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memorandum

date February 10, 2025
to Sarah McCormick (City of Fort Bragg)
from Louis White, PE, and Selena Whitney, AICP
subject DRAFT Sea Level Rise Scenarios for City of Fort Bragg SLR, Tsunami Hazards, and Erosion Resilience Strategy (ESA Ref. 202400549.00)

1 Introduction

This memo presents a preliminary assessment of sea level rise (SLR) scenarios to be used by the ESA team for the City of Fort Bragg (city) SLR, Tsunami Hazard, and Erosion Resilience Strategy. The SLR scenarios presented below will be used as part of the technical analyses and risk assessments of vulnerable coastal assets and resources in the city over a range of time horizons.

These SLR scenarios presented in this memo are based on the latest State of California guidance documents, including the State of California's *Sea Level Rise Guidance* (OPC 2024) and the California Coastal Commission's (CCC) *Sea Level Rise Policy Guidance* (CCC 2024).

ESA recommends using three future conditions timescales for the City of Fort Bragg SLR, Tsunami Hazard, and Erosion Resilience Strategy to examine the SLR impacts by incremental amounts: 1 foot of SLR occurring by 2050 (near term), 3 feet of SLR by 2070-2100 (intermediate term), and 6 feet of SLR by 2100+ (long term). The method involves identifying specific amounts of SLR, or thresholds, at which assets become vulnerable. The SLR guidance, projections, and threshold approach are summarized in the following sections.

2 California State Sea Level Rise Policy Guidance

The OPC recently finalized the State of California Sea Level Rise Guidance: 2024 Science and Policy Update (2024 Update), which provides projections for SLR at various locations along the coast of California through 2150 (OPC 2024). OPC produced the 2024 Update in partnership with the California Ocean Science Trust (OST) and a scientific Task Force. The 2024 Update is based on the National Oceanic and Atmospheric Administration (NOAA) 2022 Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al. 2022), which provides updated SLR scenarios for the United States based on global projections from the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report. The 2024 Update presents five SLR scenarios and values that incorporate: (1) SLR observations, estimated and modeled projections, and uncertainties, and (2) a

range of global greenhouse gas emissions scenarios, which rely on shared socioeconomic pathways (SSPs).¹ **Table 1** presents the SLR projections for Arena Cove for all scenarios.

TABLE 1. 2024 OPC STATE GUIDANCE: PROJECTED SEA LEVEL RISE FOR ARENA COVE IN FEET

Year	Low	Int-Low	Intermediate (Low Risk Aversion)	Int-High (Medium-High Risk Aversion)	High (Extreme Risk Aversion)
2020	0.1	0.2	0.2	0.2	0.2
2030	0.2	0.3	0.3	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.5	0.7	0.9	1.1
2060	0.5	0.7	0.9	1.4	1.8
2070	0.5	0.8	1.2	2.1	2.8
2080	0.6	1.0	1.7	2.8	3.9
2090	0.7	1.2	2.2	3.6	5.1
2100	0.8	1.4	2.9	4.5	6.4
2110	0.8	1.6	3.6	5.4	7.6
2120	0.9	1.7	4.1	6.1	8.7
2130	0.9	1.9	4.6	6.7	9.6
2140	1.0	2.1	5.1	7.3	10.5
2150	1.0	2.3	5.6	7.8	11.4

NOTE:

Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion.

SOURCE: 2024 OPC Guidance

The 2024 Update provides a summary of each scenario, as follows:

Low Scenario: Aggressive emissions reductions leading to very low future emissions; the scenario is on the lower bounding edge of plausibility given current warming and sea level trajectories, and current societal and policy momentum.

Intermediate-Low Scenario: A range of future emissions pathways; a reasonable estimate of the lower bound of most likely SLR in 2100 based on support from sea level observations and current estimates of future warming.

