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RECOMMENDED SCIENCE UPDATES TO THE CCC SLR POLICY GUIDANCE

AUGUST 9, 2018

EXHIBITS

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California Coastal Commission
Sea Level Rise Policy Guidance

Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits

Sunset Beach, Photo by Mario Fernandez

Chula Vista, Photo by Lisa Cox

San Francisco, Photo by Mike Baird

Arcata, Photo by Humboldt Baykeeper

Draft Science Update – July 2018

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The ***California Coastal Commission Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits*** was **unanimously adopted** by the California Coastal Commission on August 12, 2015.

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SUMMARY OF DOCUMENT REVISIONS

A first draft of this Guidance was released for public review on October 14, 2013. The public comment period was open for 120 days, until February 14, 2014. During that time, the Commission received over 100 comment letters that broke down into over 800 distinct comments. A revised draft was released on May 27, 2015 and presented at the June 2015 Coastal Commission hearing in Newport Beach. Written comments were requested by July 10, 2015, and 28 comment letters were submitted.

On August 12, 2015 the Commission adopted the Recommended Final Draft (dated July 31, 2015 and updated with addenda August 10, 2015) as interpretive guidelines pursuant to Public Resources Code section 30620. The final draft has been posted on the Commission's website and used by the Commission, local governments, project applicants, and other stakeholders since its adoption.

Draft updates have now been developed to address evolving science. Acting on direction from Governor Brown, the Ocean Protection Council has released two reports that update our understanding of sea level rise science and best practices for planning for and addressing anticipated impacts. The first of these reports, *Rising Seas in California: An Update on Sea-Level Rise Science*, synthesizes recent evolving research on sea level rise science, and forms the foundation for the second report, the *State of California Sea-Level Rise Guidance: 2018 Update.* The 2018 OPC SLR Guidance provides higher level recommendations for how to plan for and address sea level rise impacts, notably including a set of projections recommended for use in planning, permitting, investment, and other decisions.

In order to reflect the updated best available science, a set of focused updates for the Coastal Commission SLR Policy Guidance have been developed. These include:

- ***References to best available science throughout the document, including SLR projection tables, which formerly referenced the 2012 NRC Report, have been updated to reference the 2018 OPC SLR Guidance.***
- ***Sections of the Guidance that provided extensive details about the NRC report and/or how to use the information provided within the NRC report (mainly in Chapters 3, 5, and 6 and Appendices A and B) have been removed. In their place, summaries of the Rising Seas science report (2017) and the 2018 OPC SLR Guidance have been added (Chapters 3, 5, and 6, and Appendices A, B, and G).***
- ***Some updates have been made to tables of resources meant to assist interested parties in addressing sea level rise (e.g., SLR mapping and modeling tools, grant funding sources, and agency and other stakeholder guidance). However, these tables have not been exhaustively updated, and additional resources may be available.***

New language throughout the document is shown in bold underline. A clean version of the updated Guidance will be provided after Coastal Commission review and adoption.

How to Use this Document

This document is:	This document is NOT:
Guidance	**Regulations**
This Guidance is advisory and not a regulatory document or legal standard of review for the actions that the Commission or local governments may take under the Coastal Act. Such actions are subject to the applicable requirements of the Coastal Act, the federal Coastal Zone Management Act, certified Local Coastal Programs, and other applicable laws and regulations as applied in the context of the evidence in the record for that action.	
Dynamic	**Static**
This Guidance will be updated periodically to address new sea level rise science, information, and approaches regarding sea level rise adaptation, and new legal precedent. The Commission will also continue working on sea level rise through other projects and in a collaborative manner, as outlined in Chapter 9: Next Steps.	
Multi-purpose for multiple audiences	**Meant to be read cover-to-cover**
This Guidance is a comprehensive, multi-purpose resource and it is intended to be useful for many audiences. As such, it includes a high level of detail on many subjects. However, chapters were written as stand-alone documents to provide usable tools for readers.	
A menu of options	**A checklist**
Since this document is intended for use statewide, it is not specific to a particular geographic location or development intensity (e.g., *urban or rural locations).Therefore, not all of the content will be applicable to all users, and readers should view the content as a menu of options to use only if relevant, rather than a checklist of required actions.*	

Reading Tips

- Look carefully at the Table of Contents and identify sections of interest.
- Do not expect all of the content to apply to your particular situation. As a statewide document, a wide variety of information is included to address the concerns of various users.
- Navigate to your desired level of detail: The *Executive Summary* provides a basic summary of the content; the body of the document provides a detailed discussion; and the *Appendices* provide more scientific and technical detail and a variety of useful resources.

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Commonly Used Acronyms and Agency Names

Terms:

CCT – California Coastal Trail

CDP – Coastal Development Permit

CoSMoS – Coastal Storm Modeling System

ENSO – El Niño Southern Oscillation

ESHA – Environmentally Sensitive Habitat Area

GHG – Greenhouse gas

IPCC – Intergovernmental Panel on Climate Change

LCP – Local Coastal Program

LUP – Land Use Plan

NRC Report – National Research Council Report "*Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*"

PDO – Pacific Decadal Oscillation

SLR – Sea level rise

TNC – The Nature Conservancy

Agency Names:

BCDC – San Francisco Bay Conservation and Development Commission

BOEM – Bureau of Ocean Energy Management

BSEE – Bureau of Safety and Environmental Enforcement

Cal OES – California Governor's Office of Emergency Services

Caltrans – California Department of Transportation

CCC/Commission – California Coastal Commission

CDFW – California Department of Fish and Wildlife

CNRA – California Natural Resources Agency

CO-CAT – Coast and Oceans Climate Action Team

Conservancy – California State Coastal Conservancy

EPA – Environmental Protection Agency

FEMA – Federal Emergency Management Agency

NERR – National Estuarine Research Reserve

NMS – National Marine Sanctuary

NOAA – National Oceanic and Atmospheric Administration

NPS – National Park Service

OPC – California Ocean Protection Council

OPR – California Governor's Office of Planning and Research

State Lands – California State Lands Commission

State Parks – California Department of Parks and Recreation

SWRCB – State Water Resources Control Board

USACE – United States Army Corps of Engineers

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

Executive Summary

Climate change is upon us, affecting almost every facet of California's natural and built environment. Increasing global temperatures are causing significant effects at global, regional, and local scales. In the past century, average global temperature has increased by about 0.8°C (1.4°F), and average global sea level has increased by 7 to 8 in (17 to 21 cm) (IPCC 2013). Sea level at the San Francisco tide gauge has risen 8 in (20 cm) over the past century, and **recent reports developed by the California Ocean Protection Council (OPC) (in conjunction with the OPC Science Advisory Team) project that by the year 2100, sea levels may rise by approximately 2.4 to 6.9 feet, with the potential for rapid ice loss to result in an extreme scenario of 10.2 feet of sea level rise (Griggs *et al.*, 2017; OPC 2018)**. While the California coast regularly experiences erosion, flooding, and significant storm events, sea level rise will exacerbate these natural forces, leading to significant social, environmental, and economic impacts. The third National Climate Assessment notes that there is strong evidence showing that the cost of doing nothing to prepare for the impacts of sea level rise exceeds the costs associated with adapting to them by about 4 to 10 times (Moser *et al*. 2014). Therefore, it is critically important that California plan and prepare for the impacts of sea level rise to ensure a resilient California coast for present and future generations.

The California Coastal Act is one of the state's primary coastal management laws for addressing land use, public access and recreation, and the protection of coast and ocean resources in the coastal zone. It is also the primary coastal hazards law governing development along the coast. Using the Coastal Act, the Coastal Commission and local governments have more than four decades of experience managing coastal development, including addressing the challenges presented by coastal hazards like storms, flooding, and erosion as well as responses to these hazards such as armoring. However, sea level rise and the changing climate present management challenges of a new magnitude, with the potential to significantly threaten many coastal resources, including shoreline development, coastal beach access and recreation, habitats, agricultural lands, cultural resources, and scenic resources, all of which are subject to specific protections and regulations in the Coastal Act. Therefore, effective implementation of the Coastal Act and the protection of California's coast must address global sea level rise and the greater management challenges it will bring.

This document focuses specifically on how to apply the Coastal Act to the challenges presented by sea level rise through Local Coastal Program (LCP) certifications and updates and Coastal Development Permit (CDP) decisions. It organizes current science, technical, and other information and practices into a single resource to facilitate implementation of the Coastal Act by coastal managers at the state and local level. While the document is intended to guide LCP planning and development decisions to ensure effective coastal management actions, it is advisory and does not alter or supersede existing legal requirements, such as the policies of the Coastal Act and certified LCPs. However, one of the Commission's priority goals is to coordinate with local governments to complete and update LCPs in a manner that adequately addresses sea level rise and reflects the recommendations in this Guidance.

This Guidance document is also part of a larger statewide strategy to respond to climate change that includes both emissions reductions and adaption planning to address the impacts of a changing climate. In 2008, Governor Schwarzenegger issued an Executive Order (S-13-08) directing state agencies to consider sea level rise as part of planning projects and to support the preparation of the National Research Council report on sea level rise. Additionally, on April 29, 2015, Governor Brown issued an Executive Order (B-30-15) to establish a new greenhouse gas emission reduction target and called for further action on adaptation. This Guidance is also being coordinated with many statewide initiatives to address climate change and sea level rise, including the 2014 *Safeguarding California* plan (an update to the 2009 *California Adaptation Strategy*; CNRA 2009, 2014), the ongoing update to the *General Plan Guidelines* (Cal OPR 2015), the 2013 update to the California Governor's Office of Emergency Services' (Cal OES) *State Hazard Mitigation Plan*, and others.[1] Commission staff has also been and will continue to participate in multi-agency partnerships, including the Coast and Ocean Workgroup of the multi-state agency Climate Action Team and the *State Coastal Leadership Group on Sea-Level Rise*. For more detail on these efforts, see the Introduction.

PRINCIPLES FOR ADDRESSING SEA LEVEL RISE IN THE COASTAL ZONE

This Guidance is rooted in certain fundamental guiding principles, many of which derive directly from the requirements of the Coastal Act. These Principles broadly lay out the common ideas and a framework by which sea level rise planning and permitting actions can be assessed, and as such represent the goals to which actions should aspire. Individual actions and outcomes may vary based on a variety of factors, including applicable policies and location- or project-specific factors that may affect feasibility. The Guiding Principles are summarized below and discussed in greater detail in Chapter 2.

Use Science to Guide Decisions [Coastal Act Sections 30006.5; 30335.5]

1. Acknowledge and address sea level rise as necessary in planning and permitting decisions.
2. Use the best available science to determine locally relevant and context-specific sea level rise projections for all stages of planning, project design, and permitting reviews.
3. Recognize scientific uncertainty by using scenario planning and adaptive management techniques.
4. Use a precautionary approach by planning and providing adaptive capacity for the highest amounts of possible sea level rise.
5. Design adaptation strategies according to local conditions and existing development patterns, in accordance with the Coastal Act.

Minimize Coastal Hazards through Planning and Development Standards [Coastal Act Sections 30253, 30235; 30001, 30001.5]

6. Avoid significant coastal hazard risks to new development where feasible.
7. Minimize hazard risks to new development over the life of authorized structures.

[1] See the Governor's Office of Planning and Research's webpage for the California Climate Change Document, which includes a matrix of additional efforts.

8. Minimize coastal hazard risks and resource impacts when making redevelopment decisions.
9. Account for the social and economic needs of the people of the state; assure priority for coastal-dependent and coastal-related development over other development.
10. Ensure that property owners understand and assume the risks, and mitigate the coastal resource impacts, of new development in hazardous areas.

Maximize Protection of Public Access, Recreation, and Sensitive Coastal Resources [Coastal Act Chapter 3 policies]

11. Provide for maximum protection of coastal resources in all coastal planning and regulatory decisions.
12. Maximize natural shoreline values and processes; avoid expansion and minimize the perpetuation of shoreline armoring.
13. Recognize that sea level rise will cause the public trust boundary to move inland. Protect public trust lands and resources, including as sea level rises. New shoreline protective devices should not result in the loss of public trust lands.
14. Address other potential coastal resource impacts (wetlands, habitat, agriculture, scenic, *etc.*) from hazard management decisions, consistent with the Coastal Act.
15. Address the cumulative impacts and regional contexts of planning and permitting decisions.
16. Require mitigation of unavoidable coastal resource impacts related to permitting and shoreline management decisions.
17. Consider best available information on resource valuation when mitigating coastal resource impacts.

Maximize Agency Coordination and Public Participation [Coastal Act Chapter 5 policies; Sections 30006; 30320; 30339; 30500; 30503; 30711]

18. Coordinate planning and regulatory decision making with other appropriate local, state, and federal agencies; support research and monitoring efforts.
19. Consider conducting vulnerability assessments and adaptation planning at the regional level.
20. Provide for maximum public participation in planning and regulatory processes.

BEST AVAILABLE SCIENCE AND CONSEQUENCES OF SEA LEVEL RISE

The Coastal Act directs the Coastal Commission and local governments to use the best available science in coastal land use planning and development. This Guidance recommends using the best available science on sea level rise projections to inform planning decisions and project design. **The State of California has long supported the preparation and provision of scientific information on climate change and sea level rise to help guide appropriate and resilient planning, permitting, investment, and other decisions. For example, the State supported the preparation of the 2012 National Research Council's Report, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future*, as well as the 2017 *Rising Seas in California: An Update on Sea-Level Rise Science* (OPC Science Report) and the *State of California Sea-Level Rise Guidance: 2018 Update* (2018 OPC SLR Guidance). The 2018 OPC SLR Guidance contains a set of projections for 12 tide gauges throughout California, and the Coastal Commission recommends using these projections and related information as best available science on sea level rise in California (see Table 1 for the projections at the San Francisco tide gauge, and Appendix G for projections for other tide gauges)**. The Coastal Commission will re-examine best available science periodically and as needed with the release of new information.

In addition to sea level rise projections, the 2012 NRC report, the **2017 OPC Science Report, and the 2018 OPC SLR Guidance** provide information on the impacts of sea level rise in California[2]. According to these reports, sea level rise will cause flooding and inundation, increased coastal erosion, changes in sediment supply and movement, and saltwater intrusion to varying degrees along the California coast. These effects in turn could have a significant impact on the coastal economy and could put important coastal resources and coastal development at risk, including ports, marine terminals, commercial fishing infrastructure, public access, recreation, wetlands and other coastal habitats, water quality, biological productivity in coastal waters, coastal agriculture, and archaeological and paleontological resources.

[2] **Note that while the Coastal Commission now recognizes the 2018 OPC SLR Guidance as best available science, the 2012 NRC Report and other related studies still contain valuable information, and references to these documents and studies throughout this guidance remain relevant and applicable**.

Table 1. **Sea Level Rise Projections for the San Francisco Tide Gauge[3] (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.

[3] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

ADDRESSING SEA LEVEL RISE IN LOCAL COASTAL PROGRAMS

This document provides a step-by-step process for addressing sea level rise and adaptation planning in new and updated Local Coastal Programs. These Steps, summarized below in text and in Figure 1, can be tailored to fit the needs of individual communities and to address the specific coastal resource and development issues of a community, such as dealing with bluff erosion or providing for effective redevelopment, urban infill, and concentration of development in already developed areas. Ideally, Commission and local government staff will establish regular coordination and work together in the early steps of any LCP planning process. For a detailed explanation of these LCP planning Steps, see Chapter 5. Communities in areas where sea level rise vulnerability assessment work is already underway can start later in the process, at Step 4, or other relevant Step(s).

Step 1. **Determine a range of sea level rise projections relevant to LCP planning area/segment** using best-available science, which is currently the **2018 OPC SLR Guidance**.

Step 2. **Identify potential physical sea level rise impacts in the LCP planning area/segment**, including inundation, storm flooding, wave impacts, erosion, and/or saltwater intrusion into freshwater resources.

Step 3. **Assess potential risks from sea level rise to coastal resources and development in the LCP planning area/segment,** including those resources addressed in Chapter 3 of the Coastal Act.

Step 4. **Identify adaptation measures and LCP policy options** to include in the new or updated LCP, including both general policies and ordinances that apply to all development exposed to sea level rise, and more targeted policies and land use changes to address specific risks in particular portions of the planning area.

Step 5. **Draft updated or new LCP for certification with California Coastal Commission**, including the Land Use Plan and Implementing Ordinances.

Step 6. **Implement the LCP and monitor and re-evaluate strategies as needed** to address new circumstances relevant to the area.

