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To: Coastal Commission staff, local planners, and interested parties
From: Carey Batha, Coastal Commission Sea Level Rise Team
Date: Last updated: January 2019

Re: **Summary of the steps for conducting sea level rise vulnerability assessments and practical lessons learned**

Sea level rise and its potential impacts on coastal resources and development are important topics that should be addressed in Local Coastal Program (LCP) updates and new LCPs. The Coastal Commission's 2018 Sea Level Rise Policy Guidance (Guidance) describes the recommended step-by-step process for conducting sea level rise (SLR) vulnerability assessments, specifically in Chapter 5. Please refer to this chapter for a high level of detail on SLR vulnerability assessments.

This memo summarizes key points in Chapter 5 and shares some of the practical lessons that Coastal Commission staff have learned through their recent work with local governments on SLR vulnerability assessments. Consideration of these lessons may help expedite or improve future work by ensuring that the SLR vulnerability assessments are scoped and performed in such a way that effectively supports sea level rise adaptation planning, alternatives analysis, and LCP policy development.

Scoping the Vulnerability Assessment

Before a vulnerability assessment is actually conducted, the scope of the effort will be established. Coastal Commission staff broadly encourages using SLR vulnerability assessments to inform the development of LCPs, and the Guidance recognizes that vulnerability assessments should be tailored to fit the needs of individual communities and address their specific coastal resource and development issues. Below is a summary of the lessons Coastal Commission staff have learned about scoping vulnerability assessments.

PRACTICAL LESSONS LEARNED

- **Leverage existing resources**. Vulnerability assessments often vary in their level of detail for a number of reasons, including the availability of funding, the timing of the study, availability of informational resources, staff capacity, and consultant timelines. When resources are limited, it is important to consider leveraging existing resources to inform or supplement the effort, such as regional SLR models, vulnerability assessments with transferable methodologies, and adaptation strategies and policies that may that may serve as the foundation for more location-specific policy development. It also may be appropriate to include policy language in the LCP update that calls for additional SLR studies and future LCP updates.

- **Include the maximum possible level of detail**. While logistical limitations should be acknowledged, the SLR vulnerability assessment should include the best available information and the maximum level of analysis possible. Furthermore, the SLR vulnerability assessment should, to the extent possible, include the topics that will be addressed specifically in the LCP. Ensuring that the hazards identified in the vulnerability assessment are addressed in LCP policies—and that the subjects of known policy gaps are scoped into the SLR vulnerability assessment—are actually some of the most common challenges in the SLR planning process yet also fundamental to its success.

- **Describe the implications of assumptions in the methodology.** Many vulnerability assessments contain assumptions and/or simplifications in data or methodology. Commonly, the vulnerability assessment will state these assumptions in the methodology section or in an appendix but not explain how those assumptions may have impacted the results of the analysis. Commission staff recommends explaining whether each assumption results in an overestimation or underestimation (or unknown effect) on the physical extent of coastal hazards and the associated community impacts identified in the report. This explanation is important because it may inform how a user of the vulnerability assessment weighs issues related to risk tolerance, the need for trigger-based or adaptive management, the efficacy of potential adaptation measures, or policy development. Therefore, a robust discussion of the implications of assumptions in the methodology should be scoped into the report.

  As an example, a vulnerability assessment that assumes that beach nourishment will continue at the historical rate should explain that this assumption could result in an underestimation of SLR hazards. If nourishment were to stop or become less effective, SLR hazards could be more intense than predicted by the vulnerability assessment.

- **Consider including analysis of fiscal impacts.** Analysis of the fiscal impacts associated with various SLR hazards in the vulnerability assessment is often a critical element needed to support effective decision-making. This information can be used to help compare the costs of alternative adaptation approaches—from engineered solutions to managed retreat. The information can also be a useful communication tool to illustrate the need for proactive adaptation planning to the public, stakeholders, and/or decision makers. See the City of Goleta's *Coastal Hazards and Fiscal Impacts Report* for an example of this type of fiscal analysis.

- **Address deferred analyses.** Some vulnerability assessments might overlook certain issues/geographic areas or earmark them for future analysis, but those issues often constitute the most significant SLR vulnerabilities. If those topics cannot be addressed with the time and resources available, it may be appropriate to identify in the LCP a specific timeline for when those studies will be completed, and to use sunset provisions in certain policies to ensure that the re-examination of the topics is triggered. Similarly, if a vulnerability assessment included assumptions or simplifications in its methodology that limited its results (as described above), it may be appropriate to flag those topics for future analysis and policy development.