¹ SSP background from OPC 2024 guidance: *Developed more recently, the SSPs are a collection of narrative descriptions of alternative futures of socio-economic development in the absence of climate policy intervention. Five SSPs describe five different pathways that the world could take, drawing on data including population, economic growth, education, urbanization, and the rate of technological development. The SSPs are important inputs into the IPCC sixth assessment and are used to explore how societal choices will affect greenhouse gas emissions. Pathways 5-85 (SSP 585) assumes heavy fossil-fueled development with high percentage of coal and energy-intensive lifestyles worldwide and assumes a radiative forcing of 8.5 W/m².*

Intermediate Scenario: A range of future emissions pathways; could include contribution from low confidence processes. Based on sea level observations and current estimates of future warming, a reasonable estimate of the upper bound of most likely SLR in 2100.

Intermediate-High Scenario: Intermediate-to-high future emissions and high warming; this scenario is heavily reflective of a world where rapid ice sheet loss processes are contributing to SLR.

High Scenario: High future emissions and high warming with large potential contributions from rapid ice-sheet loss processes; given the reliance on sea level contributions for processes in which there is currently low confidence in their understanding, a statement on the likelihood of reaching this scenario is not possible.

Note that the OPC's 2024 Update recommends using a range of SLR amounts between the Intermediate and High Scenarios to inform appropriate SLR planning and project decisions.

The 2024 Update included several changes made from the previous State of California Sea Level Rise Guidance (OPC 2018). The updated 2024 Update removes the extreme risk aversion SLR scenario (i.e., H++) that was included in the previous guidance. The H++ scenario assumed rapid ice sheet loss on Antarctica, which authors alleged could drive rates of SLR 30-40 times faster than the SLR experienced over the last century. This scenario is not included in the 2024 Update, as the rates and amounts of SLR are no longer supported by the best available science. Additionally, the 2024 Update provides a greater certainty of SLR through 2050, with a California statewide average of 0.8 to 1.2 feet for intermediate to high scenarios, respectively. By 2100, the expected range of the statewide average SLR is between 3.1 and 6.6 feet for intermediate to high scenarios, respectively. Beyond 2100, SLR uncertainty increases, with the potential for statewide average sea levels to rise up to 11.9 feet by 2150.

The 2024 Update recommends evaluation of the Intermediate, Intermediate-High, and High Scenarios in SLR planning and projects. The High Scenario is sufficiently precautionary for even the most risk averse applications. The High Scenario assumes high future greenhouse gas emissions. Note that future emissions are inherently uncertain because emissions depend on societal choices; therefore, it is not possible to estimate the probability that future emissions will be high. Assuming high emissions and considering the range of model projections for a high emissions scenario, the High Scenario's SLR estimates have less than a 1% chance of exceedance in 2100.² Each of the three recommended scenarios corresponds with low, medium-high, and extreme risk aversion applications:

- *Low risk aversion* is appropriate for adaptive, lower consequence projects (e.g., unpaved coastal trails). The *Intermediate Scenario* is recommended for consideration in low risk aversion applications.
- *Medium-high risk aversion* is appropriate as a precautionary projection that can be used for less adaptive, more vulnerable projects or populations that will experience medium to high consequences as a result of underestimating SLR (e.g., coastal housing development). The *Intermediate-High Scenario* is recommended for consideration in medium-high risk aversion applications.
- *Extreme risk aversion* is appropriate for high consequence projects with little to no adaptive capacity and which could have considerable public health, public safety, or environmental impacts (e.g., coastal airport, power plant, wastewater treatment plant, etc.). The *High Scenario* is recommended for consideration in extreme risk aversion applications.

² As stated in OPC (2024): "It is important to note that probabilistic projections do not provide actual probabilities of occurrence of sea level rise but provide probabilities that the ensemble of climate models used to estimate contributions of sea-level rise (from processes such as thermal expansion, glacier and ice sheet mass balance, and oceanographic conditions, among others) will predict a certain amount of sea-level rise." Also, note that the High Scenario has an 8% chance of exceedance when accounting for low confidence processes associated with Antarctica and Greenland ice-sheet loss.