Planning Process for Local Coastal Programs and Other Plans

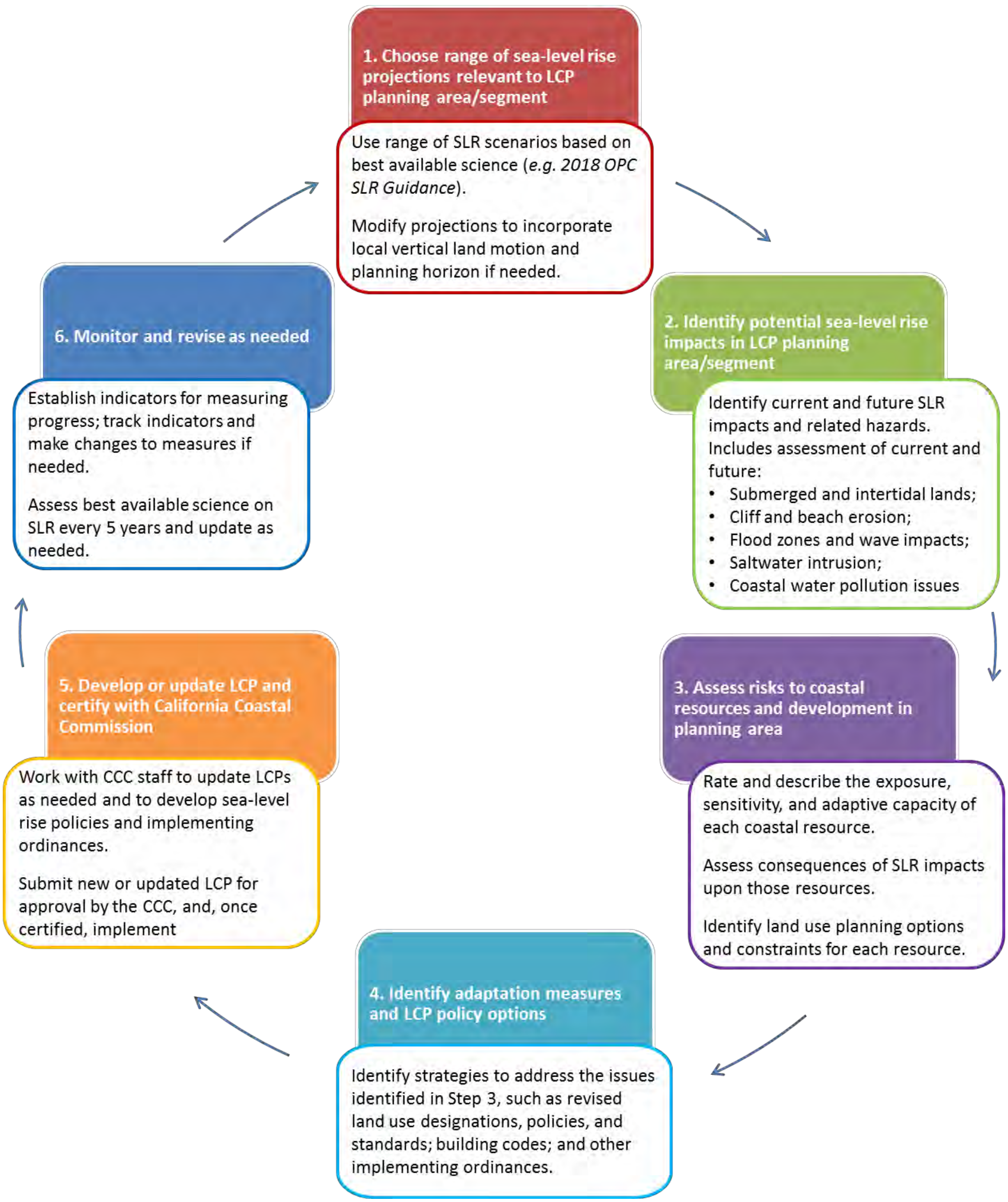

Figure 1. Flowchart for addressing sea level rise in Local Coastal Programs and other plans

ADDRESSING SEA LEVEL RISE IN COASTAL DEVELOPMENT PERMITS

New development within the coastal zone generally requires a Coastal Development Permit (CDP). Many projects reviewed through the CDP application process already examine sea level rise impacts as part of the hazards analysis, though not every CDP application will need to consider sea level rise. In general, sea level rise is only likely to affect those projects that are on low-lying land, on eroding coastal bluffs, are in close proximity to water, or rely upon a shallow aquifer for water supply. This document offers a step-by-step outline, summarized below in text and in Figure 2, for how to conduct such an analysis as a standard part of the CDP application process. The goal of these Steps is to ensure careful attention to minimizing risk to development and avoiding impacts to coastal resources over the life of the project. Early coordination with the Coastal Commission staff is highly recommended, and staff will be available to consult with applicants during this process. Adopting or updating LCPs as recommended in this Guidance should facilitate subsequent review of CDPs. LCPs can identify areas where a closer review of sea level rise concerns is necessary. If kept up to date, they can also provide information for evaluation at the permit stage and specify appropriate mitigation measures for CDPs to incorporate. For a detailed explanation of these steps, see Chapter 6 of this Guidance.

Step 1. **Establish the projected sea level rise range for the proposed project**'s planning horizon using the best available science, which is currently the **2018 OPC SLR Guidance**.

Step 2. **Determine how physical impacts from sea level rise may constrain the project site,** including erosion, structural and geologic stability, flooding, and inundation.

Step 3. **Determine how the project may impact coastal resources, considering the influence of future sea level rise upon the landscape** as well as potential impacts of sea level rise adaptation strategies that may be used over the lifetime of the project.

Step 4. **Identify alternatives to avoid resource impacts and minimize risks** throughout the expected life of the development.

Step 5. **Finalize project design and submit CDP application.**

Planning Process for Coastal Development Permits

1. Establish the projected sea-level rise range for the proposed project

- Determine time period of concern using expected project life.
- Use range of SLR scenarios based on best available science (*e.g. 2018 OPC SLR Guidance*).
- Modify projections to incorporate local vertical land motion and planning horizon if needed.

2. Determine how sea-level rise impacts may constrain the project site

Using locally relevant SLR projections, determine site- or project-specific hazards or impacts for the time period of concern, including current and future hazard impacts. Consider:

- Geologic Stability and Erosion
- Flooding and Inundation
- Wave Impacts
- Other Impacts

3. Determine how the project may impact coastal resources over time, considering SLR

Determine how the project may impact coastal resources (below) considering how SLR may alter the resources over the expected lifetime of the project.

- Public Access and Recreation
- Coastal Habitats
- Agriculture
- Water Quality
- Archaeological/Paleontological resources
- Scenic Resources

4. Identify project alternatives to both avoid resource impacts and minimize risks to the project

- Ideally, locate the project in a site that avoids conflicts with natural resources and SLR impacts
- Alternatively, minimize the likelihood that the project will come into contact with hazards, and design an adaptation strategy for unavoidable impacts.
- Modify project if impacts cannot be avoided
- Summarize these alternatives

5. Finalize project design and submit permit application

Complete the CDP application. Submit the application. Receive permit action. Monitor and revise project as needed.

Figure 2. Flowchart for addressing sea level rise in Coastal Development Permits

ADAPTATION STRATEGIES

Steps 1 through 3 of the processes for addressing sea level rise in LCPs and CDPs will help planners and project applicants identify particular vulnerabilities to the planning region and specific project sites. Such vulnerabilities may include impacts to a number of resources identified in the Coastal Act, including development and infrastructure; public access and recreational opportunities; beaches, wetlands, environmentally sensitive habitat areas (ESHA), and other coastal habitats; agricultural resources; water quality; archaeological and paleontological resources; and scenic and visual resources. Planners and project applicants will need to identify, develop, and implement various adaptation strategies designed to protect coastal resources. These strategies should fulfill the hazard minimization and resource impact avoidance policies of the Coastal Act and should account for local conditions. In many cases, strategies will need to be implemented incrementally as conditions change, and planners, project applicants, and partners will need to think creatively and adaptively to ensure that coastal resources and development are protected over time. Chapter 7 of this Guidance summarizes a number of strategies to protect different coastal resources and meet the goals and requirements of the Coastal Act.

ADDITIONAL INFORMATION

In addition to providing a summary of best available science on sea level rise, step-by-step approaches for addressing sea level rise in LCPs and CDPs, and a discussion of numerous adaptation strategies, the Guidance includes the following supplemental information:

- A brief discussion of the legal context of adaptation
- Next steps for Commission staff in coordination with other relevant partners and research institutions, based on objectives and actions from the Commission adopted *California Coastal Commission Strategic Plan 2013-2018* (2013a)
- Additional research needs directed toward research institutions at academic, state, federal, and local levels to help communities understand and prepare for sea level rise
- Detailed information on the drivers of sea level rise and sea level rise projections
- A step-by-step methodology for assessing local hazard conditions based on regional sea level rise projections, which is applicable to both LCPs and CDPs
- Lists of useful resources and references, including examples of sea level rise adaptation documents from other state agencies
- Key Coastal Act policies relevant to sea level rise and coastal hazards

CONTEXT OF THIS DOCUMENT

This Guidance is part of a larger body of work on climate change by State agencies, regional collaborations, local leadership, academic research, and other organizations. Many of these efforts are included as resources in Appendix C. Users of the document should take advantage of these existing resources, collaborate with others, and share best practices as much as possible.

Finally, this document is intended to function as interpretive guidance for effective implementation of the Coastal Act and LCPs in light of sea level rise. It is not a regulatory document and does not contain any new regulations. Further, it does not amend or supersede existing legal authorities or the standard of review for Local Coastal Programs and coastal development permit decisions pursuant to the Coastal Act. Those actions are subject to the applicable requirements of the Coastal Act, the Coastal Zone Management Act, certified LCPs, and other applicable laws and regulations as applied in the context of the evidence in the records for those actions. The Commission is adopting this Guidance as interpretive guidelines pursuant to its authority under Public Resources Code Sections 30620.

Chapter 1

Introduction

Climate change is happening now. Rapidly melting ice caps, rising sea levels, floods, extreme heat waves, droughts, and fires are just a few of the effects of climate change. These effects are having profound impacts on our coast and are changing coastal management planning and decision making at global, national, state, regional, local, and individual scales.

Given current trends in greenhouse gas emissions, sea levels are expected to rise at an accelerating rate in the future, and scientists project an increase in California's sea level in coming decades. Until mid-century, the most damaging events for the California coast will likely be dominated by large El Niño-driven storm events in combination with high tides and large waves. Eventually, sea level will rise enough that even small storms will cause significant damage, and large events will have unprecedented consequences (Caldwell *et al*. 2013).

This Guidance provides a framework for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs). The intended audience for this document includes the Commission and Commission staff, local governments, other public agencies, permit applicants, members of the public, and others who are interested in how to implement and comply with the California Coastal Act (Coastal Act) while taking steps to address sea level rise.

ENVIRONMENTAL, ECONOMIC, AND SOCIAL IMPACTS OF SEA LEVEL RISE

The potential environmental, economic, and social impacts of sea level rise in California underscore the importance of addressing the issue in land use planning and regulatory work. Just over 21 million people lived in California's coastal counties as of July 2014 (CDF 2014), and the state supports a $40 billion coastal and ocean economy (NOEP 2010).

Many aspects of the coastal economy, as well as California's broader economy, are at risk from sea level rise, including coastal-related tourism, beach and ocean recreational activities, transfer of goods and services through ports and transportation networks, coastal agriculture, and commercial fishing and aquaculture facilities.

In addition to potential losses in revenue, Heberger *et al.* (2009) estimate that $100 billion worth of property is at risk of flooding during a 100-year coastal flood with 4.6 ft (1.4 m) of sea level rise (the amount projected to occur by the year 2100 in their Pacific Institute study). This property includes seven wastewater treatment plants, commercial fishery facilities, marine terminals, Coastal Highway One, 14 power plants, residential homes, and other important development and infrastructure.

Sea level rise also poses environmental and social justice challenges. This is particularly true for communities that may be dependent upon at-risk industries, are already suffering from economic hardship, or which have limited capacity to adapt, including lower-income, linguistically isolated, elderly, and other vulnerable populations.

Proactive steps are needed to prepare for sea level rise and to protect the coastal economy, California livelihoods, and coastal resources and the ecosystem services they provide. The magnitude of the challenge is clear – not only might the impacts of sea level rise be severe, the costs and time associated with planning for them can be daunting. The third National Climate Assessment, released in May 2014, notes that there is strong evidence to suggest that the costs of inaction are 4 to 10 times greater than the costs associated with proactive adaptation and hazard mitigation (Moser *et al*. 2014). It is critical for California to take proactive steps to address the impacts sea level rise may have on the state's economy, natural systems, built environment, human health, and ultimately, its way of life.

SEA LEVEL RISE AND THE CALIFORNIA COASTAL ACT

The potential impacts of sea level rise fall directly within the Coastal Commission's (and coastal zone local governments') planning and regulatory responsibilities under the Coastal Act. Sea level rise increases the risk of flooding, coastal erosion, and saltwater intrusion into freshwater supplies, which have the potential to threaten many of the resources[4] that are integral to the California coast, including coastal development, coastal access and recreation, habitats (*e.g.*, wetlands, coastal bluffs, dunes, and beaches), coastal agricultural lands, water quality and supply, cultural resources, community character, and scenic quality. In addition, many possible responses to sea level rise, such as construction of barriers or armoring, can have adverse impacts on coastal resources. For example, beaches, wetlands, and other habitat backed by fixed or permanent development will not be able to migrate inland as sea level rises, and will become permanently inundated over time, which in turn presents serious concerns for future public access and habitat protection.

The Coastal Act mandates the protection of public access and recreation along the coast, coastal habitats, and other sensitive resources, as well as providing priority visitor-serving and coastal-dependent or coastal-related development while simultaneously minimizing risks from coastal hazards. This Guidance document has been created to help planners, project applicants, and other interested parties continue to achieve these goals in the face of sea level rise by addressing its effects in Local Coastal Programs and Coastal Development Permits. Although the focus of the Guidance is on LCPs and CDPS, much of the information contained herein can be useful for other planning documents such as Port Master Plans[5], Long Range Development Plans, and Public Works Plans. For example, the science applies regardless of the planning documents, and the discussions of how to analyze sea level rise impacts as well as a number of adaptation options may be applicable. In all cases, specific analyses performed and actions implemented will vary based on relevant policies, local conditions, feasibility, and other factors as described throughout the rest of this document.

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[4] The term "coastal resources" is used throughout this Guidance and is meant to be a general term for those resources addressed in Chapter 3 of the California Coastal Act including but not limited to beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities.

[5] Ports are generally subject to Chapter 8 of the Coastal Act. The policies of Chapter 8 acknowledge the special role and needs of ports and differ in significant ways from the Chapter 3 policies of the Act. Significant categories of development in ports, however, remain subject to Chapter 3, including categories of development listed as appealable pursuant to Section 30715 and development located within specified wetlands, estuaries, and recreation areas.

Coastal Commission reports and briefings on sea level rise: Sea level rise is not a new concern for the Commission. The Coastal Act policies on hazard avoidance and coastal resource protection provide the basis for the Commission to consider the impacts of sea level rise (see *Appendix F: Coastal Act Policies Relevant to Sea Level Rise and Coastal Hazards*), and the Commission has long considered sea level rise, erosion rates, and other effects of a dynamic climate in its analysis of permits and LCPs, staff recommendations, and Commission decisions. In 1992, Section 30006.5 was added to the Coastal Act which, among other things, directs the Commission to both develop its own expertise and interact with the scientific community on various technical issues, including coastal erosion and sea level rise. The Commission's staff also coordinates its work on sea level rise with other state and federal agencies, local governments, academic institutions, non-profit organizations, citizen groups, permit applicants, property owners, and others.

The Commission has documented its sea level rise adaptation and climate change efforts in numerous papers and briefings, including:

- 1989 Report: *Planning for Accelerated Sea Level Rise along the California Coast*
- 2001 Report: *Overview of Sea Level Rise and Some Implications for Coastal California*
- 2006 Briefing: *Discussion Draft: Global Warming and the California Coastal Commission*
- 2008 Briefing: *A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues for a Briefing to the Coastal Commission*
- 2008 White paper: *Climate Change and Research Considerations*
- 2010 Briefing: *A Summary of the Coastal Commission's Involvement in Sea Level Rise Issues for a Briefing to the Coastal Commission*[6]
- **2015 Report: *CCC Sea Level Rise Policy Guidance* *(Adopted)***
- **2016 Report: *CCC Statewide Sea Level Rise Vulnerability Synthesis***
- **2016 Briefing: *Implementation of the Adopted Sea Level Rise Policy Guidance***

The Importance of Addressing Sea Level Rise in Local Coastal Programs

The impacts of sea level rise will be felt at the local level, and therefore local responses will necessarily be part of effective management of these impacts. Fortunately, the California Coastal Act lays out a legal and planning framework for community climate preparedness and resiliency planning. LCPs, in combination with Coastal Development Permits (CDPs), provide the implementing mechanisms for addressing many aspects of climate change within coastal communities at the local level.

The goal of updating or developing a new LCP to prepare for sea level rise is to ensure that adaptation occurs in a way that protects both coastal resources and public safety and allows for

[6] Verbal presentation to the Coastal Commission on December 17, 2010 by Susan Hansch (Item 4.5). This presentation can be viewed at the Cal-Span website (<http://www.cal-span.org/media.php?folder[]=CCC>) from approximately minute 22.00 to 24:30.

sustainable economic growth. This process includes identifying how and where to apply different adaptation mechanisms based on Coastal Act requirements, other relevant laws and policies, acceptable levels of risk, and community priorities. LCP and Coastal Act policies are also reflected in CDPs, which implement sea level rise management measures and adaptation strategies through individual development decisions. By planning ahead, communities can reduce the risk of costly damage from coastal hazards, can ensure the coastal economy continues to thrive, and can protect coastal habitats, public access and recreation, and other coastal resources for current and future generations.

