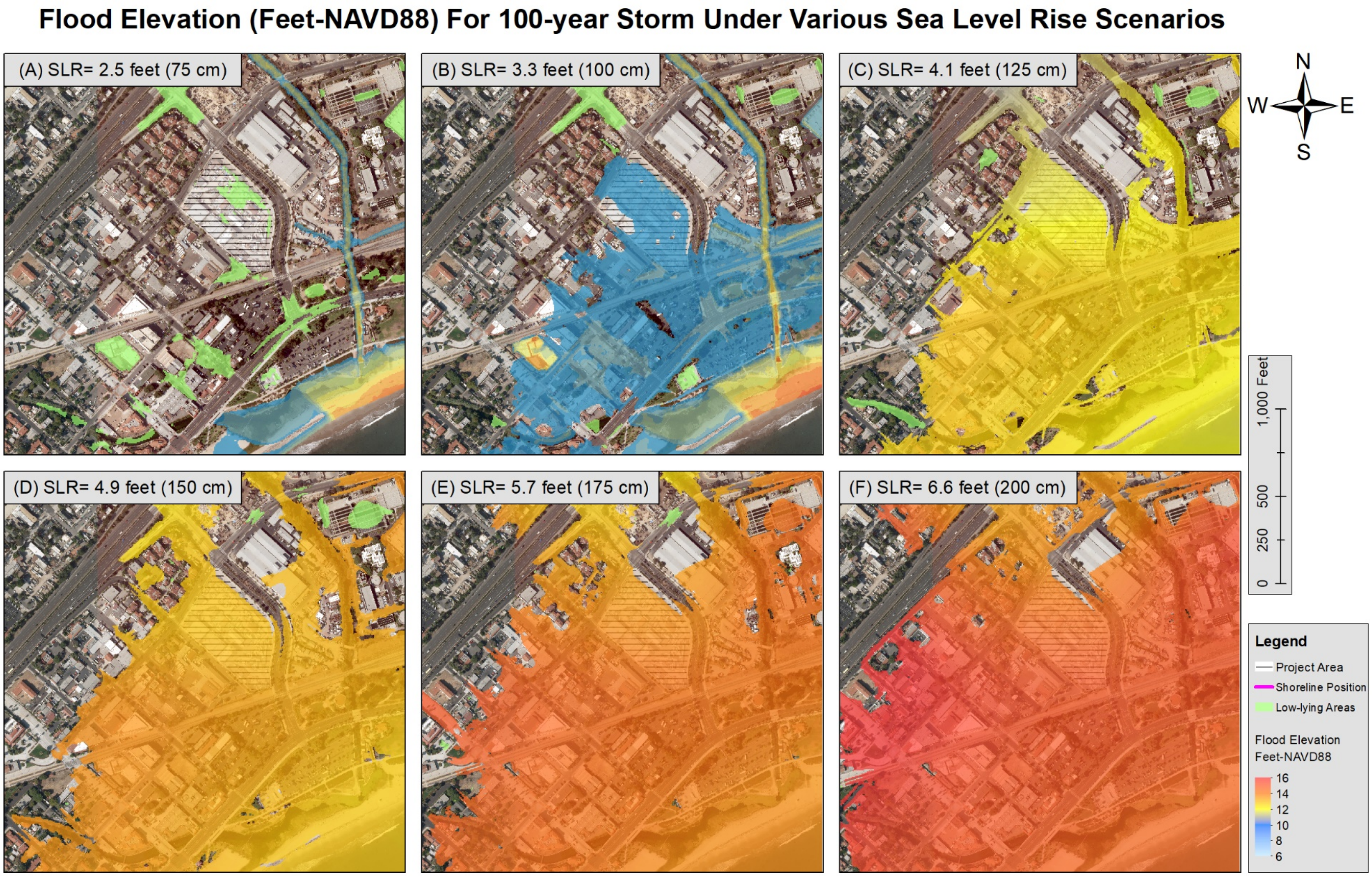

Figure 10: 100-year Coastal Storm Flood Hazard Map at Existing Grade

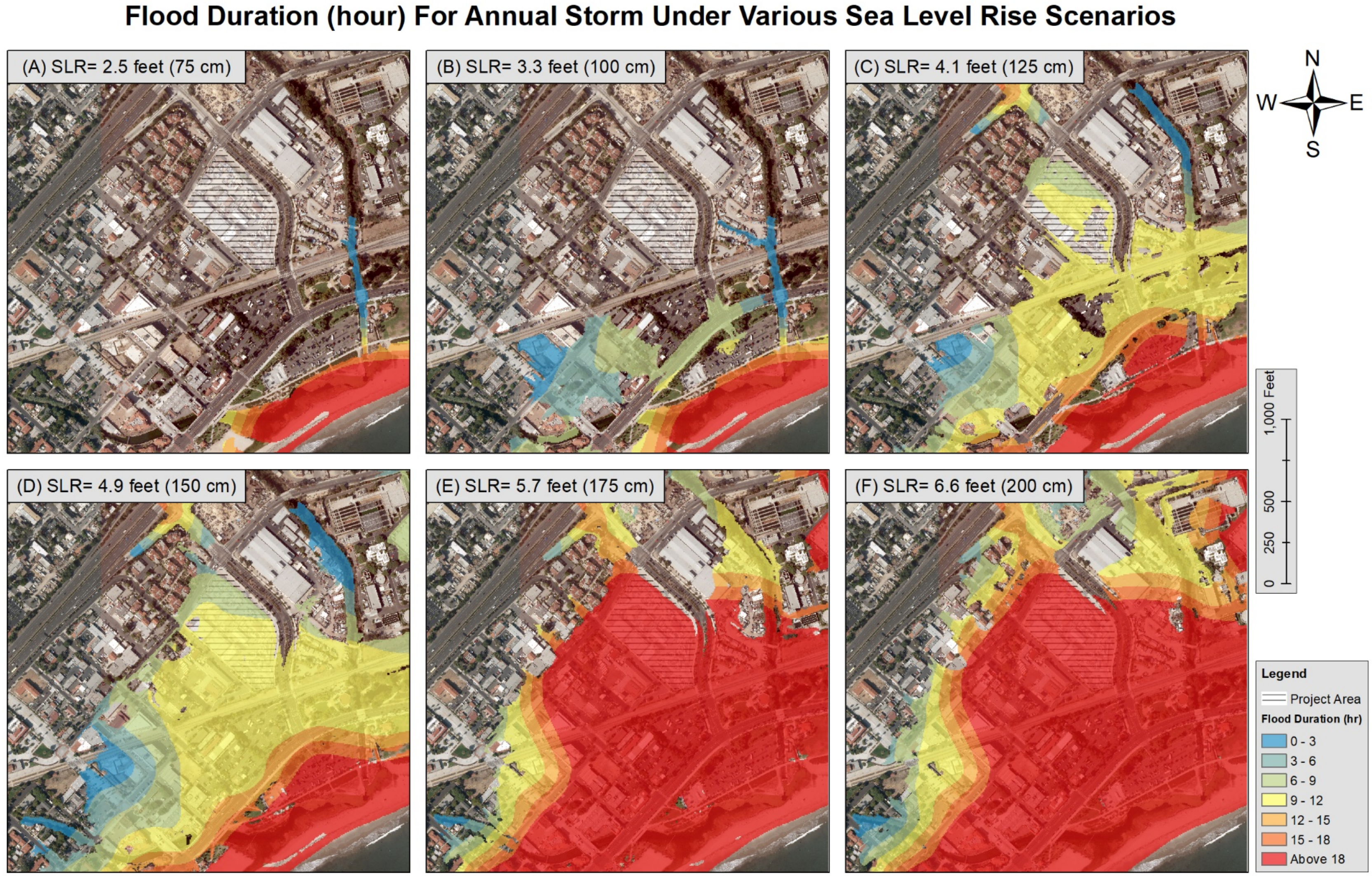

Figure 11: Annual Coastal Storm Flood Duration Map at Existing Grade

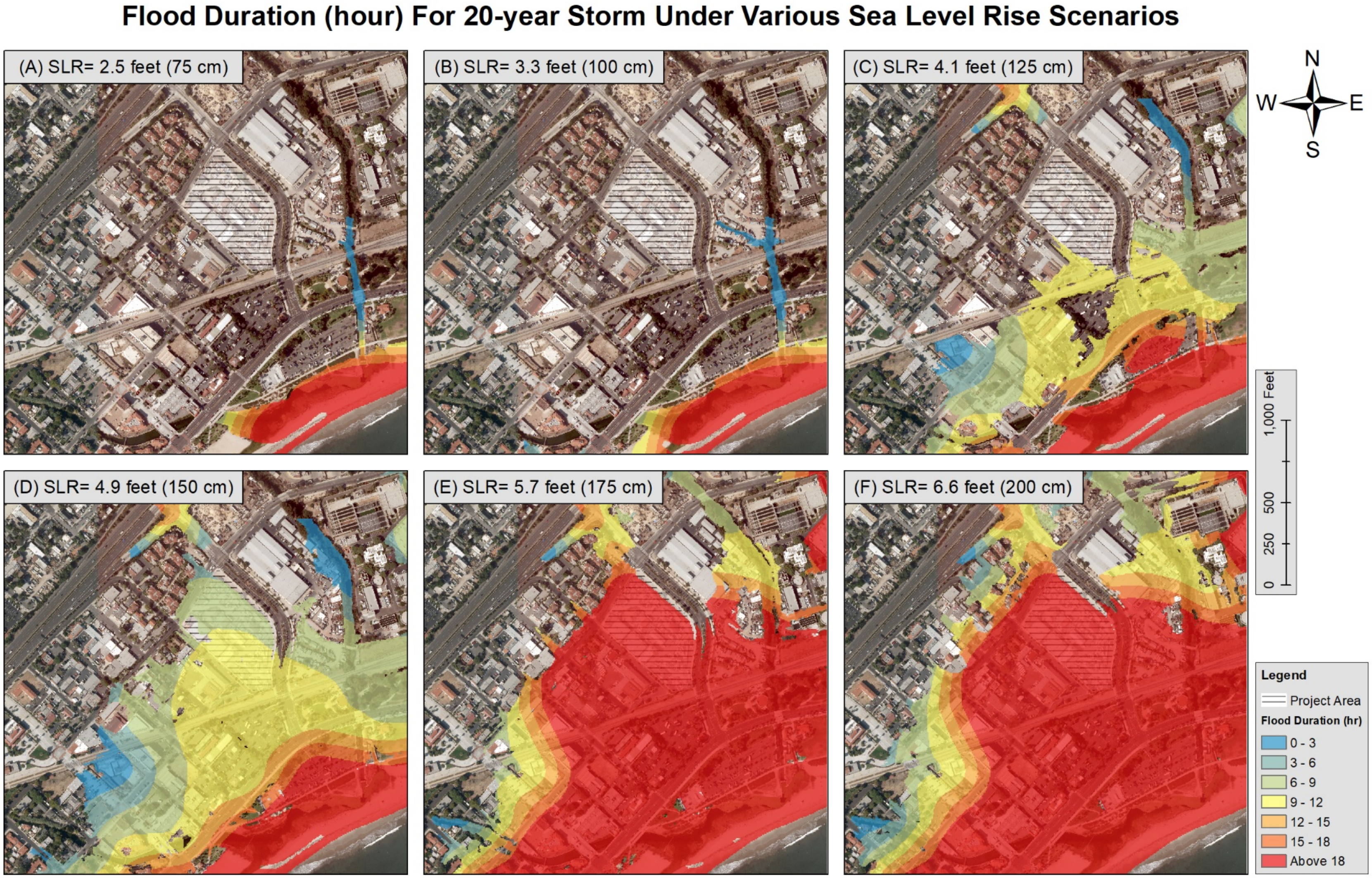

Figure 12: 20-year Coastal Storm Flood Duration Map at Existing Grade

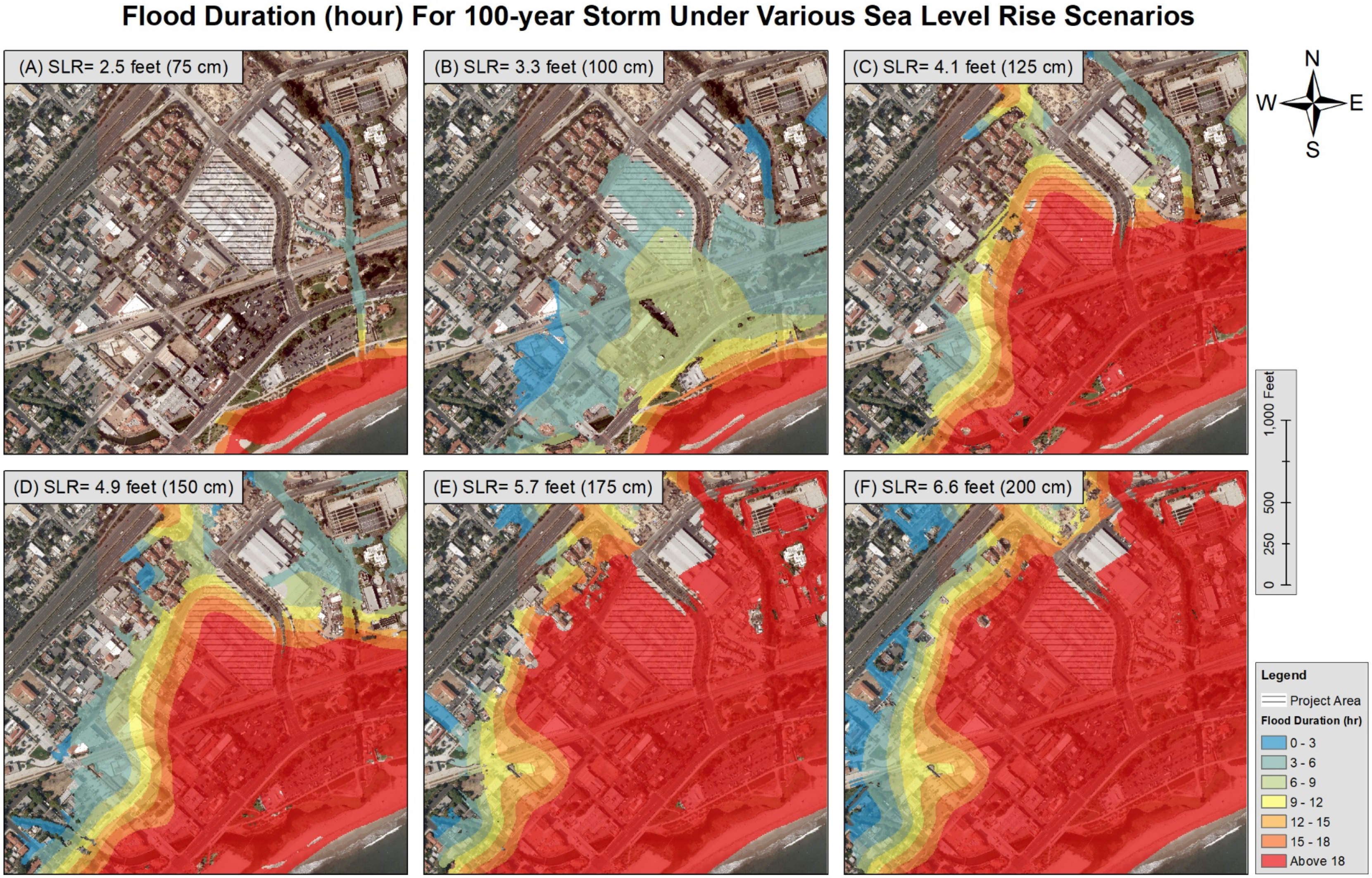

Figure 13: 100-year Coastal Storm Flood Duration Map at Existing Grade

3.3 Fluvial Storms

Two primary sources of fluvial storms within the limits of the Project area include Mission Creek and the Laguna Channel. Based on the effective flood insurance rate maps (FIRMs), the Project site is located within Zone AH of the Mission Creek floodplain which indicates it would be subject to shallow ponding of 1-3 feet in depth during a base flood (100-year) event. However, both Mission Creek and the Laguna Channel have the potential to impact the Project