The 2024 Update recommends utilizing data from one of twelve NOAA tide gauges that are located along the coast of California. Using the data from the tide gauge closest to the project site can capture local variations due to tectonic activity, including uplift or subsidence. The nearest NOAA tide gauge to Noyo Harbor is the Arena Cove tide gauge located in Point Arena (see Table 1).

Figure 1 compares the SLR projections of the 2024 Update (solid lines) to the projections from the prior 2018 Update for Arena Cove. Note that the new High Scenario tracks closely to the prior medium-high risk aversion projection and the new Intermediate Scenario tracks closely to the prior low risk aversion projection. The new Intermediate Scenario is between the new Intermediate and High Scenarios, and the older extreme risk aversion projection has been excluded.

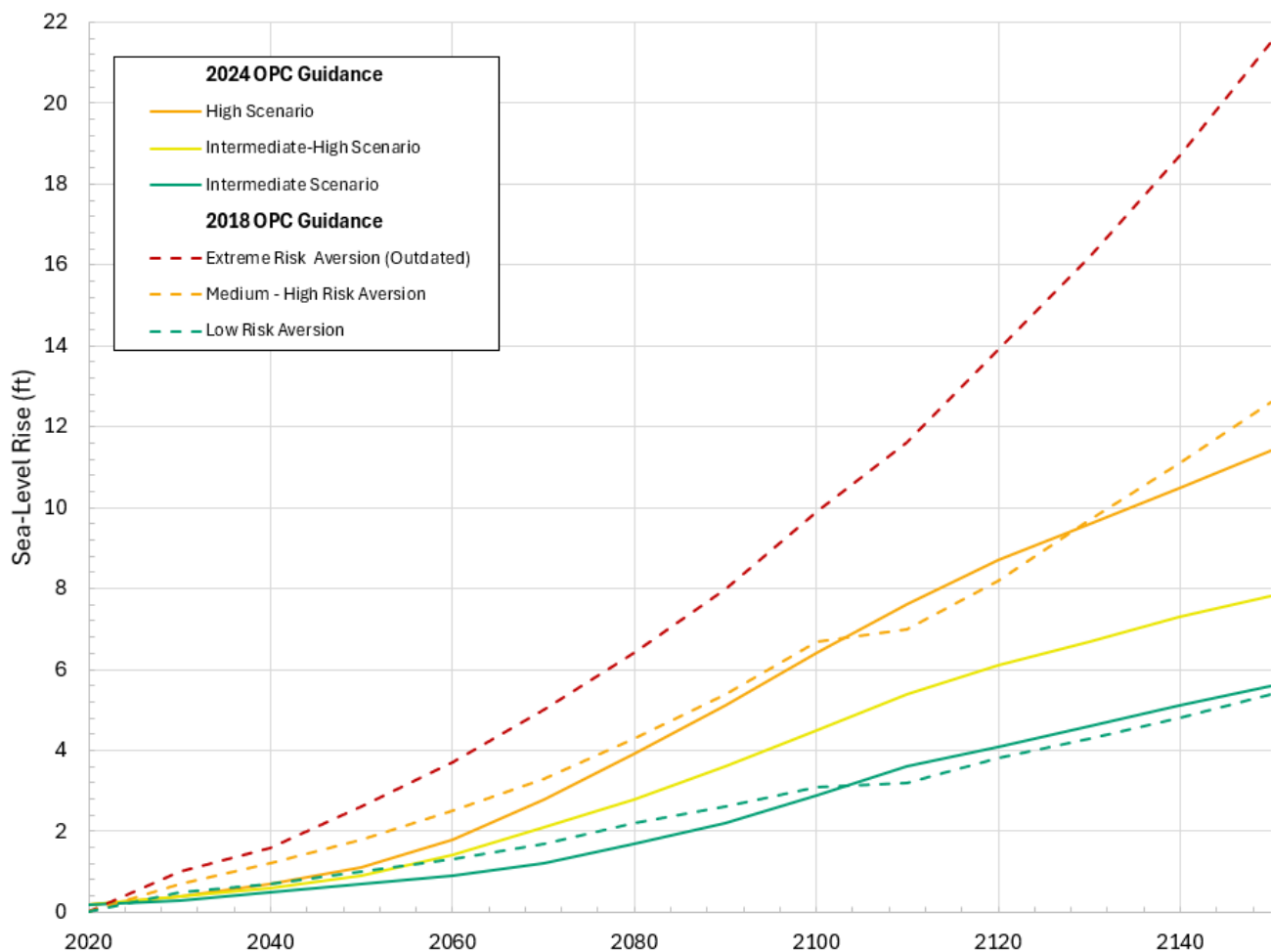


Figure 1

Sea level rise projections for Arena Cove from 2020 to 2150 from 2024 and 2018 CA OPC Sea Level Rise Guidance

While the OPC Guidance provides projections through 2150, it is important to note that SLR is expected to continue for centuries, because the earth's climate, cryosphere,³ and ocean systems will require time to respond to the emissions that have already been released to the atmosphere. Although SLR is typically presented as a range in the amount of SLR that will occur by a certain date (e.g., 0.8-1.2 feet of SLR by 2050), it can also be presented

³ The cryosphere is the portions of the Earth's surface where water is in solid form, like glaciers and ice caps.

as a range of time during which a certain amount of SLR is projected to occur (e.g., 3 feet of SLR between 2070 and 2100 under the high and intermediate scenarios, respectively). Even if emissions are reduced to levels consistent with the low-emissions-based projections, sea level will continue to rise to higher levels, just at a later date.

2.1 Critical Infrastructure Guidance for Sea Level Rise Adaptation Planning

In 2021, the California Coastal Commission (CCC) adopted the Critical Infrastructure Guidance for Sea Level Rise Adaptation Planning with specific guidance for SLR adaptation of at-risk critical infrastructure (CCC 2021). The CCC Critical Infrastructure Guidance is based on the previous 2018 OPC California Sea Level Rise Guidance (OPC 2018), which is superseded by the 2024 OPC guidance. The CCC Critical Infrastructure Guidance is summarized below for reference.