The Coastal Commission has made it a priority to support the update of LCPs to address climate change, as demonstrated by Goal 3 of the Commission's *Strategic Plan* (CCC 2013a), which is to "address climate change through LCP planning, coastal permitting, inter-agency collaboration, and public education." Specifically, Objective 3.1.1 directs the Commission to "adopt general sea level rise (SLR) policy guidance for use in coastal permitting and LCP planning and amendment based on best available science…." This Guidance document fulfills Objective 3.1.1 and is one of multiple ongoing Commission efforts to support local governments in updating LCPs to address sea level rise.

Funding for LCP updates: Both the *California Climate Adaptation Strategy* (CNRA 2009) and the *Safeguarding California* plan (CNRA 2014) identified amendments to LCPs as a key strategy for addressing sea level rise in California. However, there are significant funding constraints at both the Commission and local government levels that limit the capacity to update LCPs. Fortunately, three grant programs have recently been funded to support California local governments in updating LCPs to address sea level rise. These grant programs have partially overlapping objectives, as described below. Grant-related information as of the publication of this Guidance is summarized below. For up-to-date information regarding grants, please visit the Local Assistance Grant Program page on the Coastal Commission website.

- **Coastal Commission LCP Local Assistance Grant Program:** This grant program provides funding to local governments to complete the certification of new and updated LCPs, with an emphasis on addressing impacts from sea level rise and climate change. For fiscal years (FY) 2013/14 and 2014/15, the Coastal Commission received $1 million per year ($2 million total) in local assistance funds for the LCP Grant Program. In January 2014, the Coastal Commission awarded $1 million in LCP Grant funds to 11 jurisdictions throughout the state. In November 2014, the Coastal Commission awarded $1 million to 12 jurisdictions. This second round of funding was coordinated through a joint application and review process with the OPC LCP Sea Level Rise Grant program (below) in order to maximize funding opportunities. **Funding of $3 million was provided in Commission's FY 2015/16 Budget. This funding was awarded in two additional grant rounds to a total of 21 jurisdictions. Additional funding from the State's Greenhouse Gas Reduction Fund is provided in the Commission's FY 2017/18 and 2018/19 budgets for this grant program; however funding has not yet been awarded.**

- **Ocean Protection Council LCP Sea Level Rise Grant Program:** The OPC grant program includes $2.5 million to support local governments in updating LCPs to address sea level rise, including support of sea level rise modeling, vulnerability assessments, and adaptation planning and policy development. The OPC is administering the program in partnership with the Coastal Commission and the Coastal Conservancy. In November 2013, the OPC awarded $1,305,000 to seven jurisdictions based on recommendations from the three coordinating agencies. The remaining funds were awarded to seven jurisdictions in the second round of the grant program in December 2014. This second round of funding was coordinated through a joint application and review process with the Coastal Commission Grant Program, as described above.

- **State Coastal Conservancy Climate Ready Grant Program:** The Climate Ready Grant Program provides funding for climate change-related projects including projects to update LCPs to address sea level rise. **Through three rounds of grants, the Conservancy has awarded $7.3 million for 42 projects. Additional funding is available for this program through the Greenhouse Gas Reduction Fund for projects that use nature-based solutions to adapt to the impacts of climate change.**

Coastal Commission Staffing Increase to Support LCP planning: Governor Brown and the California Legislature also approved temporary augmentations to the Coastal Commission's FY 2013/2014, FY 2014/15 and FY 2015/16 budgets of $3 million for state operations and 25 additional authorized positions for Coastal Commission staff to work with local governments to prepare, update, amend, and review LCPs with an emphasis on including climate change issues. **In FY 2016/17, the $3 million in funding was included in the Commission's baseline budget, effectively making the additional $3 million for state operations and 25 authorized positions a permanent part of the Commission's budget.**

COASTAL RESILIENCY AND PREPARING FOR SEA LEVEL RISE: THE FEDERAL AND STATE CONTEXT

Sea level rise planning efforts are currently taking place at the local, regional, state, and national levels. Framing the efforts in California is a federal strategy to address climate change by both reducing greenhouse gas emissions and adapting to climate change impacts. Recent efforts promoted by the White House include President Obama's January 2015 Executive Order 13960, which modifies Executive Order 11988, Floodplain Management, by expanding the federal approach for establishing flood risk to include the consideration of climate change. Specifically, it recommends using a new flood standard that accounts for climate change in establishing flood elevation and hazard areas when federal funds are used to build, significantly retrofit, or repair structures.

Additionally, Governor Brown, Supervisor Carbajal (Santa Barbara County), Mayor Garcetti (Los Angeles), and Mayor Johnson (Sacramento) **were on President Obama's** State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, which recently released recommendations for how to modernize programs and policies to incorporate climate change.[7] The Coastal Commission's Guidance document implements many of the Task Force's recommendations by providing tools and assistance to support sea level rise decision making, by establishing a framework for state, local, and federal partnership and coordination on sea level

[7] https://obamawhitehouse.archives.gov/administration/eop/ceq/initiatives/resilience/taskforce

rise, and by providing guidance on how to improve the resilience of California's coastal infrastructure, natural resources, human communities, and coastal industries.

The State of California has long been a leader in preparing for sea level rise, and in 2008, Governor Schwarzenegger issued an Executive Order (S-13-08) directing state agencies to prepare guidance on sea level rise and to address sea level rise in any state projects located in vulnerable areas. Since then, state agencies have worked collaboratively to accomplish a variety of different actions related to sea level rise adaptation, many of which are listed below. Ten state and federal agencies[8] also commissioned the National Research Council's report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (2012), to improve understanding of sea level rise projections for California.

More recently, Governor Brown's April 2015 Executive Order B-30-15 addresses climate change and sea level rise adaptation, stating that state agencies shall take climate change into account in their planning and investment decisions. The order requires agencies to ensure that priority is given to actions that build climate preparedness and reduce greenhouse gas emissions, provide flexible and adaptive approaches, protect the state's most vulnerable populations, and promote natural infrastructure solutions. Additionally, AB2516, authored by Assemblymember Gordon and approved in September 2014, established a Planning for Sea Level Rise Database that is anticipated to be available online in early 2016. The database will provide the public with an educational tool from which to learn about the actions taken by cities, counties, regions, and various public and private entities to address sea level rise.

Much of the state's climate change adaptation work has been coordinated with the *Coast and Ocean Workgroup* of the *Climate Action Team* (CO-CAT), of which the Commission is a member. In addition, Commission staff has been involved in the *State Coastal Leadership Group on Sea-Level Rise*, which was established in early 2014 to develop and implement coordinated approaches to address sea level rise across state agencies. The partnership includes senior management from the Coastal Zone Management Agencies (Coastal Commission, San Francisco Bay Conservation and Development Commission, and State Coastal Conservancy) and land management agencies (State Lands Commission and State Parks) along with the Ocean Protection Council and Natural Resources Agency. This Guidance is being coordinated closely with this work[9] to ensure that various initiatives do not conflict and to assure an effective response to challenges such as sea level rise.

To that end, the content of this Guidance is aligned with several key concepts in the *Safeguarding California* plan, including hazard avoidance for new development, encouraging innovative designs and adaptation strategies for structures in areas vulnerable to sea level rise hazards, and addressing climate impacts in Local Coastal Programs and General Plan updates,

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[8] The assessment of sea level rise was commissioned by California Department of Water Resources, California Energy Commission, California Department of Transportation, California State Water Resources Control Board, California Ocean Protection Council, Oregon Watershed Enhancement Board, Washington Department of Ecology, National Oceanic and Atmospheric Administration (NOAA), US Army Corps of Engineers (USACE), and US Geological Survey (USGS).

[9] See the Governor's Office of Planning and Research's webpage for the California Climate Change Document which includes a matrix of additional efforts. Available at: http://opr.ca.gov/s_publications.php

among many others. *Safeguarding California* also calls out the need for state agencies to produce guidance documents addressing climate adaptation, and this sea level rise Guidance is part of the statewide effort to fulfill that mandate. As *Safeguarding California* promotes, this Guidance will be a living document that will be updated and revised as sea level rise science advances and new insights are gained regarding adaptation.

State agency policies and guidance on climate change and sea level rise: As a result of the Executive Order S-13-08 and agency needs for guidance, many state agencies have developed climate change and sea level rise policies and guidance documents. For example:

- The California Natural Resources Agency (CNRA) developed the 2009 *California Climate Adaptation Strategy* and the 2014 and **2018** updates (*Safeguarding California)*
- CNRA and the Governor's Office of Emergency Services (Cal OES) collaboratively developed the *California Climate Adaptation Planning Guide* (2012)
- The Governor's Office of Planning and Research is updating its *General Plan Guidelines* to address climate change (a draft update is anticipated in 2015)
- The Ocean Protection Council established *State Sea-Level Rise Guidance* (interim, 2010, and update, 2013) and passed a *State Sea-Level Rise Resolution* (March 11, 2011)
- The San Francisco Bay Conservation and Development Commission (BCDC) amended the *San Francisco Bay Plan* (1968) to update its policies regarding sea level rise (2011) and has been working on actions to reduce vulnerability to sea level rise throughout the San Francisco Bay through the Adapting to Rising Tides (ART) project
- The California State Coastal Conservancy (Conservancy) established climate change policies, application guidelines for sea level rise, and climate ready principles (2011)
- Cal OES updated the State Multi-Hazard Mitigation Plan in 2013
- The California Department of Transportation (Caltrans) developed guidance on incorporating sea level rise into the planning and development of Project Initiation Documents (2011), and how to address adaptation in Regional Transportation Plans (2013), and has completed numerous other climate change related activities

Other agencies including the California Department of Parks and Recreation and the California State Lands Commission are in the process of developing guidance. The California Department of Fish and Wildlife, the Division of Boating and Waterways, and the Department of Water Resources are all actively addressing sea level rise and have taken steps to conduct research on sea level rise impacts, integrate sea level rise into planning documents, and educate staff on climate change impacts (see Appendix C for a description of these efforts).

Other efforts: Sea level rise planning efforts taking place at all levels of government and across numerous sectors helped inform this Guidance. Commission staff reviewed scientific publications on sea level rise and climate change, adaptation guidebooks, and existing adaptation principles and best practices described in documents such as *Indicators of Climate Change in California* (Cal EPA 2013), *Adapting to Sea Level Rise: A Guide for California's Coastal Communities* (Russell and Griggs 2012), *Climate Smart Conservation: Putting Adaptation Principles into Practice* (Stein *et al.* 2014), *Ecosystem Adaptation to Climate Change in*

California: Nine Guiding Principles (RLF 2012), and *Climate Smart Principles* (PRBO 2013), and applied relevant information to the Guidance where applicable and consistent with the Coastal Act.

LOOKING AHEAD: PLANNING AND PROJECT DESIGN WITH SEA LEVEL RISE

The coast has always been a place of change due to land modifications such as erosion and vertical land motion, and to water variability such as tides, waves, and storms. Despite this dynamic nature, many areas of the California coast have been developed with an expectation that there will be some permanence to the land area and site safety. Development efforts have used such techniques as setbacks, avoidance of existing floodplain areas, elevation above some base flood level, and compliance with design standards to reduce or minimize coastal risks and to ensure an acceptable level of safety.

However, hazards are rarely eliminated or avoided completely. Sea level rise will exacerbate existing hazards and reduce the period of time over which some existing development can remain relatively safe. As noted in *Governing California through Climate Change,* "The notion of stable, predictable geography in which to live, work and build permanent buildings will be off the table in decades ahead" (Little Hoover Commission 2014, p. 2). Locations that might have seemed relatively safe from erosion or flooding 20 or 30 years ago may now be shown to have greater vulnerability due to sea level rise. Sites that might have seemed safe for 80 or 100 years might now only be safe for 40 or 50 years.

As coastal change accelerates, it will become more apparent that development close to the coast cannot be treated in the same way as more inland development, where hazardous conditions may be less dynamic. Coastal dynamics have long been part of land use planning considerations and project design; however, the focus on this change will grow in importance with rising sea level. This may mean that as properties are evaluated for proposed development, the type and intensity of the proposed development may need to change to address the dynamic nature of the property and changing nature of the hazards. As coastal areas erode, the carrying capacity of the area may need to be revised. The trend of redeveloping with additions and larger structures may need to change to one of maintaining what is there or redeveloping with smaller structures that better suit site constraints. The changing expectations are an important aspect of sea level rise adaptation and are an important part of the following discussions on how to include sea level rise in Local Coastal Programs, applications for Coastal Development Permits, and adaptation planning.

Sea level rise is one of many climate change effects that will have impacts on coastal resources and development along the California coast. Accelerated coastal erosion, changing precipitation patterns, increasing temperatures, and more extreme storms will pose planning challenges in concert with sea level rise. There are other climate change impacts in the coastal zone, such as changes in water supply, terrestrial habitats, and fire hazards, that are also important to consider in decision making, and the Commission intends to provide guidance on a range of anticipated climate change impacts in the future.

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Chapter 2

Principles for Addressing Sea Level Rise in the Coastal Zone

This chapter summarizes the Coastal Commission's framing principles for addressing sea level rise, many of which derive directly from the requirements of the Coastal Act. These principles broadly lay out the common ideas and a framework by which sea level rise planning and permitting actions can be assessed, and as such, represent the goals to which actions should aspire. Individual actions and outcomes may vary based on a variety of factors, including applicable policies and location- or project-specific factors that may affect feasibility. There are four categories of principles: using science to guide decisions; minimizing coastal hazards through planning and development standards; maximizing protection of public access, recreation, and sensitive coastal resources; and maximizing agency coordination and public participation. Each category groups important and related concepts that are central to addressing the challenge of rising sea levels. Building on the cumulative knowledge and experience of the Commission, subsequent chapters of this Guidance use these principles to frame practical guidance for addressing sea level rise through planning and permitting decisions in the coastal zone, consistent with the statewide policies of the California Coastal Act as well as the statewide vision of climate resilience outlined in the 2014 *Safeguarding California* plan.

USE SCIENCE TO GUIDE DECISIONS [Coastal Act Sections 30006.5; 30335.5]

1. **Recognize and address sea level rise as necessary in planning and permitting decisions.** Address sea level rise science in all applicable coastal management and decision-making processes, including Local Coastal Programs (LCPs), Port Master Plans (PMPs), Public Works Plans (PWPs), Long Range Development Plans (LRDPs), Coastal Development Permits (CDPs), federal consistency reviews, and other Coastal Act decision processes. Sea level rise should be addressed in both hazard analyses and identification of adaptation strategies/alternative analyses, consistent with the policies of the Coastal Act and LCPs as applicable[10].

2. **Use the best available science to determine locally relevant (context-specific) sea level rise projections and potential impacts for all Coastal Act planning processes, project design, and permitting reviews.** Sea level rise science continues to evolve, and some processes that are not fully understood (*e.g.*, ice sheet dynamics) could potentially have large effects on future sea level rise. **At the time of this 2018 update, the best available science on sea level rise in California is the 2018 OPC Guidance, *State of California Sea-Level Rise Guidance: 2018 Update*** (See Table 2 and **Appendix G**). As discussed in greater detail in Chapter 3 of this Guidance, these projections should be used in a scenario-based analysis

[10] This Guidance document is intended to help implement the Coastal Act and LCPs in the context of sea level rise concerns. However, the standard of review for Commission actions remains the California Coastal Act or applicable certified LCPs. In particular, the recommendations of this Guidance do not constitute "enforceable policies" for purposes of CZMA federal consistency reviews. The enforceable policies for conducting federal consistency reviews will remain the policies of Chapter 3 of the Coastal Act. Also, for federal agency activities, the standard is consistency "to the maximum extent practicable," with Chapter 3, *i.e.*, federal agency activities must be fully consistent unless existing law applicable to the federal agency prohibits full consistency. See 15 CFR. §§ 930.32 and 930.43(d). However, the Commission looks at sea level rise as one part of determining the coastal effects from an activity through CZMA federal consistency reviews and the use of this Guidance by all parties should help determine what those coastal effects may be or how effects from sea level rise may be mitigated. Pursuant to 15 CFR § 930.11(h), implementation of this guidance would not be grounds for an objection (because it is not an "enforceable policy") but it might be one means that "would allow the activity to be conducted consistent with the enforceable policies of the program" in order to avoid an objection.

to identify potential local impacts from sea level rise, incorporating storms, extreme water levels, and shoreline change. Other authoritative sea level science and projections may also be used, in part or in full, provided they are peer-reviewed, widely accepted within the scientific community, and locally relevant.

The Commission will re-examine the best available science periodically and as needed with the release of new information on sea level rise.[11] In addition, Commission staff intends to submit a periodic status report to the Commission describing updates on the best available science and adaptation practices, and any potential recommended changes to the Guidance document.