site. The lower reaches of both channel systems are limited in capacity and unable to convey the base flood resulting in widespread urban flooding of this area of Santa Barbara (Figure 2).

3.3.1 Laguna Channel

The Laguna Creek Watershed covers approximately 2,020 acres of almost entirely urban land on the southeast side of Santa Barbara. Most of the watershed is residential and overland flows eventually reach to Laguna Channel just above and below Highway 101 (City of Santa Barbara, 2013). There is a tide gate at the mouth of the channel to prevent tidal influx, and water in the creek is pumped onto the beach if necessary. Pumps convey runoff until water level in the channel (behind the tide gates) exceeds water level in lagoon (seaward of tide gates) (ESA PWA, 2014). The lagoon at the mouth of Mission Creek near the Laguna Channel typically breaches when flood level exceeds the beach berm (assumed to be +9 feet NAVD in water balance analysis performed by ESA PWA). The tide gate does not open until the lagoon breaches and cuts a path to the ocean, which is typically caused by stormwater pumped out of the Laguna Channel. This breach flood level can be used as a simple proxy for fluvial and sea level rise hazards and represents a scenario in which the Laguna Channel pump station is not working and, therefore, stormwater ponds behind the beach berm and the tide gates cannot open until the breach occurs.

To evaluate the influence of sea level rise on fluvial hazards it can be assumed the beach berm elevation will increase linearly with sea level rise. For example, 4.1 feet of sea level rise (corresponding to ~2080) would increase the elevation of the beach berm from 9 to 13.1 feet NAVD, which could be a concern if the proposed finish floor elevation is 13 feet. However, the actual flood risk for the Project under this