- **Ensure maximum public participation, particularly early on**. When scoping a project that includes a SLR vulnerability assessment, opportunities for public participation should be planned, funded, and scheduled with the intent to provide for maximum public input. Of particular importance is ensuring the public and stakeholders have the opportunity to provide input on the project from the start, and that visitors, coastal employees and other affected non-residents are included to the maximum extent feasible. Special effort should also be made to ensure that disadvantaged communities, including low-income, minority, and other underserved communities, have equitable opportunities to engage in the process, and that barriers to participation, such as language, location, and scheduling are addressed. Establishing this partnership early on and providing ongoing opportunities for involvement should facilitate and streamline the next steps in the planning process, including adaptation planning and LCP development. In addition to helping ensure a successful planning process, maximizing public participation is also a central mandate of the Coastal Act.

Step 1: Identify Sea Level Rise Projections

The first step in a vulnerability assessment is to identify sea level rise projections to carry through the analysis, which is discussed at length in the Guidance. Below is a summary of the content included in the Guidance, as well as a list of the lessons Coastal Commission staff have learned about this step.

SUMMARY OF STEP 1 OF CHAPTER 5 OF THE GUIDANCE

- Identify the best available, locally-relevant SLR projections. Currently, the projections stemming from the report entitled *Rising Seas in California* (Griggs et al. 2017), constitute the best available science on SLR projections in California[1]. These projections are now incorporated into both the 2018 State Sea Level Rise Guidance (OPC 2018) and the 2018 Coastal Commission Sea Level Rise Policy Guidance (Guidance).

  Due to local conditions that influence SLR projections, separate sets of SLR projections are provided for 12 locations along the California coast. Users should refer to the set of projections associated with the location nearest to their location of interest. The Coastal Commission Sea Level Rise Policy Guidance provides slightly simplified sets of projections for each of the 12 locations (as compared to the projection in *Rising Seas* and the State Guidance), which can be found in Appendix G of the document. The projections for the San Francisco location are provided below as an example:

[1] Until the publication of *Rising Seas in California* (Griggs et al. 2017), the National Research Council's 2012 report, Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future (NRC 2012) was considered the best available science on SLR projections. Readers who previously used NRC 2012 projections should transition to using the updated projections described here.

Table G-5. **Sea Level Rise Projections for the San Francisco Tide Gauge[110] (OPC 2018)**

Projected Sea Level Rise (in feet): *San Francisco*			
	Probabilistic Projections (in feet) (based on Kopp et al. 2014)		H++ Scenario (Sweet et al. 2017)
	Low Risk Aversion	Medium-High Risk Aversion	Extreme Risk Aversion
	Upper limit of "likely range" (~17% probability SLR exceeds...)	*1-in-200 chance (0.5% probability SLR exceeds...)*	*Single scenario (no associated probability)*
2030	0.5	0.8	1.0
2040	0.8	1.3	1.8
2050	1.1	1.9	2.7
2060	1.5	2.6	3.9
2070	1.9	3.5	5.2
2080	2.4	4.5	6.6
2090	2.9	5.6	8.3
2100	3.4	6.9	10.2
2110*	3.5	7.3	11.9
2120	4.1	8.6	14.2
2130	4.6	10.0	16.6
2140	5.2	11.4	19.1
2150	5.8	13.0	21.9

Most of the available climate model experiments do not extend beyond 2100. The resulting reduction in model availability causes a small dip in projections between 2100 and 2110, as well as a shift in uncertainty estimates (see Kopp et al., 2014). Use of 2110 projections should be done with caution and acknowledgement of increased uncertainty around these projections.

(Coastal Commission Sea Level Rise Policy Guidance, page 297)

- Select planning horizons to examine in the vulnerability assessment (e.g., the years 2030, 2050, and 2100). Analyze time steps out to the year 2100, or further. Once the appropriate planning horizons have been identified, the associated projections for that time period can be identified using the projection tables from Appendix G of the Guidance. These tables include projections for each decade from 2030 to 2150.