3. **Recognize and address scientific uncertainty using scenario planning and adaptive management techniques.** Given the uncertainty in the magnitude and timing of future sea level rise, particularly over longer time periods, planners and project designers should use scenario-based analysis to examine a range of possible shoreline changes and sea level rise risks to shape LCPs and other plans and project development designs. As appropriate, development projects, resource management plans, and LCP and other planning updates should incorporate an adaptive management framework with regular monitoring, reassessments, and dynamic adjustment in order to account for uncertainty.

4. **Use a precautionary approach by planning and providing adaptive capacity for the highest amounts of possible sea level rise.** LCPs and CDPs should analyze the highest projections of sea level rise in order to understand the implications of a worst case scenario. In some cases, it may be appropriate to *design* for the local hazard conditions that will result from more moderate sea level rise scenarios, as long as decision makers and project applicants *plan* to implement additional adaptation strategies if conditions change more than anticipated in the initial design. Similar to the recommendation in the Ocean Protection Council's 2011 *State Sea-Level Rise Resolution* **as well as the 2018 OPC SLR Guidance, the Commission does not recommend using values solely from the lower end of the ranges** as this does not give a full picture of the risks. Looking instead at both the high and low projections allows users to build an understanding of the overall risk sea level rise poses to the region or site.

5. **Design adaptation strategies according to local conditions and existing development patterns, in accordance with the Coastal Act.** Design adaptation strategies using best management practices for adaptation, and tailor the design to the specific conditions and development patterns of the area, in accordance with the Coastal Act and certified LCPs. LCPs should continue to serve as a key implementing mechanism for these adaptation strategies. Adaptation strategies should be evaluated for their ability to both minimize hazards and protect coastal resources.

[11] Major scientific reports include the release of National and State Climate Assessments, IPCC Assessment Reports, and/or State guidance.

Table 2. **Sea Level Rise Projections for the San Francisco Tide Gauge[12] (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.

[12] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Minimize Coastal Hazards through Planning and Development Standards

[Coastal Act Sections 30253; 30235; 30001, 30001.5]

6. **Avoid significant coastal hazard risks to new development where feasible.** Section 30253 of the Coastal Act requires new development to minimize risks to life and property in areas of high geologic and flood hazard. The strongest approach for minimizing hazards is to avoid siting new development within areas vulnerable to flooding, inundation, and erosion, thus ensuring stable site conditions without the need for long-term financial and resource commitments for protective devices. Methods to direct new development away from hazardous locations are included in Chapter 7 of this Guidance.

7. **Minimize hazard risks to new development over the life of the authorized development.** Coastal Act Section 30253 requires that new development minimize coastal hazard risks without the use of bluff retaining or shoreline protection devices that would substantially alter natural landforms. When hazards from sea level rise cannot be avoided, new development should include provisions to ensure that hazard risks are minimized for the life of the development without shoreline protection, including through future modification, relocation, or removal when they become threatened by natural hazards, including sea level rise.

8. **Minimize coastal hazard risks and resource impacts when making redevelopment decisions.** LCPs should encourage and require, as applicable, existing at-risk structures to be brought into conformance with current standards when redeveloped. Improvements to existing at-risk structures should be limited to basic repair and maintenance activities and not extend the life of such structures or expand at-risk elements of the development, consistent with the Coastal Act.
9. **Account for the social and economic needs of the people of the state, including environmental justice; assure priority for coastal-dependent and coastal-related development over other development.** In planning and project development concerning sea level rise, assure that the social and economic needs of the people of the state are accounted for in accordance with Coastal Act Section 30001.5(b), with special consideration for working persons employed within the coastal zone (Coastal Act Section 30001(d)). Recognize that low-income communities are less equipped to prepare for and respond to the impacts of sea level rise and ensure that LCP and CDP decisions account for environmental justice concerns and include low-income persons and communities in planning efforts.

10. **Ensure that property owners understand and assume the risks, and mitigate the coastal resource impacts, of new development in hazardous areas.** Property owners should assume the risks of developing in a hazardous location (often referred to as internalizing risk). They should be responsible for modifying, relocating or removing new development if it is threatened in the future. Any actions to minimize risks to new development should not result in current and/or future encroachment onto public lands or in impacts to coastal resources inconsistent with the Coastal Act. LCPs and Coastal Development Permits should require recorded assumptions of risk, "no future seawall" conditions, and/or other appropriate mitigation measures to internalize risk decisions with the private land owner.

MAXIMIZE PROTECTION OF PUBLIC ACCESS, RECREATION, AND SENSITIVE COASTAL RESOURCES [Coastal Act Chapter 3 policies]

11. **Provide for maximum protection of coastal resources in all coastal planning and regulatory decisions.** New and existing development, redevelopment, and repair and maintenance activities as well as associated sea level rise adaptation strategies should avoid or minimize impacts to coastal resources, including public access, recreation, marine resources, agricultural areas, sensitive habitats, archaeological resources, and scenic and visual resources in conformity with Coastal Act requirements. Impacts from development and related activities should be avoided or minimized; unavoidable impacts should be mitigated as necessary.

12. **Maximize natural shoreline values and processes; avoid expansion and minimize the perpetuation of shoreline armoring.** If existing development (both private and public) is threatened by sea level rise hazards, it should employ the least environmentally damaging feasible alternatives and minimize hard shoreline protection. Priority should be given to options that enhance and maximize coastal resources and access, including innovative nature-based approaches such as living shoreline techniques or managed/planned retreat. If traditional hard shoreline protection is necessary and allowable under the Coastal Act, use the least-environmentally damaging feasible alternative, incorporate projections of sea level rise into the design of protection, and limit the time-period of approval, for example, to the life of the structure the device is protecting. Major renovations, redevelopment, or other new development should not rely upon existing shore protective devices for site stability or hazard protection. Where feasible, existing shoreline protection that is no longer being relied upon in this way, or no longer needed otherwise, should be phased out.

13. **Recognize that sea level rise will cause the public trust boundary to move inland. Protect public trust lands and resources, including as sea level rises. New shoreline protective devices should not result in the loss of public trust lands.** Where allowed under the Coastal Act or the relevant LCP, shoreline protective devices should be sited, designed, and conditioned to ensure that they do not result in the loss of public trust lands[13] or encroach onto public trust lands without the permission of the appropriate trustee agency. When sea level rise causes the public trust boundary to move inland such that a protective device that was located on uplands becomes subject to the public trust, the permittee should either obtain permission from the appropriate trustee agency for the encroachment or apply for a permit to remove any encroachments.

14. **Address potential secondary coastal resource impacts (to wetlands, habitat, agriculture, scenic and visual resources, *etc.*) from hazard management decisions, consistent with the Coastal Act.** Actions to address sea level rise in LCPs or permits should not exacerbate other climate-related vulnerabilities or undermine conservation/protection goals and broader ecosystem sustainability. For example, siting and design of new development should not only

[13] The State holds and manages all tidelands, submerged lands, and beds of navigable waterways for the benefit of all people of the State for statewide purposes consistent with the common law Public Trust Doctrine ("public trust"). In coastal areas, the landward location and extent of the State's trust lands are generally defined by reference to the ordinary high water mark, as measured by the mean high tide line. Public trust uses include such uses as maritime commerce, navigation, fishing, boating, water-oriented recreation, and environmental preservation and restoration.

avoid sea level rise hazards, but also ensure that the development does not have unintended adverse consequences that impact sensitive habitats or species in the area.

15. **Address the cumulative impacts and regional contexts of planning and permitting decisions.** Sea level rise will have impacts at both the site-specific and regional scales. In addition to the evaluation of site-specific sea level rise impacts, LCPs and projects should include an evaluation of the broader region-wide impacts, in two different contexts. First, the LCP or project should consider how sea level rise impacts throughout an entire littoral cell or watershed could affect the LCP jurisdiction or project. Second, the LCP or project should consider how options to adapt to sea level rise could result in cumulative impacts to other areas in the littoral cell or watershed. Actions should be taken to minimize any identified impacts.

16. **Require mitigation of unavoidable coastal resource impacts related to permitting and shoreline management decisions.** Require mitigation for unavoidable public resource impacts over the life of the structure as a condition of approval for the Coastal Development Permit. For example, for impacts to sand supply or public recreation due to armoring and the loss of sandy beach from erosion in front of shoreline protection devices, require commensurate in-kind mitigations, a sand mitigation fee, and other necessary mitigation fees (for example, public access and recreation mitigation). Because the longer term effects can be difficult to quantify, especially given uncertainty about the exact rate of future sea level rise, consider requiring periodic re-evaluation of the project authorization and mitigation for longer term impacts.

17. **Consider best available information on resource valuation when planning for, managing, and mitigating coastal resource impacts.** Planning, project development, and mitigation planning should evaluate the societal and ecosystem service benefits of coastal resources at risk from sea level rise or actions to prepare for sea level rise. These benefits can include flood protection, carbon sequestration, water purification, tourism and recreation opportunities, and community character. Resource values can be quantified through restoration costs or various economic valuation models.

MAXIMIZE AGENCY COORDINATION AND PUBLIC PARTICIPATION [Coastal Act Chapter 5; Sections 30006; 30320; 30339; 30500; 30503; 30711]

18. **Coordinate planning and regulatory decision making with other appropriate local, state, and federal agencies; support research and monitoring efforts.** Given the multitude of sea level rise planning, research, and guidance efforts occurring in California, it is critical for agencies and organizations to share information, coordinate efforts, and collaborate where feasible to leverage existing work efforts and improve consistency. Additionally, since many sea level rise hazards affect multiple jurisdictions, their management may also need to be coordinated through multi-agency reviews and coordinated decision making. The Commission will continue to meet this goal through coordination, engagement with stakeholders, and trainings. However, ongoing financial support for these Commission efforts is critical.

19. **Consider conducting vulnerability assessments and adaptation planning at the regional level**. Where feasible, local governments should coordinate vulnerability assessments and adaptation planning with other jurisdictions in the region that face common threats from sea level rise. A regional vulnerability assessment provides an opportunity to evaluate impacts that span multiple jurisdictions, assess and implement regional adaptation strategies, coordinate responses, and leverage research and planning funds.

20. **Provide for maximum public participation in planning and regulatory processes.** The Coastal Commission will continue to provide avenues for maximum public participation in planning and regulatory processes, and will continue to establish and/or expand non-traditional alliances (*e.g.*, between/among public and private resource managers, tribal groups, scientists, decision makers), share knowledge openly and actively, and regularly and clearly communicate to the public on the science as well as on a range of solutions to prepare for sea level rise.

This document and its guiding principles both reflect and complement the priorities outlined in the State of California's climate adaptation strategy, the 2014 *Safeguarding California* plan. While this Guidance specifically focuses on the California Coastal Act and the regulatory work of the Coastal Commission, it also echoes key concepts in *Safeguarding California* that apply statewide. For example, a central theme in *Safeguarding California* is to provide risk reduction measures for California's most vulnerable populations, something that is addressed here in Guiding Principle #9. Similarly, this Guidance and *Safeguarding California* both emphasize the use of best available science (Guiding Principle #2) and the need for communication, outreach, and public participation to increase understanding of climate risks and adaptation options (Guiding Principle #20).

Safeguarding California's Coast and Oceans chapter also states that "new development and communities must be planned and designed for long-term sustainability in the face of climate change," which captures a central purpose and focus of this Guidance. It goes on to specify that "California must ensure public access to coastal areas and protect beaches, natural shoreline, and park and recreational resources" and "the state should not build or plan to build, lease, fund, or permit any significant new structures or infrastructure that will require new protection from sea level rise, storm surges or coastal erosion during the expected life of the structure, beyond routine maintenance of existing levees or other protective measures, unless there is a compelling need." Again, these values are reflected here, as Guiding Principles #6 and #12. In these ways, and through the shared goal of ensuring planning for and resilience against climate change impacts, the two documents are readily consistent and complementary.

Chapter 3

Sea Level Rise Science

This chapter provides information on sea level rise science and covers the following subjects:

- The best available science on sea level rise
- Using scenario-based analysis in response to sea level rise projection ranges
- The physical impacts of sea level rise
- Storms, extreme events, and abrupt change

Sea level rise science continues to evolve, and the discussion below reflects the best available science at the time this document was published.

BEST AVAILABLE SCIENCE ON SEA LEVEL RISE

Scientists widely agree that the climate is changing and that it has led to global increases in temperature and sea level. In the past century, global mean sea level (MSL) has increased by 7 to 8 in (17 to 21 cm; IPCC 2013). It is extremely likely (>95% probability of occurrence) that human influence has been the dominant cause of the observed warming of the atmosphere and the ocean since the mid-20th century (IPCC 2013).

There are a number of methods for projecting future changes in global sea level, including using extrapolations from historical trends and observations, estimations from physical models, and combinations of observations and modeling, known as semi-empirical methods. For a detailed description of these techniques, see Appendix A.

Scientists also measure sea level change at a variety of scales, from the global down to the local level. For example, the sea level rise projections in Intergovernmental Panel on Climate Change (IPCC) reports are based on large scale models that give global projections. But sea level does not change uniformly around the globe, so modifications for local conditions are necessary for adaptation planning.

In particular, global average sea level rise is driven by the expansion of ocean waters as they warm, the addition of freshwater to the ocean from melting land-based ice sheets and glaciers, and from extractions in groundwater (Figure 3). However, regional and local factors such as tectonics and ocean and atmospheric circulation patterns result in relative sea level rise rates that may be higher or lower than the global average. As such, global-scale models are often "downscaled" through a variety of methods to provide locally relevant data.

For California, **the 2018 OPC SLR Guidance, described below, provides sea level rise projections that have been refined for 12 tide gauges throughout California**. More detailed refinement of sea level rise projections is not considered necessary at this time, **as variations from the nearby tide gauges will often be quite small, and may be insignificant compared to other sources of uncertainty**[14]. It is important to note, though, that while the sea level rise projections are fairly similar throughout the state, the physical impacts may be quite different,

[14] **Although the Commission believes that the OPC Guidance projections can be used without modification, it recognizes that other studies exist with localized data, for example those completed in the Humboldt Bay region, which may also be appropriate for use**.

and locally-specific analysis of impacts will be very important. Detail on physical impacts and how to assess them is provided in Section C of this chapter and in Appendix B.

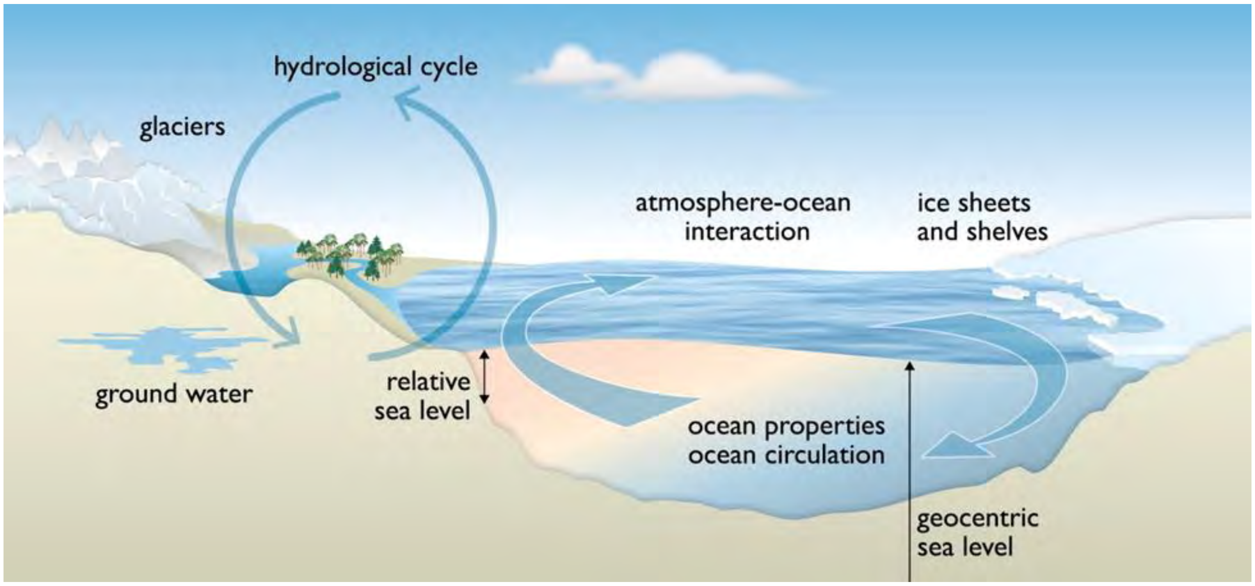

Figure 3. Climate-sensitive processes and components that can influence global and regional sea level. Changes in any one of the components or processes shown will result in a sea level change. The term "ocean properties" refers to aspects such as temperature, salinity, and density, which influence and are dependent on ocean circulation. (*Source*: IPCC 2013, Figure 13.1)

Global Sea Level Rise Projections

The IPCC 5th Assessment Report (AR5), which was released in September 2013, is the most recent global scale assessment of sea level rise. The report projects a rise in *global* average sea level by 10-39 in (26 to 98 cm) by the year 2100 (relative to mean sea level from 1985 to 2005) depending on the emissions scenario[15] (Figure 4). These projections are about 50% higher than the projections from the IPCC 4th Assessment Report (AR4, released in 2007). This is because the IPCC changed the climate model inputs between AR4 and AR5. In particular, much of the increase in the amount of sea level rise projected in the AR5 is due to the inclusion of sea level rise resulting from the loss of ice sheets. Ice sheet dynamics were not included in the AR4, but enhancements in physical models that account for such ice sheet dynamics have allowed for a better understanding and greater confidence in this input, and as such were included in the AR5[16].