scenario would depend on the more complicated interaction of the stage-storage relationship in each creek/channel and the runoff response (timing) of each watershed.

3.3.2 Mission Creek

Mission Creek Watershed extends approximately 7.5 miles from the Santa Ynez Mountains to the ocean and covers approximately 7,400 acres. The lower reaches of Mission Creek include one mile of creek between the Canon Perdido Street Bridge, at the upstream end, and Cabrillo Boulevard Bridge, near the outlet to the ocean. The creek in this area is highly constrained due to adjacent development, and the channel banks are armored in many areas (Questa, 2005).

According to Lower Mission Creek Feasibility Study completed by USACE (USACE, 1999), during large flood events, excess flood flows that leave the Mission Creek floodplain flow easterly and enter the Laguna Channel floodplain both upstream and downstream of Highway 101. Flooding analysis shows that due to the low and flat nature of the area immediately north and south of Highway 101, a ponded condition would develop for the 25-, 50-, and 100-year events in the Laguna Channel drainage area north of the freeway, and water overflows into the Laguna Channel significantly reducing the channel’s capacity.

Mission creek is allowed to breach naturally and is not managed or controlled. However, some sand guide berms are used to prevent any meander of the creek mouth toward the pier and harbor area. Model simulations of lagoon flooding performed by ESA PWA indicated that pumping from the Laguna Channel typically causes a breach in the lagoon before the peak of the Laguna Channel flood hydrograph arrives. Since Mission Creek is a larger watershed with slower rainfall-runoff response, it typically peaks after the Laguna Channel has caused a breach in the lagoon and is less constrained by the beach berm.