  The Coastal Commission recommends that all communities evaluate the impacts from the "medium-high risk aversion" scenario provided in each table in Appendix G. Local governments should also include the "extreme risk aversion" scenario to evaluate the vulnerability of planned or existing assets that have little to no adaptive capacity, that would be irreversibly destroyed or significantly costly to repair, and/or would have considerable public health, public safety, or environmental impacts should that level of sea level rise occur—such as critical infrastructure. Planners may also consider evaluating the lower projections (those with a higher probability) to gain an understanding on what is likely to be vulnerable regardless of modeling uncertainty and future greenhouse gas emissions; or projections associated with particular thresholds of impact.

PRACTICAL LESSONS LEARNED

- **Select SLR scenarios that achieve multiple planning objectives.** Sea level rise scenarios should be selected to complement the planning objectives relevant to the jurisdiction. For example, if a certain SLR scenario is similar to the water elevation used

for the development of the Local Hazard Mitigation Plan, that scenario should be selected for its dual benefits.

- **Consider different approaches.** Note that there are two basic approaches to handling SLR scenarios. One approach is to pick specific *years* to examine and provide ranges of SLR amounts that occur by those years, as shown in the tables of SLR projections in the Guidance (usually focusing on the medium-high and extreme risk aversion scenarios). Another approach is to pick *SLR amounts* to examine, and then deduce the range of years during which that amount of SLR could occur under either the medium-high risk aversion scenario or the extreme risk aversion scenario. Both approaches are effective. There are SLR models and visualization tools that utilize both, so it helps to be aware that both approaches exist. Additionally, it is important to remember that the SLR rates may be updated over time as research on the subject continues. Therefore, SLR vulnerability assessments that examine various SLR amounts should include a caveat that those amounts of SLR could happen sooner or potentially later than predicted by the current best available science.

Step 2: Analyze the physical effects of SLR

The second step in a vulnerability assessment is to analyze the physical effects of SLR, which is discussed at length in the Guidance. Below is a summary of the content in the Guidance, as well as a list of the lessons Coastal Commission staff have learned about this step.

SUMMARY OF STEP 2 OF CHAPTER 5 OF THE GUIDANCE:

- Analyze the following hazards under each SLR scenario:
    - Erosion of beaches, bluffs, cliffs, and other landforms
    - Tidal inundation of shoreline areas
    - Flooding (wave run-up and storm impacts)
    - Saltwater intrusion and groundwater impacts

PRACTICAL LESSONS LEARNED:

- **Use the best available tool for the area**. Several sea level rise visualization tools and datasets are available, but their level of complexity, methodologies, and underlying assumptions differ. It is important to identify the SLR visualization tool with the most advanced and best available methodology. For more information on existing tools, see the "Lifting the Fog" matrix, available here. Contact the Commission's SLR team for more information if you have questions about which tool is best for your area or the assumptions that underlie each tool. It may be appropriate to use an existing SLR visualization tool, but to also recognize its limitations and supplement it with additional analysis to fill those gaps.

- **Distinguish inundation and flooding.** Some vulnerability assessments include storm events (usually a 100-year event) in all of the SLR scenarios selected to be analyzed in the vulnerability assessment. While storms are important to include, the vulnerability assessment should also examine non-storm scenarios in order to provide information on

the "everyday" hazard conditions that may occur in the future with SLR. This analysis is particularly important for understanding future impacts on beaches and other coastal habitats and may lead to different adaptation approaches implemented through the LCP. For example, analysis of non-storm conditions may lead to the development of LCP policies on sediment management and trigger-based managed retreat of existing development and/or zoning changes, whereas analysis of storm flooding may lead to LCP policies that require flood proofing and other flood resiliency measures in areas expected to be impacted by future storm events.

It is also often useful to include storm events of various return periods, such as annual, 10-year, 20-year, and/or 5-year storm events in addition to 100-year storm events in order to understand the hazards associated with storm events that are more common.