[15] See Appendix A for more detail on emissions scenarios and the IPCC reports.

[16] Many of the other reports and studies cited in this Guidance used the AR4 as a reference (and for this reason detail on the AR4 is included in Appendix A). It is important to note, though, that while these other reports relied on the AR4 scenarios and model outputs for some climatic changes, many (*e.g.*, the *National Climate Assessment* (Melillo *et al*. 2014) and the NRC (2012) reports highlighted below) accounted for the loss of ice sheets through the use of semi-empirical models or other methods, further honing their results.

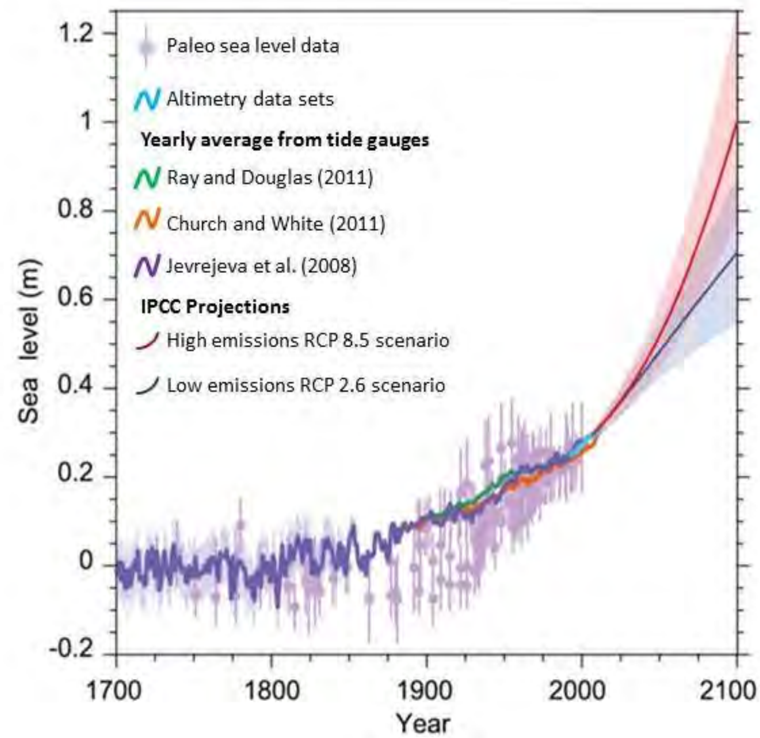

Figure 4. Past and projected future sea level trends (IPCC). Compilation of paleo sea level data, tide gauge data, altimeter data, and central estimates and likely ranges for projections of global mean sea level rise for low emissions RCP2.6 (blue) and high emissions RCP8.5 (red) scenarios, all relative to pre-industrial values. (*Source*: IPCC 2013, Figure 13.27)

National Sea Level Rise Projections

The third National Climate Assessment (NCA; Melillo *et al.*) was released in May 2014, and includes the current best-available science on climate change and sea level rise at the *national* scale[17]. The sea level rise projections in the NCA were informed by the 2012 NOAA report titled *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris *et al.* 2012). This report provides a set of four global sea level rise scenarios ranging from 8 in to 7 ft (0.2 to 2.0 m) by the year 2100 (using mean sea level in 1992 as a baseline) reflecting different amounts of future greenhouse gas emissions, ocean warming and ice sheet loss (Figure 5). The low and intermediate-low scenarios assume very significant reductions in greenhouse gas emissions, and limited changes in ocean warming and ice sheet loss. The intermediate-high scenario is based on the average of the high projections from semi-empirical models, which are based on the highest IPCC 4th Assessment Report (AR4; 2007) emissions scenario (A1FI).[18] The

[17] **Note that the 4th National Climate Assessment is due to be released in late 2018.** https://www.globalchange.gov/nca4

[18] The IPCC emissions scenarios make assumptions about future changes in population growth, future economic growth and the introduction of clean and efficient technology. The A1FI scenario assumes continued intensive use of fossil fuels, high economic growth, and low population growth that peaks mid-century. The B1 scenario assumes significant reduction in fossil fuel use, an increase in clean technologies, and the same low population growth that peaks mid-century. The A1F1 yields the highest CO_2 emissions by 2100 and the B1 scenario yields the lowest.

highest scenario (2.0 m) combines the IPCC AR4 projections with the maximum possible ice sheet melt that could occur by 2100. Given the recent studies that suggest that glacier and ice sheet loss could contribute significantly to rising sea levels (*e.g.*, Rahmstorf 2007; Vermeer and Rahmstorf 2009; IPCC 2013; McMillan *et al*. 2014; Morlighem *et al*. 2014) and evidence that current greenhouse gas emissions are tracking with intermediate IPCC AR4 scenarios (Rahmstorf *et al*. 2012), the low and intermediate-low scenarios likely underrepresent future sea level rise unless demonstrable reductions in global greenhouse gas emissions occur soon.

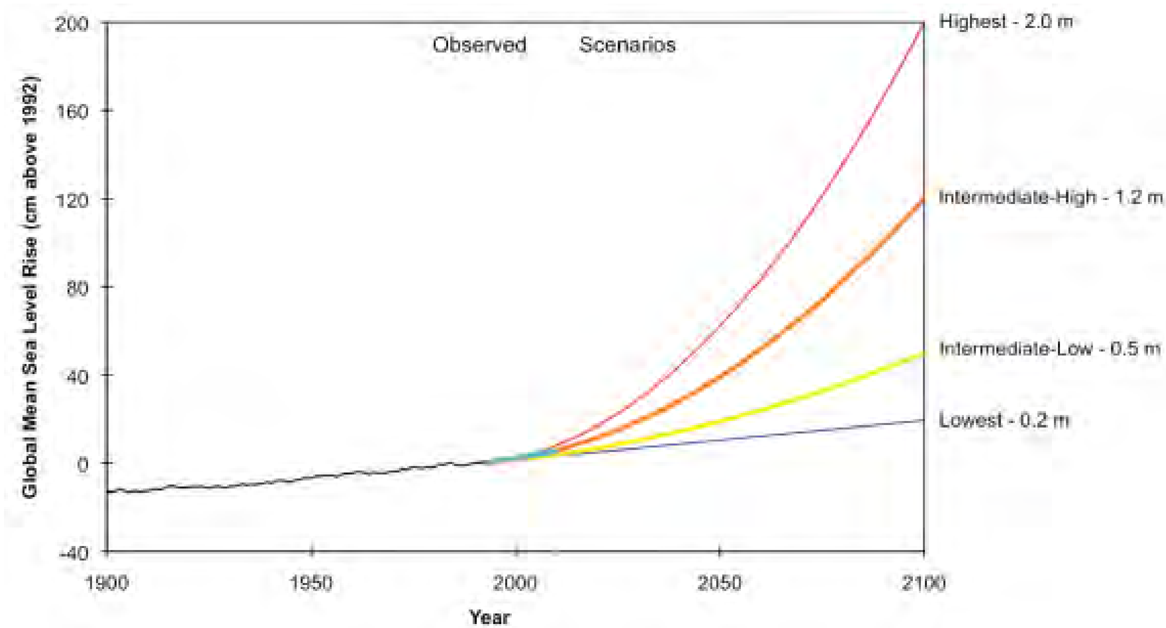

Figure 5. Observed and projected future sea level rise scenarios (Melillo *et al.* 2014). Global mean sea level rise scenarios used in the *US National Climate Assessment*. The Intermediate High Scenario is an average of the high end of ranges of global mean SLR reported by several studies using semi-empirical approaches. The Intermediate Low Scenario is the global mean SLR projection from the IPCC AR4 at 95% confidence interval. (*Source: Global Sea Level Rise Scenarios for the United States National Climate Assessment (*Parris *et al*. 2012))

Sea Level Rise Projections for California

Tide gauges and satellite observations show that in the past century, mean sea level in California has risen 8 in (20 cm), keeping pace with global rise. **For the early portion of the 21st century (through approximately 2011)**, mean sea level in California remained relatively constant, and may have been suppressed due to factors such as offshore winds and other oceanographic complexities. Bromirski *et al*. (2011, 2012) postulated that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors could offset the global sea level rise trend in this region. However, localized sea level suppression will not continue indefinitely. As the Pacific Decadal Oscillation, wind, and other conditions shift, California sea level will continue rising (NRC 2012; Bromirski *et al.* 2011, 2012). **Indeed, satellite altimetry data shows that sea level along the west coast of the United Sates has increased over the past five years, and studies suggest that the shift in sea level in the Pacific Ocean will likely persist in the coming years, leading to substantially higher sea level off the west coast of the United States and lower sea level in the western tropical Pacific (Hamlington *et al.*, 2016).**

The State of California has undertaken significant research to understand how much sea level rise to expect over the coming decades and the likely impacts of such sea level rise. In 2013, the Ocean Protection Council (OPC) recognized the National Research Council (NRC) report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future*, as best available science for the State of California, and recommended in its 2013 State Sea-Level Rise Guidance that state agencies and others use these projections in their planning processes. Likewise, when the Coastal Commission initially adopted this Sea Level Rise Policy Guidance in 2015, it recommended using the NRC report as best available science.

The NRC Report presents sea level rise projections in ranges due to several sources of uncertainty. One significant source of uncertainty is over future greenhouse gas emissions: researchers cannot know the amount or rate of greenhouse gases emissions that will be generated over the coming decades. Large-scale curtailment of greenhouse gas emissions would keep sea level rise towards the lower end of the projections, while business as usual emissions scenarios would result in the higher end of the projections. Because the rate of future greenhouse gas emissions is dependent on global policy decisions, researchers use various climate models that account for different emissions scenarios (business as usual, with little reduction in the current rate of greenhouse gas emissions; large-scale emissions reductions that begin in the near future; and various intermediate scenarios).

A second significant source of uncertainty is related to the dynamics of ice sheet loss. This topic has continued to be extensively researched since the NRC report was published, and recent studies have since informed updated statewide guidance. In April 2017, a Working Group of the Ocean Protection Council's Science Advisory Team released a report synthesizing current sea level rise science. The report, titled *Rising Seas in California: An Update on Sea-Level Rise Science*, presents advances in sea level rise modeling, notably including improved understanding of the processes that could drive extreme global sea level rise from ice loss from the Greenland and Antarctic ice sheets. A significant finding from this report is that Antarctic ice sheet loss could have an outsized impact on sea level rise in California compared to the global average due to ocean circulation dynamics. Further, the report states that rapid ice sheet loss could result in upwards of 10 feet of sea level rise along the California coast by 2100 (this scenario is referred as an "extreme scenario" or "H++ scenario" throughout the OPC Science Report and this Guidance).

The Science Report also includes new "probabilistic projections" which associate a likelihood of occurrence with the sea level rise amounts and rates. These probabilistic projections are based on the probabilities that the ensemble of climate models used to estimate contributions of sea level rise (from thermal expansion, ice sheet loss, oceanographic conditions, and other relevant factors) will predict a certain amount of sea level rise. A critical caveat is that these probabilistic projections did not account for the most recent science regarding the potential for rapid ice sheet loss, and therefore may underestimate the probability of higher sea level rise scenarios. It is understood that as inputs to climate models change (based on evolving science for example), so too will the probabilities associated with different projections.

OPC incorporated these findings into updates to their 2013 State Sea-Level Rise Guidance. The new *State of California Sea-Level Rise Guidance: 2018 Update* (2018 OPC SLR Guidance) contains projections for 12 tide gauges throughout California (to account for localized variations in vertical land motion and other factors) for each decade from 2030 to 2150. The projection table for the San Francisco tide gauge is provided below in Table 3, and the projection tables for the other tide gauges can be found in Appendix G. The tables are adapted from the 2018 OPC SLR Guidance, and present the three scenarios that OPC recommends for use in planning, permitting, investment, and other decisions. These scenarios include:

1. ***Low risk aversion scenario:* the upper value for the "likely range" (which has approximately a 17% chance of being exceeded); may be used for projects that would have limited consequences or a higher ability to adapt.**
2. ***Medium-high risk aversion scenario:* the 1-in-200 chance (or 0.5% probability of exceedance); should be used for projects with greater consequences and/or a lower ability to adapt.**
3. ***Extreme risk aversion (H++):* accounts for the extreme ice loss scenario (which does not have an associated probability at this time); should be used for projects with 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.**

In accordance with this statewide guidance, the Coastal Commission considers the 2018 OPC Sea-Level Rise Guidance (and the related 2017 Rising Seas science report) as the best available science on sea level rise in California, and recommends using the above scenarios in relevant Coastal Commission planning and permitting decisions.[19] More information on which scenarios to use in certain circumstances can be found in Chapters 5 and 6. The Commission will continue to periodically re-examine and update sea level rise projections as they evolve with the release of new scientific reports and information on local and regional sea level trends. Additionally, as sea level rise science continues to evolve, equivalent resources may be used by local governments and applicants provided the sources are peer-reviewed, widely accepted within the scientific community, and locally relevant.

The Coastal Commission will be using and recommends that local governments and applicants use best available science, currently identified as the projections provided in the 2018 OPC Sea-Level Rise Guidance (Table 3; Appendix G), in all relevant local coastal planning and coastal development permitting decisions.

[19] **Note that while the Coastal Commission now recognizes the 2018 OPC SLR Guidance as best available science, the 2012 NRC Report and other related studies still contain valuable information, and references to these documents and studies throughout this guidance remain relevant and applicable.**

Table 3. **Sea Level Rise Projections for the San Francisco Tide Gauge[20] (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.

[20] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

USING SCENARIO-BASED ANALYSIS IN RESPONSE TO SEA LEVEL RISE PROJECTION RANGES

Despite the recent advances in sea level rise science, sea level rise projections, **including those in the 2018 OPC SLR Guidance** (Table 3; Appendix G) and other state, national, and global reports, are typically presented in ranges due to several sources of significant uncertainty.

The two primary sources of uncertainty in global sea level projections include:

1) Uncertainty about future greenhouse gas emissions and concentrations of sulfate aerosols, which will depend on future human behavior and decision making, and
2) Uncertainty about future rates of land ice loss (NRC 2012; McMillan *et al*. 2014; Morlighem *et al*. 2014; Griggs *et al.* 2017; OPC 2018).

Additionally, the further into the future sea level rise is projected, the greater the uncertainty (and therefore the range in projections) becomes. This occurs because the longer the projection period, the greater the likelihood that models will deviate from the actual impacts of climate change (NRC 2012) **and the more dependent projections become on the trajectory of greenhouse gas emissions (OPC 2018). This is reflected in the projections included in the 2018 OPC SLR Guidance, which includes single values for the years 2030, 2040, and 2050, but projections for both low and high emissions scenarios in 2060 and beyond. According to the 2018 OPC SLR Guidance, near-term sea level rise has been locked in by past greenhouse gas emissions whereas sea-level rise over the longer-term will become increasingly dependent on efforts to curtail greenhouse gas emissions**.

This Guidance recommends using scenario-based analysis to address the uncertainty in sea level projections. Scenario-based analysis (or planning) refers to the idea of developing multiple scenarios from which to analyze vulnerabilities, generate new ideas and adaptation options, and/or test strategies. In the context of this Guidance, scenario-based analysis includes choosing several possible sea level rise amounts as a starting point to evaluate impacts to coastal resources and potential risks to development over time. This type of scenario-based approach is useful because it reveals the full range of possible consequences of sea level rise that can be reasonably expected for particular regions or sites according to the best available science. Additionally, a scenario-based analysis helps to reveal the tipping points indicating if or when sea level rise will become a serious issue in a particular location. In many cases, using multiple sea level rise scenarios will help to hone in on the types of hazards for which to prepare.

In general, the Coastal Commission recommends using best available science **(currently the 2018 OPC SLR Guidance) to identify a range of sea level rise scenarios, including the low, medium-high, and, as appropriate, extreme risk aversion scenario**[21]. In practice, the process for choosing scenarios and performing scenario-based analysis will be slightly different for LCP

[21] Similar to the recommendation in the OPC's 2011 *State Sea-Level Rise Resolution,* **as well as the 2018 OPC SLR Guidance**, the Commission does not recommend using projections solely from the lower end of the ranges, as this does not give a full picture of the risks. Looking instead at a range of projections allows users to build an understanding of the overall risk sea level rise poses to the region or site.

planning and CDP applications due to the different planning goals and levels of technical detail required for each.