The CCC (2021) guidance document is focused on transportation and water/wastewater infrastructure and builds upon the 2018 science update to the CCC Sea Level Rise Policy Guidance (CCC 2018). The purpose of the critical infrastructure guidance is to provide policy and planning information to inform SLR planning and adaptation decisions that are consistent with the California Coastal Act. The guidance presents key considerations for successful infrastructure adaptation planning with specific recommendations for each infrastructure category, describes the regulatory framework for infrastructure adaptation planning and provides model policies.

Consistent with direction from OPC (2018) guidance on the potential for extreme SLR, CCC recommended evaluating the extreme risk aversion (i.e., H++) scenario for critical infrastructure due to the long lifespans and significant consequences associated with extreme SLR and related hazard impacts. CCC guidance was to:

“understand and plan for the H++ scenario, not necessarily to site and design for the H++ scenario. In other words, in some cases it may not be appropriate or feasible to site or design a project today such that it will avoid the impacts associated with, for example, ~10 feet of sea level rise (the approximate H++ scenario in 2100 for much of the California coast). However, it is important to analyze this scenario to understand what the associated impacts could be and to begin planning options to adapt to this scenario if and when it occurs, and to ensure that the risks and benefits of economic investments in critical infrastructure are fully understood.”

Given that the 2024 Update is the best available science and does not include the H++ scenario, the superseded OPC 2018 guidance’s extreme risk aversion (H++) scenario is not recommended for this study and the 2024 Update’s high SLR scenario is used instead.

3 Suggested Approach for the City of Fort Bragg SLR, Tsunami Hazard, and Erosion Resilience Strategy

SLR scenarios are recommended by considering the 2024 Update discussed above (which is based on the latest SLR science) and the availability of existing SLR hazard data for this study.

ESA recommends assessing SLR impacts for the City of Fort Bragg SLR, Tsunami Hazard, and Erosion Resilience Strategy using three SLR amounts that correspond to three different time ranges that are defined by the intermediate and high SLR scenarios. ESA recommends looking at three timescales that will cover the near future and projected future impacts of SLR (e.g., 2050, 2100 and 2150).