Previous studies indicate that Mission Creek is influenced by lagoon breaching at its downstream end and the interaction of the heavily managed Laguna Channel system. Therefore, we can assume that sea level rise will increase the elevation of the beach berm at the mouth of Mission Creek resulting in similar flooding hazards as described for Laguna Channel. Other general conclusions are that rising sea levels will increase the downstream controlling water surface elevation of the creek, reducing the storage volume in the creek channel and result in a higher water surface profile for a certain distance upstream of the ocean. Considering these factors and the limited conveyance capacity of the lower Mission Creek channel it is very likely that sea level rise will trigger adaptation measures at the City or County scale to address the increased risk of widespread flooding along Lower Mission Creek. The long-term fluvial hazard exposure of the Project will also be influenced by these adaptation measures.

4. Adaptation Plan

Based on the results of the hazard analysis in Section 3, the Project site has a higher vulnerability of episodic nuisance flooding from fluvial events rather than extreme coastal storms over the 75-100-year design life. Since the Project is located within the 100-year floodplain of Mission Creek, adaptation measures over the short term should focus on reducing the potential for flood damage from fluvial sources. Any measures implemented to reduce flooding from fluvial sources will also increase adaptive capacity for sea level rise and associated coastal hazards.

4.1 Fluvial Hazards

The present-day fluvial hazards consist of shallow ponding in the 1 to 3-foot depth range, relative to the existing site grades. In accordance with the City's floodplain ordinance, the Building and Safety Division of the City of Santa Barbara determined the design flood elevation (DFE) to be 13 feet, based on the mapped BFE plus one foot of freeboard. The freeboard above the base flood will provide some buffer against a more extreme storm event (>100-year return period) and climate change impacts such as increased precipitation or reduced capacity of the lower reaches of Mission Creek and Laguna Channel due to sea level rise. The following strategies can be developed to mitigate potential hazards in the design of the facility:

- Raise the finish floor elevation of sensitive facilities to reduce potential damages from flooding. Elevating critical facilities such as electrical system buildings, backup power generators etc. can help reduce/minimize the damage during extreme storm events.
- If raising the finish floor elevation of sensitive structures is not feasible beyond a certain point, then deploying removable flood barriers in various building structures such as entrances and parking lots can provide additional protection against extreme events. This type of protection can provide several feet of additional capacity to reduce damage from flooding and generally are more affordable than permanent barriers.
- The City could reduce widespread coastal and fluvial flooding potential by implementing techniques described in the Mission Lagoon – Laguna Creek Restoration Project Conceptual Project Plan (ESA PWA, 2014) such as inlet management to lower lagoon breach elevation, Laguna Channel widening, implementation of detention basin, and increasing pumping capacity.
- At the Project site scale, check valves or tide gates could be installed to reduce potential for backflow from the Laguna Channel into the Project site. Over the long-term additional onsite flood storage and protection features could be integrated with the landscape surrounding the proposed development to supplement any regional adaptation strategies pursued by the City or County.

4.2 Coastal Hazards

The coastal hazards evaluated in Section 3 indicate that the Project site is not exposed to shoreline erosion even, with no further beach nourishment for the entire design life of the project. The Project site also has adaptive capacity for up to 5.7 feet (175 cm) of sea level rise in combination with a 20-year coastal storm event. A 100-year coastal storm event in combination with 5.7 feet of sea level rise would result in flooding about ~1 foot higher than the finish floor elevation. However, there is a 98% chance sea level rise will not exceed 5 feet this century indicating the Project has a very low exposure to coastal storm hazards through 2100.

In the event sea level rise accelerates faster than current probabilistic projections and in-line with the H++ scenario, sea level rise could reach 5 to 6 feet in the 2070 – 2080 time horizon. Based on the very low exposure to coastal storm erosion and flooding over the next 50 years the following strategy is recommended to prepare and adapt for potential long-term coastal hazard vulnerabilities:

- Update the Project specific sea level rise analysis in 2050 or when local MSL has risen 3 feet above MSL of the 1983-2001 tidal epoch. The updated analysis should account for updated sea level rise science, the latest coastal and fluvial hazard projections and regional adaptation efforts or land use changes that could affect the Project's long-term exposure to coastal and fluvial hazards.

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