For a Local Coastal Program (LCP), the general goal is to assess the potential impacts from sea level rise over the entire planning area and over a range of time horizons so that both short and long term adaptation strategies can be identified and implemented. Another important facet of LCP planning is identifying locations that are particularly vulnerable so that additional, more detailed studies can be performed if necessary, and adaption options and actions can be prioritized. Scenario-based analysis in the context of LCP planning includes choosing a range of sea level rise projections to analyze so as to understand the best and worst case scenarios and to identify amounts of sea level rise and related conditions that would trigger severe impacts and the associated time period for when such impacts might occur. Choosing sea level rise scenarios in the context of LCP planning is described in greater detail in Chapter 5.

In the context of a Coastal Development Permit (CDP) application, the goal is to understand how sea level rise will impact a specific site and a specific project over its expected lifetime so as to ensure that the proposed development is safe from hazards and avoids impacts to coastal resources. Thus, in the context of a CDP, it is important to identify the amounts of sea level rise that could result in effects to a particular site as well as the time period(s) over which those effects could occur so that the proposed development can be safely sited and designed to avoid resource and development impacts. However, some sites will be completely safe from sea level rise under even the highest projection scenarios, while others will depend on the timing and magnitude of sea level rise to determine safety. Therefore, scenario-based planning analysis can be used as a screening process to identify if and when sea level rise might become a problem. Identifying sea level rise scenarios in the context of CDPs is described in greater detail in Chapter 6.

Overall, scenario-based planning should help planners make reasonable and informed decisions about whether their projects or plans are compatible with the local hazards influenced by sea level rise, and identify the types of adaptation measures that might be appropriate given the local circumstances and requirements of the Coastal Act. By exploring the range of future scenarios based on the best available science, users of this document can make decisions based on full understanding of possible future hazards, ultimately achieve outcomes that are safer for both development and coastal resources, and avoid costly damages to projects.

For more information on scenario-based planning in the context of LCPs and CDPs see Chapters 5 and 6, respectively. A number of additional resources related to scenario-based planning are available, including a handbook from the National Park Service (2013) and guidance from Point Blue Conservation Science and the California Coastal Conservancy (Moore *et al*. 2013). See Appendix C for these and other resources related to scenario-based analysis and adaptation planning.

PHYSICAL EFFECTS OF SEA LEVEL RISE

Continued and accelerated sea level rise will have widespread adverse consequences for California's coastal resources (See summary in Figure 8). The main physical effects of sea level rise include increased flooding, inundation, wave impacts, coastal erosion, changes in sediment dynamics, and saltwater intrusion. These impacts are interrelated and often occur together. Absent any preparatory action, an increase in sea level may have serious implications for coastal resources and development, as described in Chapter 4. In addition, these physical effects could have disproportionate impacts on vulnerable communities that have lower capacity to adapt.

Physical effects from sea level rise to the coastal zone include the following:

- **Flooding and inundation:** Low lying coastal areas may experience more frequent flooding (temporary wetting) or inundation (permanent wetting), and the inland extents of 100-year floods may increase. **Only a 10 cm rise in sea level could double the flooding potential along the west coast in locations such as San Francisco and Los Angeles (Vitousek *et al*. 2017)**. Riverine and coastal waters come together at river mouths, coastal lagoons, and estuaries, and higher water levels at the coast may cause water to back up and increase upstream flooding (Heberger *et al*. 2009). Drainage systems that discharge close to sea level could have similar problems, and inland areas may become flooded if outfall pipes back up with salt water. In addition, other climate change impacts such as increases in the amount of precipitation falling as rain rather than snow will add to river flooding in some areas.
- **Wave impacts:** Wave impacts can cause some of the more long-lasting consequences of coastal storms, resulting in high amounts of erosion and damage or destruction of structures. The increase in the extent and elevation of flood waters from sea level rise will also increase wave impacts and move the wave impacts farther inland. Erosion rates of coastal cliffs, beaches, and dunes will increase with rising sea level and are likely to further increase if waves become larger or more frequent (NRC 2012).
- **Erosion:** Large sections of the California coast consist of oceanfront bluffs that are often highly susceptible to erosion. With higher sea levels, the amount of time that bluffs are pounded by waves would increase, causing greater erosion (NRC 2012). This erosion could lead to landslides and loss of structural and geologic stability of bluff top development such as homes, infrastructure, the California Coastal Trail, Highway 1, and other roads and public utilities. The Pacific Institute (Heberger *et al*. 2009) estimated that 41 square miles (106 square km) of coastal land from the California-Oregon border through Santa Barbara County could be lost due to increased erosion with 4.6 ft (1.4 m) of sea level rise by the year 2100, and approximately 14,000 people now live in those vulnerable areas. Increased erosion will not occur uniformly throughout the state. Dunes in Humboldt County could erode a distance of approximately 2000 ft (nearly 600 m) by the year 2100 (Heberger *et al*. 2009; Revell *et al*. 2011). **In southern California, higher sea level rise could result in a two-fold increase in bluff retreat rates over historic rates, causing a total land loss of 62 – 135 feet by 2100 (Limber *et al.* 2018 (in press)**. Man-made structures like dikes and levees may also be impacted by erosion, increasing flooding risk of the areas protected by those structures, such as low-lying agricultural land. Over the long term, rising sea levels will also cause landward migration of beaches due to the combined effects inundation and loss of sediment due to erosion (NRC 2012).

Figure 6. Photo of Esplanade Apartments threatened by cliff erosion in 2013 in Pacifica, CA. (*Source: California Coastal Records Project*)

- **Changes in beaches, sediment supply and movement:** Sediment is important to coastal systems in, for example, forming beaches and mudflats and as the substrate for wetlands. Sea level rise will result in changes to sediment availability. Higher water levels and changing precipitation patterns could change erosion and deposition patterns. Loss of sediment could worsen beach erosion and possibly increase the need for beach nourishment projects (adding sand to a beach or other coastal area), as well as decrease the effectiveness and long-term viability of beach nourishment if sand is quickly washed away after being placed on a beach (Griggs 2010). **Shoreline change models predict that by 2100, 30 to 67% of Southern California beaches may be completely lost due to rising sea level (Vitousek *et al.* 2017)**. Sediment supplies in wetland areas will also be important for long-term marsh survival. Higher water levels due to sea level rise, however, may outpace the ability of wetlands to trap sediment and grow vertically (Titus 1988; Ranasinghe *et al*. 2012; Van Dyke 2012).
- **Saltwater intrusion and rising groundwater:** An increase in sea level could cause saltwater to enter into groundwater resources, or aquifers. Existing research suggests that rising sea level is likely to degrade fresh groundwater resources in certain areas, but the degree of impact will vary greatly due to local hydrogeological conditions. Generally, the most vulnerable hydrogeological systems are unconfined aquifers along low-lying coasts, or aquifers that have already experienced overdraft and saline intrusion. In California, saline intrusion into groundwater resources is a problem in multiple areas, including but not limited to the Pajaro Valley (Hanson 2003), Salinas Valley (Hanson *et al*. 2002a; MCWRA 2012), Oxnard Plain (Izbicki 1996; Hanson *et al*. 2002b), and the heavily urbanized coastal plains of Los Angeles and Orange Counties (Edwards and Evans 2002; Ponti *et al*. 2007; Nishikawa *et al*. 2009; Barlow and Reichard 2010). Groundwater sources for coastal agricultural lands may also be susceptible to saltwater intrusion. **Sea level rise can also result in higher groundwater, presenting another source of flood rise (Hoover *et al.* 2016).**

STORMS, EXTREME EVENTS, AND ABRUPT CHANGE

Much of the California coast is currently vulnerable to flooding and wave damage during large storm events, and even more of the coast is vulnerable to storm impacts when they occur during times of heightened water levels, such as high tides, El Niño events, a warm phase of the Pacific Decadal Oscillation, or a combination of these factors. Sea level rise will increase vulnerability to storms even more because rising water levels will result in more areas being impacted.

Climate change will likely modify or change much more than just sea level. One potential climate change-related impact that will interact most directly with sea level rise hazards is a change in frequency or intensity of coastal storms (storminess) and extreme events. The extremes associated with high-intensity events may be particularly devastating since they have the potential to cause broad-scale damage, as seen from recent events such as Hurricanes Katrina and Rita, Superstorm Sandy, and the Tohoku tsunami. Abrupt change in sea levels is another potential impact of climate change. Both potential impacts are described below.

Extreme Events and Storms

There are several ways to describe extreme events, and most definitions tend to frame these events in terms of consequences or past observations. Kruk *et al*. 2013 define extreme events as "the floods that displace us from our homes, the high waves that wash out coastal roads, or the toppling of trees and power poles from a passing storm." The IPCC defines climate extremes as "the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variables" (IPCC 2012, p. 5). In general, extreme events, by their very nature, are those beyond the normal events that are considered in most shoreline studies. For example, for storm waves and flood conditions, an extreme event will normally be anything worse than the 100-year event.

Extreme events are of particular concern to the examination of coastal vulnerability and damage because they tend to cause the greatest community upheaval and can result in irreversible changes to the coastal landscape. In the El Niño winter of 1982-1983, for example, a series of storms, several of which coincided with high tide, caused more than $200 million in damage (in 2010 dollars) to coastal California (OPC 2013). The 2012 NRC report notes that "waves riding on these higher water levels will cause increased coastal damage and erosion—more than that expected by sea level rise alone" (NRC 2012, p.107). **Similarly, the 2015/16 El Niño was one of the strongest on record, resulting in significant changes to the shoreline.** These impacts result because a rise in sea level will mean that flooding and damage will likely reach further inland. The IPCC *Fifth Assessment Report* (2013) states that it is very likely[22] that there will be a significant increase in the occurrence of future sea level extremes primarily as a result of an increase in mean sea level, with the frequency of a particular sea level extreme increasing by an order of magnitude or more in some regions by the end of the 21st century.

[22] The IPCC has assigned quantitative levels to various terms of confidence and likelihood. High confidence means there is about an 8 out of 10 chance of being correct. Very likely has a greater than 90% probability of occurrence. Other terms that will be used later in this discussion are likely (> 66% probability of occurrence), medium confidence (about a 5 out of 10 chance), low confidence (about a 2 out of 10 chance). *Source of terms*: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note_ar4.pdf

According to the 2012 NRC report, if the frequency or intensity of storms changes, then so will the frequency and intensity of extreme sea level events. However, the evidence that storminess will change in the North Pacific Ocean is conflicting and inconclusive (Cayan *et al*. 2009; Lowe *et al*. 2010; Dettinger 2011). Still, even if storminess does not change, sea level rise will exacerbate storm surge and high waves, magnifying their impact on the coastline. For this reason, it is important to include these factors in the analysis of sea level rise hazards. Methodologies for these analyses are included in Appendix B.

Abrupt change

Currently, the best available science is inconclusive as to whether sea level could change abruptly. Thermal expansion and direct melting of land ice is expected to be gradual, leading to slow and steady sea level rise. However, rapid collapse of land-based ice sheets could lead to sudden acceleration of sea level rise, **as discussed in the 2017 Rising Seas science report and the 2018 OPC SLR Guidance. Specifically, the science report explains that if greenhouse gas emissions are not curtailed, "glaciological processes could cross thresholds that lead to rapidly accelerating and effectively irreversible ice loss." Recent ice sheet observations and model simulations that consider positive feedback loops associated with ice sheet melting and related non-linear acceleration of sea level rise have attempted to estimate the maximum physically plausible amount of sea level rise. These studies informed the extreme/H++ scenario included in the OPC science report and 2018 SLR OPC Guidance (of approximately 10 feet by 2100). Importantly, it will be difficult to determine if the world is on track for extreme and irreversible ice loss for some time because the processes that drive extreme ice loss in the later part of the century or beyond are different than those that are driving ice loss now.** Thus, the likelihood of extreme sea level rise is uncertain and remains an area in need of future research (NRC 2012; **Griggs *et al.* 2017; OPC 2018**).

Rapid change in land elevation during an earthquake is another potential cause of an abrupt sea level change in a localized area. A large earthquake in the Cascadia Subduction Zone could cause land in northern California, Oregon, and Washington to suddenly subside relative to sea level, causing a sudden rise in relative sea level by 3-6.5 ft (NRC 2012). Large earthquakes in this zone are expected to occur about every several hundred to one thousand years, and the most recent such earthquake occurred in 1700. The sudden rise or drop in land elevation would occur in a matter of minutes. If the land were to subside, the relative rise in sea level would be rapid and it would add to sea level rise already occurring from climate-related forcing.

There is also potential for oceanographic conditions to lead to a relatively rapid rate of sea level rise in California. Examination of the tidal gauge records indicate that there was no significant interannual rise in California's sea level from 1983 to 2011, despite a rise in global sea level over the same time period. One explanation, presented by Bromirski *et al*. (2011, 2012), links this suppression of sea level rise with persistent alongshore winds and an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. However, this suppression will not continue indefinitely and as the Pacific Decadal Oscillation, wind, and other conditions shift, California sea level will continue rising, likely at an accelerated rate (NRC 2012; Bromirski *et al.* 2011, 2012).

Chapter 4

Consequences of Sea Level Rise for Communities, Coastal Resources, and Development

The physical effects of sea level rise described in the previous chapter could have significant consequences for California's citizens, coastal communities and the resources protected by the Coastal Act. This chapter describes some of these consequences and notes the relevant Coastal Act policies for convenience. It is important to consider both the direct impacts of sea level rise on coastal resources and what these impacts mean for the people and communities who use and enjoy these coastal resources. It is also important to consider environmental justice when analyzing sea level rise impacts, as described in greater detail in the section below.

Sea Level Rise Adaptation Planning and Environmental Justice

Sea level rise and how we respond to it may result in significant changes in the distribution of environmental benefits, or environmental justice, in California. General planning law in California specifically recognizes and defines environmental justice as "the fair treatment of people of all races, culture and income with respect to the development, adoption, implementation and enforcement of environmental laws, regulations, and policies" (Government Code Section 65040.12; and see Public Resources Code Section 71110-71116). Environmental justice demands that all people, regardless of their race, ethnicity, or level of income, are able to enjoy the benefits of our environmental protection programs and our environment generally. *Safeguarding California* (CNRA 2018) identifies **climate** justice as an important cross-sector theme in the state's climate adaptation and resilience planning efforts. **Additionally, the 2018 OPC SLR Guidance recommends prioritizing social equity, environmental justice, and the needs of vulnerable communities in adaptation planning.**

The California Coastal Act also recognizes the fundamental importance of the fair distribution of environmental benefits in Section 30001:

> *The Legislature hereby finds and declares: (a) That the California coastal zone is a distinct and valuable natural resource of vital and enduring interest to all the people and exists as a delicately balanced ecosystem. (b) That the permanent protection of the state's natural and scenic resources is a paramount concern to present and future residents of the state and nation. (c) That to promote the public safety, health, and welfare, and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to protect the ecological balance of the coastal zone and prevent its deterioration and destruction. (d) That existing developed uses, and future developments that are carefully planned and developed consistent with the policies of this division, are essential to the economic and social well-being of the people of this state and especially to working persons employed within the coastal zone.*

The Act thus declares that the protection of the coast is of vital interest to *all* the people, of paramount concern *to present and future residents* of the state and nation, and that careful planning and development is essential to *the economic and social well-being* of the people. This broad direction to protect the coast for everyone is underscored in Section 30006, which declares:

> *. . . the public has a right to fully participate in decisions affecting coastal planning, conservation and development; that achievement of sound coastal conservation and development is dependent upon public understanding and support; and that the*

> *continuing planning and implementation of programs for coastal conservation and development should include the widest opportunity for public participation.*

Hence, everyone is entitled to participate in the management decisions that determine how the benefits and burdens of managing California's coast will be distributed. Ensuring low-income and underserved communities are included in environmental decisions is a key tenet of environmental justice and will minimize disproportionate environmental and public health impacts. **Furthermore, in 2016, the Governor signed AB 2616 (Burke), which amended the Coastal Act and gives the Commission new authority to specifically consider environmental justice when making permit decisions. This legislation also cross-references existing non-discrimination and civil rights law in the government code and requires the governor to appoint an environmental justice Commissioner to our board.**

The Coastal Act's broad concern for all the people is best borne out in its public access policies, which require the maximum provision and protection of the public's rights of access to and along the shoreline (Sections 30210-214). These policies reflect the judgement of the people of California in passing Proposition 20 in 1972 that public access and recreation along our coast is a fundamental environmental benefit to be protected for and enjoyed by all, not just by those with the good fortune or means to live along the shoreline. Public access to the coast is important to the health and well-being of the public, and promoting public access for all citizens provides low-cost, outdoor recreation that can improve the overall quality of life of the public, including low-income and underserved communities.

Unfortunately, public access is also one of the coastal resources most at risk from accelerating sea level rise. As discussed elsewhere in this Guidance, beaches, accessways, recreational amenities, and even surfing resources may be dramatically impacted by rising seas. Where development already exists, and particularly where there is substantial shoreline armoring to protect this development, California stands to lose significant recreational beach areas. These places that are at increased risk provide environmental benefits for everyone, generally at very low cost, or even free. Thus, the potential loss of beach and shoreline recreation areas represents a significant potential impact to a resource that both is especially important to those with fewer economic resources and one that we endeavor to provide for everyone without discrimination, no matter their income levels, ethnicities or cultures; no matter if they are from coastal or inland areas or from outside the state.