Table 2 presents a summary of the recommended SLR scenarios to use for the project in addition to the existing condition with no SLR. These selected levels of SLR will allow for multiple projections to be analyzed. One foot of SLR will allow for the near-term (2050) projections for intermediate-high and high scenarios to be analyzed. Three feet of SLR covers projections between 2070 and 2100 for the Intermediate and High Scenarios,

respectively, to be analyzed. Six feet of SLR covers projections between 2100 and 2150 for the Intermediate and High Scenarios, respectively, to be analyzed. Since SLR projections after 2100 have increasing uncertainty due to limited climate models extending past 2100, ESA is recommending that a maximum of six feet of SLR is analyzed.

TABLE 2. RECOMMENDED SLR SCENARIOS TO APPLY TO CITY OF FORT BRAGG SLR, TSUNAMI HAZARD, AND EROSION RESILIENCE STRATEGY

Scenario	SLR Amount (feet) ^a	Time (High Scenario) ^b	Time (Intermediate Scenario) ^c
Near Term	1	2040	2050
Intermediate Term	3	2070	2100
Long Term	6	2100	2150

Notes:

a. ESA selected a SLR amount to the nearest foot to simplify analysis and reporting.

b. This time corresponds to the approximate earliest time that a given amount of SLR is projected under the high scenario.

c. This time corresponds to the approximate latest time that a given amount of SLR is projected under the intermediate scenario.

Note that future global greenhouse gas emissions scenarios drive the SLR projections reported by the OPC. These emissions scenarios are influenced by societal choices and therefore their likelihood of occurrence is inherently uncertain. SLR scenarios are determined by modeling a range of global emissions projections and considering a range of uncertainties in SLR processes. Due to the inherent uncertainty of future emissions scenarios, the probability of sea levels rising a specific amount by a specific date cannot be determined. Instead, the probability of exceedance of a particular SLR scenario provided by the 2024 OPC guidance is contingent or conditional on the assumption of a particular future emissions and warming scenario.

We understand that the city will review these recommendations and confirm them with ESA prior to completing further technical analysis and mapping of hazards.

4 References

- California Coastal Commission (CCC), 2024. *Sea level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea level Rise in Local Coastal Programs and Coastal Development Permits*. 2024 Update adopted on November 13, 2024. Accessed online: <https://documents.coastal.ca.gov/assets/slr/guidance/2024/2024AdoptedSLRPolicyGuidanceUpdate.pdf>.
- California Coastal Commission (CCC), 2021. *Critical Infrastructure at Risk: Sea Level Rise Planning Guidance for California's Coastal Zone. Final Adopted Guidance*, November 17, 2021. Accessed online: <https://www.coastal.ca.gov/climate/slr/vulnerabilityadaptation/infrastructure/>.
- Ocean Protection Council (OPC), 2018. *State of California Sea level Rise Guidance 2018 Update*. Prepared by the California Natural Resources Agency and the California Ocean Protection Council, March 2018.
- Ocean Protection Council (OPC), 2024. *State of California Sea Level Rise Guidance: 2024 Science and Policy Update*. Prepared by California Sea Level Rise Science Task Force, California Ocean Protection Council, California Ocean Science Trust. Accessed online: <https://opc.ca.gov/wp-content/uploads/2024/05/California-Sea-Level-Rise-Guidance-2024-508.pdf>.
- Sweet, W., Hamlington, B., Kopp, R., Weaver, C., Barnard, P., Bekaert, D., Brooks, W., Craghan, M., Dusek, G., Frederikse, T., Garner, G., Genz, A.S., Krasting, J.P., Larour, E., Marcy, D., Marra, J.J., Obeysekera, J., Osler, M., Pendleton, M., Roman, D., Schmied, L., Veatch, W., White, K.D., Zuzak, C., 2022. *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*. NOAA Technical Report NOS 01. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service, 111 pp. Accessed online: <https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf>.