- **If possible, integrate the analysis of the various physical hazards**. For example, ensure that flood waters are being projected onto a coastline that reflects the erosion that is projected to occur over time with SLR. (Some SLR visualization tools do not do this.) If it is not possible to integrate these data layers, ensure that the combined effects of these hazards are qualitatively described in the Vulnerability Assessment report, and state whether the mapped hazards constitute a possible underestimation –or overestimation— of the physical extent of hazards.
- **Consider the SLR impacts with and without the presence of existing shoreline protective devices (SPDs) or major pieces of infrastructure**. The "with existing protective devices" scenario should include a description of the impacts of SLR seaward of the device—for example, what would happen to the sandy beach or other coastal land as sea levels rise. The "without existing protective devices" scenario should describe the impacts that would occur in the area, including landward of the device's location, if relevant. Together, these analyses will support alternatives analysis of management and land use options for both the protective device and the structure or area it is protecting.
- **Identify when impacts are expected to occur.** Information on the timing of impacts will become important in the adaptation planning stage, because adaptation strategies need to be implemented with enough lead time to address the hazard. Ideally, SLR vulnerability assessments should discuss the timing of impacts so that adaptation plans can explore the timeframes, funding, and other resources necessary to implement the identified adaptation strategies. This would allow the LCP to define trigger points at which certain policies or programs would be implemented. This discussion should acknowledge that expected SLR rates may change as science and research on the subject advances.

Step 3: Assess Impacts to Community and Environmental Assets

The third step in a vulnerability assessment is to analyze impacts to community and environmental assets, which is discussed at length in the Guidance. Below is a summary of the content in the Guidance, as well as a list of the lessons Coastal Commission staff have learned about this step.

SUMMARY OF STEP 3 OF CHAPTER 5 OF THE GUIDANCE:

- Include assessment of:
    - Coastal Act resources (including but not limited to public access points, beaches, recreational areas, ESHA, wetlands, critical infrastructure, archaeological resources, visual resources, etc.)
    - Changes in tidal, inter-tidal, shoreline and upland habitats
    - Public tidelands
    - Secondary and/or cumulative impacts
    - Specific assets of key local importance to the community, such as popular recreational areas
    - Coastal-dependent development, residential communities or key infrastructure.

PRACTICAL LESSONS LEARNED:

- **Analyze impacts of sea level rise and coastal hazards on environmental justice, disadvantaged and other vulnerable communities**. Vulnerability assessments should determine whether physical hazards and coastal resource impacts from SLR affect certain populations disproportionately. It is important to evaluate not only the impacts upon the local constituency, but also impacts to those who live outside the coastal zone and instead travel there to recreate, work, and/or visit. This analysis should consider how populations are (directly and indirectly) not only affected by vulnerabilities to residential, commercial, and infrastructure assets, but also recreational and other resource assets, including beaches and wetlands. It should also consider how impacts to archeological and cultural resources would impact Native American groups or others, as well as how disproportionate impacts from SLR could exacerbate unequal burdens that already exist due to disproportionate exposure to existing hazards and/or pollution. Finally, the analysis should consider whether the costs and consequences of different adaptation alternatives could fall disproportionately upon certain segments of the population.
- **As described above, analyze the long-term consequences of maintaining existing legally permitted protective devices,** including impacts to the resources that exist seaward of the protective device such as beaches and wetlands. It is critical to analyze the ecological, economic, and other implications of this loss, and identify any associated impacts to public access, recreational opportunities, or other coastal resources. In addition, it is important to understand how long permitted protective devices will remain functional, considering the expected rate of sea level rise, and to analyze the costs of maintenance, repair and potential re-engineering of shoreline armoring that may be needed on an increasingly frequent basis as coastal hazards intensify with sea level rise.
- **Analyze "coastal squeeze" of beaches and other coastal resources.** "Coastal squeeze" refers to the incremental loss of recreational beach area and other shoreline habitats that lie seaward of hardened shorelines due to the inability of these habitats to naturally migrate inland. As mentioned above, exploring the impacts of SLR on beaches, dunes and wetlands, along with the associated impacts to coastal resources like access and recreation, is crucial. These resources are protected by the Coastal Act and comprise important components of coastal economies. If possible, the SLR vulnerability assessment should generate information about the timeframes over which beaches could

be narrowed or lost under different management scenarios –e.g., with and without development preventing the landward migration of the beach; or with or without sediment management practices such as nourishment.

Summary

The information from Steps 1 through 3 comes together to form the basic content of a SLR vulnerability assessment. Again, please consult Chapter 5 of the Guidance for more detailed information on these steps. The Guidance also describes the next phase of the SLR planning process—adaptation planning and LCP policy development—in which adaptation measures are developed to address the identified vulnerabilities.

For more information on sea level rise vulnerability assessments, please consult the 2018 Update to the Sea Level Rise Policy Guidance. Appendix B provides a detailed description of how to perform key analyses relevant to a vulnerability assessment, and Appendix C contains extensive lists of additional resources and examples.

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