The exacerbation of environmental injustices by anticipated sea level rise may be particularly concerning when the Commission and local governments need to make decisions about shoreline protection and hazard mitigation. As discussed elsewhere in this Guidance, the Coastal Act provides for the protection and mitigation of coastal hazards for existing and new development. But some hazard mitigation, such as seawall development or elevated development on beaches, may have significant impacts to public trust shoreline resources. Thus, we face a situation where widely available public beach resources may be diminished in order to protect private or public development along the shoreline – potentially a significant environmental justice concern. Because of this, it will be important for decision makers to proactively consider all aspects of this Guidance in an effort to avoid and mitigate the potential impacts to coastal resources from hazard response. This is particularly true for recommendations to consider alternatives to shoreline structure development and, where shoreline structures must be approved, for recommendations to fully mitigate the impacts of such structures on public shoreline resources.

A May 2015 decision made by the Coastal Commission emphasizes the importance of analyzing low-cost recreational opportunities in addition to other coastal resource impacts when evaluating shoreline protection and other responses to sea level rise and coastal hazards. The Coastal Commission approved a revetment at the west end of the Goleta Beach County Park to provide protection against erosion. This park is an important public resource in Santa Barbara County and receives up to 1.5 million visitors each year, a large fraction of which are low-income visitors. Park facilities include picnic areas, open parkland, and access to the ocean and a recreational beach for no or low cost. The revetment was approved contingent upon specific conditions, including continued free public access and vehicle parking for the term of the permit. This decision highlights the importance of protecting wide accessibility to shoreline resources even as sea level rises.

The potential impacts of adaptation responses on public shoreline resources, and thus the potential environmental justice impacts of such actions, will need to be considered for all resources protected under the Coastal Act. It is also true that due to current development patterns along the coast, sea level rise hazards may affect various sections of the population differently, as could the implementation and effectiveness of various adaptation measures. The number of people living along the open coast in areas exposed to flooding from a 100-year flood would increase to 210,000 with a 4.6 ft (1.4 m) increase in sea level; approximately 27% or 56,000 of these are lower income people (those earning less than $30,000 annually); 45,000 are renters; and 4,700 are linguistically isolated and less likely to understand flood warnings (Heberger *et al*. 2009). According to Heberger *et al*. (2009), the greatest increases in the number of people vulnerable to flooding will occur in Los Angeles, San Diego, Ventura, Humboldt, and San Luis Obispo counties. Sea level rise will likely result in the loss of key infrastructure, intrusion of saltwater into water sources, and the creation of additional coastal hazards. Hazards in vulnerable areas will have disproportionate impacts on communities with the least capacity to adapt, which could deepen and expand existing environmental injustice if adaptation responses are not managed appropriately.

For example, lower-income communities and those who live in rental units are more likely to be displaced by flooding or related impacts as compared to property owners because they lack the funds and/or abilities to rebuild, have less control over their safety, and often have limited access to insurance. Relatedly, these same populations are less likely to be able to take proactive steps to adapt to sea level rise. Additionally, loss of local public beaches or a reduction in public access and recreation opportunities would disproportionately affect low-income communities that have few alternative lower cost recreational opportunities. Tribal communities are also vulnerable to sea level rise because they are often tied to specific locations, and therefore can't easily relocate.

Overall, it will be important for planners and decision makers to not only consider the direct impacts and consequences of sea level rise on coastal resources, but to also consider what those consequences mean for the distribution of environmental benefits **and burdens** along the coast, and the communities that use and rely on those resources, **including those who do not live in**

the coastal zone but are still impacted by coastal resource management, including workers and visitors. Low-income and underserved communities are less equipped to prepare for and respond to sea level rise, but community engagement and social cohesion can improve coastal resilience **and lead to more equitable adaptation planning**. Planners and decision makers should consider environmental justice concerns in the analysis of alternative project designs and adaptation measures and ensure low-income and underserved communities are involved in decision-making and planning efforts. This will better ensure that adaptation efforts benefit all Californians, fairly, and that they do not increase vulnerability to sea level rise among any particular group or demographic, and do not have any unintended consequences that lead to social or environmental injustices. In particular, it will be important to consider the potential impacts of hazard mitigation actions to protect development that may only benefit a few, on the public access and shoreline resources that are available for all Californians to enjoy.

CONSEQUENCES OF SEA LEVEL RISE FOR COASTAL ACT RESOURCES

- **Coastal development (Coastal Act Sections 30235, 30236, 30250, 30253):** Sea level rise will increase the likelihood of property damage from flooding, inundation, or extreme waves, and will increase the number of people living in areas exposed to significant flooding. Increased erosion and loss or movement of beach sand will lead to an increase in the spatial extent of eroding bluffs and shorelines, and could increase instability of coastal structures and recreation areas. Levee systems could also experience damage and overtopping from an increase in water levels, extreme wave conditions, or a loss of wetlands, which buffer impacts from high water. The replacement value of property at risk from sea level rise for the California coast is approximately $36.5 billion (in 2000 dollars, not including San Francisco Bay) (Heberger *et al*. 2009).

  Impacts to public infrastructure, ports, and industrial development include:

  - **Public infrastructure:** Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, and utility infrastructure such as potable water systems and electricity transfer systems are at risk of impaired function due to erosion, flooding, and inundation. Heberger *et al*. (2009) estimated that 7 wastewater treatment plants, 14 power plants, including one in Humboldt County and 13 in Southern California, and 250 miles (402 km) of highways, 1500 miles (2414 km) of roads, and 110 miles (177 km) of railways could be at risk from a 100-year flood with 1.4-m rise in sea level (Heberger *et al*. 2009). Facilities and highways located on coastal bluffs subject to erosion will become more susceptible in the future. Sections of Highway 1 have already had to be realigned due to erosion or are in the planning stages for realignment projects, including areas in San Luis Obispo County, Monterey Bay, Half Moon Bay, and Marin County and the sections at risk in the future will likely increase.

Figure 7. Photo of infrastructure at risk near Rincon Beach, Ventura, CA, during the King Tide in December 2012. (Photo courtesy of David Powdrell, California King Tides Initiative)

- **Ports (Coastal Act Sections 30703 – 30708):** Sea level rise could cause a variety of impacts to ports, including flooding and inundation of port infrastructure and damage to piers and marina facilities from wave action and higher water levels. A possible benefit could be a decreased need for dredging. But, unless facilities have already included accommodations for larger ships than they currently service, higher water levels could increase the difficulty for cargo handling facilities due to the higher vessel position (CCC 2001; CNRA 2014). Increased water heights could reduce bridge clearance, reducing the size of ships that can access ports or restricting movement of ships to low tides, and potentially increasing throughput times for cargo delivered to ports. Heberger *et al*. (2009) found that significant flooding from sea level rise is possible at the Ports of Los Angeles and Long Beach. Given that these two ports handle 45-50% of the containers shipped into the United States, and 77% of goods that leave the state, sea level rise could affect the efficiency of goods movement, and have serious economic implications for California and the nation (Heberger *et al*. 2009).
- **Industrial development, refineries, and petrochemical facilities (Coastal Act Sections 30260-30266.5):** Sea level rise could reduce areas available for siting or expansion of industrial development. Inundation of contaminated lands near industrial development could lead to problems with water quality and polluted runoff. Sea level rise could lead to an increase in flooding damage of refineries or petrochemical facilities, and impacts from sea level rise could be an issue when locating or expanding refineries or petrochemical facilities, or when mitigating any adverse environmental effects.
- **Construction altering natural shorelines (Coastal Act Section 30235):** Sea level rise may lead to an increase in demand for construction of shoreline protection for existing development, public access, and coastal-dependent uses in danger of erosion. Shoreline protection devices alter natural shorelines and also generally have negative impacts on beaches, near-shore marine habitat, and scenic and visual qualities of coastal areas.

- **Public access and recreation (Coastal Act Sections 30210, 30211, 30213, 30220, 30221):** One of the highest priorities in the Coastal Act is the mandate to protect and maximize public access to the coast. Sea level rise could lead to a loss of public access and recreational opportunities due to permanent inundation, episodic flooding, or erosion of beaches, recreational areas, or trails. In areas where beaches cannot migrate inland due to development or more resistant landforms, beaches will become narrower or will disappear completely. Access and functionality of water-oriented activities may also be affected. For instance, sea level rise, by increasing water levels and altering sediment patterns, could lead to a change in surfing conditions or affect the safety of harbors and marinas (Kornell 2012).

- **Coastal habitats (Coastal Act Sections 30230, 30231, 30233, 30240):** Coastal habitat areas likely to be affected by sea level rise include bluffs and cliffs, rocky intertidal areas, beaches, dunes, wetlands, estuaries, lagoons and tidal marshes, tidal flats, eelgrass beds, and tidally-influenced streams and rivers.

  Importantly, there are many endemic and endangered species in California that are dependent on these coastal environments. For example, grunion need a sandy beach environment in order to reproduce and survive, the California clapper rail is dependent on marshes and wetlands, and the black abalone requires rocky intertidal habitat. Nesting habitat, nursery areas, and haul-out sites important for birds, fish, marine mammals and other animals could also disappear as sea levels rise (Funayama *et al*. 2012).

  Impacts to wetlands, intertidal areas, beaches, and dunes include:

  - **Beaches, dunes, and intertidal areas:** Inundation and increased erosion from sea level rise could convert habitats from one type to another and generally reduce the amount of nearshore habitat, such as sandy beaches and rocky intertidal areas. Sea level rise will cause landward migration of beaches over the long term, and could lead to a rapid increase in the retreat rate of dunes. Beaches with seawalls or other barriers will not be able to migrate landward and the sandy beach areas will gradually become inundated (NRC 2012). A loss of beach and dune areas will have significant consequences for beach and adjacent inland ecosystems. Beaches and dunes provide critical habitat for species and act as buffers to interior agricultural lands and habitat during storms (CNRA 2009).

  - **Wetlands:** Sea level rise will lead to wetland habitat conversion and loss as the intertidal zone shifts inland. Of particular concern is the loss of saltwater marshes from sea level rise, which have already decreased by about 90% from their historical levels in California (CNRA 2010). California's 550 square miles (885 km) of critical coastal wetland habitat (Heberger *et al*. 2009, including wetlands in San Francisco Bay) could be converted to open water by 4.6 ft (1.4 m) rise of sea level if they are not able accrete upward or to migrate inland due to natural or anthropogenic barriers. Although barriers are plentiful, inland migration of these wetlands is possible for over 50% of the potentially inundated wetland area based on land use compatibility alone (Heberger *et al*. 2009). Consideration of adequate sediment supply and additional barriers to inland migration would further constrain wetland migration potential. A 4.6 ft (1.4 m) increase in sea level would flood 150 square miles (241 km) of land immediately adjacent to wetlands, which could become future wetlands if that land remains undeveloped. Loss or reduction of wetland habitat would impact many plant and animal species, including migratory birds that depend on these habitats as part of the Pacific Flyway. Species that are salt-tolerant may have an advantage as sea level rise occurs and exposes new areas to salt water, while species that have narrow salinity and temperature tolerances may have difficulty adapting to changing conditions.

- **Biological productivity of coastal waters (Coastal Act Sections 30230, 30231):** Sea level rise could affect biological productivity of coastal waters by changing the types of habitats that are available. This change could alter species composition, and could potentially result in cascading effects through the coastal food chain. Changes in water quality can have differing impacts on biological productivity. For instance, decreased water quality due to increased nutrient pollution has been found to increase biological productivity at the base of the food chain to undesirable levels, and has been linked to harmful algal blooms which result in hypoxic conditions for other marine species (Kudela *et al*. 2010; Ryan *et al.* 2010; Caldwell *et al*. 2013).
- **Water quality (Coastal Act Section 30231):** Sea level rise could lead to declines in coastal water quality in several ways. First, coastal water quality could be degraded due to inundation of toxic soils and an increase in nonpoint source pollution from flooding. In particular, the presence of facilities or land containing hazardous materials in coastal areas susceptible to flooding or permanent inundation presents toxic exposure risks for human communities and ecosystems. Second, rising seas could impact wastewater facility infrastructure and other methods and structures designed to protect water quality near the coast. In addition to damaging equipment and blocking discharge from coastal outfall structures, floods could force facilities to release untreated wastewater, threatening nearby water quality (Heberger *et al*. 2009). Salt water draining into sewer lines as part of extreme weather flooding might also damage biological systems at wastewater facilities if the organisms present in these systems are not salt-tolerant. Third, sea level rise could lead to saltwater intrusion into valuable groundwater aquifers, potentially rendering some existing wells unusable and decreasing the total groundwater supply in coastal areas. The extent of saltwater intrusion will likely vary based upon local hydrological conditions, with the worst impacts occurring in unconfined aquifers along low-lying coasts that have already experienced overdraft and saline intrusion. This change could force affected communities to turn to more costly water sources such as surface water transfers or desalination. Finally, loss of wetlands could decrease water quality given that wetlands act to improve water quality by slowing and filtering water that flows through them.
- **Coastal agriculture (Coastal Act Sections 30241- 30243):** Sea level rise could lead to an increase in flooding and inundation of low-lying agricultural land, saltwater intrusion into agricultural water supplies, and a decrease in the amount of freshwater available for agricultural uses. Flooding of agricultural lands can cause major impacts on local businesses, national food supplies, and the state's economy.
- **Archaeological and paleontological resources (Coastal Act Section 30244):** Archaeological or paleontological resources could be put at risk by inundation, flooding, or by an increase in erosion due to sea level rise. Areas of traditional cultural significance to California Native American tribes, including villages, religious and ceremonial locations, middens, burial sites, and other areas, could be at risk from sea level rise. For

example, the Santa Barbara Channel area has thousands of archaeological sites dating over 13,000 years that are at risk of being destroyed or altered from small amounts of sea level rise (Reeder *et al*. 2010).

For a summary of some of the sea level rise impacts and potential consequences for the coast, see Figure 8. Many of these consequences are conditions that coastal managers already deal with on a regular basis, and strategies already exist for minimizing impacts from flooding, erosion, saltwater intrusion, and changing sediment patterns. Preparing for sea level rise involves integrating future projections of sea levels into existing hazard analyses, siting, design, and construction processes, ecosystem management, and community planning practices. Processes for integrating sea level rise in Local Coastal Programs and Coastal Development Permit applications are described in the following chapters.

Drivers of Global SLR

Expansion of ocean water as temperature increases

Addition of freshwater to the ocean from melting glaciers and ice sheets

Addition of freshwater to the ocean from groundwater extraction, use, and discharge

Drivers of Local/Regional SLR Variability

Vertical land movement

Oceanographic phenomena including El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO)

Physical Impacts of SLR

Inundation (permanent wetting)

Flooding (temporary wetting)

Increased erosion and bluff collapse

Increased tidal prism

Increased wave heights and force

Increased saltwater intrusion

Change in sediment movement patterns

Summary of Consequences of SLR for Coastal Resources & Development

Coastal Development: Greater likelihood of tidal damage, flooding, inundation, and extreme waves, which could lead to loss of property or physical injury; instability from increased erosion and loss/movement of beach sand; increased areas exposed to a 100-year flood.

Public infrastructure: Low-lying roads, wastewater treatment facilities, energy facilities, stormwater infrastructure, potable water systems, and electricity transfer systems are at risk of inundation and flooding, and impaired function. Infrastructure located on eroding bluffs is also subject to increased geologic hazards.

Coastal Agriculture: Increase in flooding and inundation of low-lying agricultural lands; saltwater intrusion into agricultural water supplies; potential decrease in amount of freshwater available for agricultural uses.

Public Access & Recreation: Loss of beach areas where beaches cannot migrate inland due to development; inaccessibility of public accessways and recreation sites due to flooding and erosion.

Coastal Habitats: Transformation of habitats as intertidal zone shifts inland; loss of wetlands and other habitats where areas cannot migrate up or inland due to inland barriers such as coastal development.

Water Quality: Coastal water quality could decline due to inundation of toxic soils and an increase in nonpoint source pollution from flooding. Rising seas could also impact wastewater facilities and cause saltwater intrusion into groundwater supplies.

Biological productivity of coastal waters: Sea level rise could affect biological productivity of coastal waters by changing the types of habitats that are available. This change could alter species compositions, and could potentially result in cascading effects through the coastal food chain.

Cultural Resources: Archeological and paleontological sites, including many Native American villages, religious and ceremonial locations, burial sites, and other areas could be at risk from sea level rise.

Figure 8. Summary of sea level rise impacts and consequences

Chapter 5

Addressing Sea Level Rise in Local Coastal Programs

The Coastal Act requires that the 61 cities and 15 counties in coastal California prepare Local Coastal Programs (LCPs) to govern land use and development in the coastal zone inland of the mean high tide. LCPs become effective only after the Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act.

LCPs contain the ground rules for future development and protection of resources in the coastal zone. Each LCP includes a Land Use Plan (LUP) and an Implementation Plan (IP). The LUP specifies the kinds, locations, and intensity of uses, and contains a required Public Access Component to ensure that maximum recreational opportunities and public access to the coast is provided. The IP includes measures to implement the LUP, such as zoning ordinances. LCPs are prepared by local governments and submitted to the Coastal Commission for review for consistency with Coastal Act requirements.[23]

Once an LCP's certification becomes effective, the local government becomes responsible for reviewing most Coastal Development Permit (CDP) applications. However, the Commission retains continuing permit authority over some lands (for example, over tidelands, submerged lands, and public trust lands) and authority to act on appeals for certain categories of local CDP decisions.

To be consistent with the Coastal Act hazard avoidance and resource protection policies, it is critical that local governments with coastal resources at risk from sea level rise certify or update Local Coastal Programs that provide a means to prepare for and mitigate these impacts. The overall LCP update and certification process has not changed. Now, however, the impacts of accelerated sea level rise should be addressed in the hazard and coastal resource analyses, alternatives analyses, community outreach, public involvement, and regional coordination. This Guidance is designed to complement and enhance the existing LCP certification and update steps. Although the existing LCP certification and update processes are still the same, sea level rise calls for new regional planning approaches, new strategies, and enhanced community participation.

LCPs are essential tools to fully implementing sea level rise adaptation efforts. Since many existing LCPs were certified in the 1980s and 1990s, it is important that future amendments of the LCPs consider sea level rise and adaptation planning at the project and community level, as appropriate. The *California Climate Adaptation Strategy* (CNRA 2009) and *Safeguarding California* (CNRA 2014) specifically identify LCPs as a mechanism for adaptation planning along the California coast. For general guidance on updating LCPs, see the LCP Update Guide, available here: https://www.coastal.ca.gov/rflg/.

[23] In addition there are other areas of the coast where other plans may be certified by the Commission, including Port Master Plans for ports governed by Chapter 8 of the Coastal Act, Long Range Development Plans for state universities or colleges, and Public Works Plans for public infrastructure and facilities. Following certification of these types of plans by the Commission, some permitting may be delegated pursuant to the Coastal Act provisions governing the specific type of plan.

Steps for Addressing Sea Level Rise in Local Coastal Programs and Other Plans

The Commission recommends the following six steps to address sea level rise as part of the development of an LCP, LCP Amendment, or other plan.[24] These steps can be modified and adapted to fit the needs of individual planning efforts and communities and to address the specific coastal resource and development issues of a community, such as addressing bluff erosion or providing for effective redevelopment, infill, and concentration of development in already developed areas. At the start of an LCP update to address sea level rise or a new LCP project, local government planners should contact their local Coastal Commission district office to discuss the LCP goals and to establish a plan for Coastal Commission staff coordination and public involvement throughout the entire process. A key element of any LCP project is public involvement. This can include establishing technical and community stakeholder advisory committees, establishing an interdepartmental sea level rise team of City and County staff representatives, and planning a series of public workshops to gather feedback, in addition to the required public hearings on the LCP.

The steps of this process are illustrated in Figure 9 and described below. They are similar to the standard steps of a long-range planning process and should be familiar to local planners. Steps 1-3 are often referred to as a "sea level rise vulnerability assessment" in other sea level rise planning contexts and therefore are similar to other sea level rise-related resources.

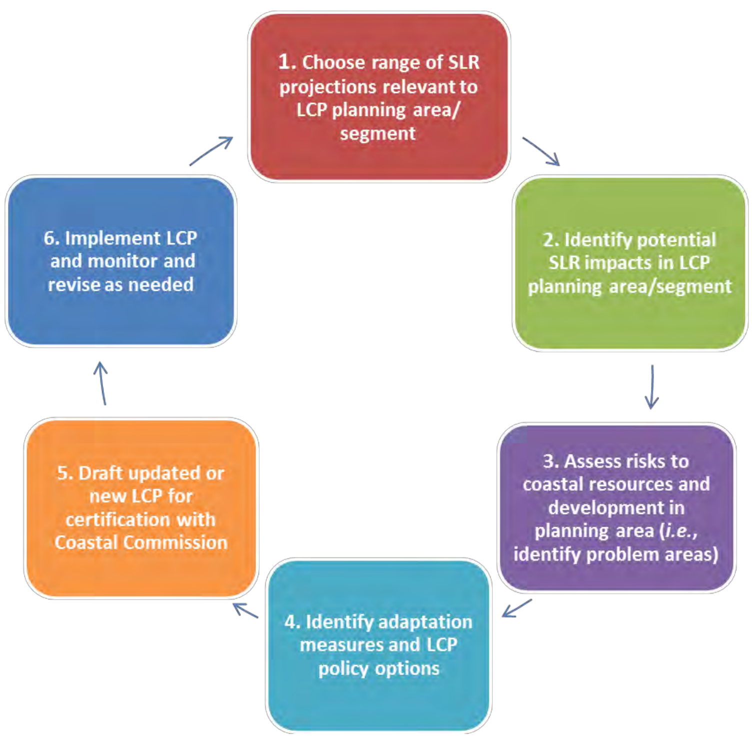

Figure 9. Sea level rise adaptation planning process for new and updated Local Coastal Programs

[24] This Guidance uses the term 'LCP process' to refer to the LCP process, but many of the concepts included here are applicable to other planning processes, including Long Range Development Plans, Public Works Plans, and Port Master Plans. For example, recommendations for how to analyze sea level rise impacts and perform a vulnerability assessment are broadly applicable. Many adaptation strategies may also be applicable, though in all cases, individual actions taken will vary based on relevant policies, local conditions, feasibility, and other factors.

The Coastal Commission also offers a *Local Coastal Program (LCP) Update Guide* (2013b) that outlines the broad process for amending or certifying an LCP, and there is naturally some overlap between the content of that document and this Sea Level Rise Policy Guidance document. The general LCP amendment steps are outlined below, in a flow chart (see Appendix D), and in the LCP Tips/Best Practices document (2013c), which is available in the *Resources for Local Governments* section of the Commission's website. Local governments should contact the Coastal Commission planner for their area when pursuing a new LCP or LCP amendment.

1. **Initial Amendment scoping and development:** Conduct issues assessment, identify need for amendment, prepare preliminary draft, coordinate with Commission staff, and share early drafts
2. **Local Amendment process:** Notify public, conduct local outreach and hearings, meet with Commission staff to discuss any issues, and adopt LCP at the local level
3. **Prepare Submittal:** assemble LCP materials, discuss with Commission staff prior to submittal, transmit to Coastal Commission, and make available to public
4. **Process Amendment at Coastal Commission:** Commission staff will review submittal within 10 working days for completeness; will address outstanding information needs; will prepare and write staff report; hold public hearing and vote; and transmit action to local government
5. **Effectuate Amendment:** Local acceptance of any modifications or resubmittal within 6 months, finalize local approval, and complete Coastal Commission Executive Director check-off
6. **Implement LCP Amendment, monitor and revise as necessary.**

The step-by-step process for incorporating sea level rise into LCPs outlined in the rest of this chapter fits into these broader LCP amendment steps. Local government planners should use the LCP Update Guide in conjunction with the Sea Level Rise Policy Guidance to inform the LCP.

Use scenario-based analysis

The Guidance recommends using a method called "scenario-based analysis" (described in Chapter 3 of this Guidance). Since sea level rise projections are not exact, but rather presented in ranges, scenario-based planning includes examining the consequences of multiple sea level rise amounts, plus extreme water levels from storms and El Niño events. The goal of scenario-based analysis for sea level rise is to understand where and at what point sea level rise, and the combination of sea level rise and storms, pose risks to coastal resources or threaten the health and safety of a developed area. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future sea level rise. For example, if there are large changes in the hazard zones between two sea level rise amounts, additional analyses may help determine the tipping points when viable land uses will change. In general, scenario-based analyses can help determine the long-term compatibility of certain areas with certain land uses. For further description of this method, see Chapter 3.

Include other topics as applicable or desired

This Guidance recommends a number of analyses that will generate useful information related to sea level rise and other environmental vulnerabilities. Performing these analyses (and the overall planning process) may provide a useful opportunity to include other studies that will complement the goals of Local Coastal Programs and provide valuable insights for community concerns. For example, planners should expand the Coastal Act consideration of lower cost visitor serving facilities to include considerations of social equity and environmental justice in the analyses by determining how climate hazards or the adaptation measures might differentially impact various demographics. Additionally, planners may want to incorporate analysis of the economic implications of various options for adaptation. Important topics such as these should be incorporated into the analyses already underway for the sake of efficiency.

Leverage analyses and share information with other planning-related processes and documents

Sea level rise is addressed in many other planning-related documents and by many other agencies and organizations. Planners should be aware of these documents and the on-going work of state and federal agencies and make an effort to share information in cases where analyses required for some of these documents may overlap with the studies appropriate for sea level rise planning in LCPs. Additionally, these agencies, organizations, and planning efforts may be good resources from which to gather information when performing these analyses for LCP updates.

For example, there is overlap between the required elements of a Local Hazard Mitigation Plan (LHMP) and Local Coastal Programs, and the Commission recommends coordinating an LHMP update with an LCP update if possible. As part of an LHMP, local governments identify the natural hazards that impact their community, identify actions to reduce the losses from those hazards, and establish a coordinated process to implement the plan.[25] In order to be eligible for certain types of non-emergency disaster assistance, including funding for hazard mitigation projects, local governments are required by FEMA to complete an LHMP[26] and to update the plan every 5 years. Any sea level rise hazard avoidance strategies included in an LCP certification or update, such as relocation of critical facilities must be included in the LHMP narrative to be eligible for funding from FEMA to implement future projects. If a local government has recently updated their LHMP, the city or county can add narrative information on sea level rise strategies through an addendum to the plan, referred to by FEMA as an annex.[27]

In many cases, the analyses and adaptation options identified in this Guidance could be used for hazard mitigation plans or vice versa, as the goal of each of these planning processes is to

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[25] http://www.fema.gov/media-library-data/20130726-1524-20490-5927/67fr8844.pdf

[26] Note that recent revisions to the State Mitigation Plan Review Guide, set to go into effect in March 2016, will require states to analyze the probability and possible impacts due to future hazard events in a way that includes the projected changes in natural hazards resulting from climate change. Failure to include such considerations may result in a state's ineligibility for certain non-emergency mitigation grants.

[27] For more information on how to complete or update an LHMP, visit http://hazardmitigation.calema.ca.gov/ or contact the Cal OES office and a hazard mitigation technical expert can assist local governments with the planning process. For contact information, visit http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/contacts.

minimize or avoid impacts from coastal hazards. As a result, there may be opportunities to leverage funding and share work efforts.

A number of other similar planning processes, projects, and documents are listed in Figure 10, and planners may be able to use these studies in the LCP planning process, or, alternatively, share analyses and information performed for LCP planning with the groups working on related projects. Additionally, the forthcoming State of California Planning for Sea Level Rise Database (established by Assembly Bill 2516 and pursuant to Public Resources Code Sections 30961-30968) may become an important tool for identifying past and/or ongoing actions that stakeholders have implemented to address sea level rise. In any case, information sharing is highly recommended to promote efficiency.

Coordinate regionally as appropriate

Many impacts of sea level rise will transcend jurisdictional boundaries. Similarly, the adaptation decisions made by coastal communities could themselves have consequences that affect areas outside the local jurisdiction. For these reasons, regional coordination will often enhance the effectiveness of local adaptation decisions. Indeed, many of the projects identified in Figure 10 have taken this regional approach. Planners should keep this concept in mind as they work through these steps and coordinate regionally where appropriate and possible.

Representative Adaptation Planning Stakeholders

Agencies

Local/Regional:

- City/county governments
- League of Cities
- Association of Counties
- Regional entities (e.g., air districts, water boards, metropolitan planning organizations, regional transportation planning agencies)

State:

- Natural Resources Agency
- Ocean Protection Council
- CA Coastal Commission
- State Coastal Conservancy
- State Lands Commission
- SF Bay Conservation & Development Commission
- Office of Planning & Research
- Caltrans
- Office of Emergency Services
- CA Geologic Survey
- Dept. of Parks and Rec.
- Dept. of Fish and Wildlife
- Dept. of Water Resources
- State Water Resources Control Board
- Air Resources Board
- Dept. of Conservation

Federal:

- FEMA
- EPA
- US Fish and Wildlife Service
- NOAA
- Gulf of the Farallones NMS
- Monterey Bay NMS
- SF Bay NERR
- Elkhorn Slough NERR
- Tijuana River NERR
- US Geologic Survey
- US Army Corps of Engineers
- BOEM, BSEE
- National Park Service
- Sea Grant

Partner Organizations

- Non-Government Organizations (e.g., environmental, social)
- Professional organizations (e.g., agricultural, fisheries, communications)
- Science organizations
- Universities
- Private consultants/industry

Examples include:

- The Nature Conservancy
- Surfrider Foundation
- Coastkeeper Alliance
- Center for Ocean Solutions
- Point Blue Conservation Science
- Pacific Institute
- Natural Capital Project
- American Society of Adaptation Professionals

Coordinated Planning Efforts

Regional Environmental Efforts

- Our Coast Our Future (CoSMoS)
- So. CA Coastal Impacts Project (CoSMoS)
- Humboldt Bay SLR Adaptation Working Group
- Monterey Bay Adaptation Group
- LA Regional Adaptation Group
- Coastal Resilience Ventura
- San Diego Regional Climate Collaborative
- Santa Barbara and Ventura Co. resilience planning

Local/Regional Plans

- Local Hazard Mitigation Plans
- General Plans
- Climate Action Plans
- Capital Improvement Plans/Programs
- Climate Change Adaptation Plans
- Integrated Regional Water Management Plans
- Regional Sediment Management Plans
- Sustainable Community Plans
- Regional Transportation Plans

Figure 10. Agencies, organizations, and planning efforts related to sea level rise adaptation

Step 1 – Determine range of sea level rise projections relevant to LCP planning area/segment

The first step in incorporating sea level rise into the LCP planning process is to identify locally relevant sea level rise scenarios that may occur at given time steps into the future. These scenarios will be carried through the rest of the steps in the sea level rise LCP planning process. Follow these steps to determine the locally relevant sea level rise projections to use in the subsequent steps:

- **Determine planning horizons of concern: The Coastal Commission recommends taking a long-term view when analyzing sea level rise impacts because the land use decisions made today will affect what happens over the long-term. For example, development constructed today is likely to remain in place over the next 75-100 years, or longer. In practice, many jurisdictions have completed assessments that look at sea level rise vulnerabilities through approximately 2100. Understanding short-term vulnerabilities is also important, and the Coastal Commission recommends assessing vulnerabilities in intermediate planning horizons. For example, many jurisdictions have assessed sea level rise scenarios that correspond to years 2030 and 2050, in line with information provided in the 2012 National Research Council (NRC)** report. These time periods may be used, or local governments may identify other relevant planning horizons for their plans and development scenarios, as long as the projections for those time frames are based on the best available and relevant scientific projections.

- **Determine the full range of sea level rise projections from the best available science:** Using best available science, **currently the 2018 OPC SLR Guidance** (or other comparable study, provided that it is peer reviewed, widely accepted within the scientific community, and locally relevant), determine the range of sea level rise for the planning horizons of concern. **The sea level rise projections for the San Francisco tide gauge from the 2018 OPC SLR Guidance are presented in Table 4 below (projection tables for all 12 California tide gauges are presented in Appendix G**)[28]. See below for a discussion of scenario-based planning in the LCP context. The LCP should include a policy to use the best available science about sea level rise.

[28] **More detailed refinement of sea level rise projections is not considered necessary at this time, as variations from the nearby tide gauges will often be quite small, and may be insignificant compared to other sources of uncertainty. However, the Coastal Commission recognizes that other studies exist with localized data, for example those completed in the Humboldt Bay region, which may also be appropriate for use.**

Table 4. **Sea Level Rise Projections for the San Francisco Tide Gauge[29] (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.

[29] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

- **Choose multiple sea level rise scenarios based on range of sea level rise projections. The Coastal Commission recommends that all communities evaluate the impacts from the "medium-high risk aversion" scenario. 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. 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.**

  In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that will cause impacts for their community, and how these impacts will change over time, with different amounts of sea level rise. Planners should evaluate enough scenarios to be able to answer the following:

  - What are the impacts from the worst-case scenario of the highest possible sea level rise plus elevated water levels from high tide, El Niño and a 100-year storm?
  - What is the minimum amount of sea level rise that causes inundation, flooding, or erosion concerns?
  - How do inundation, flooding, and erosion concerns change with different amounts of sea level rise?
  - Are there any tipping points where sea level rise impacts become more severe? (For example, is there a point at which seawalls or levees are overtopped?)

  There are two main ways to choose scenarios from which to evaluate sea level rise: by sea level rise amount or by time-period. Tools that provide maps by sea level rise amount can then be linked to the relevant time period, as shown below in the *Our Coast Our Future* example. There is no single accepted sea level rise mapping methodology for the state of California. Local governments can choose whether to use existing sea level rise tools or to develop their own scenarios and maps. See below for information on scenarios and modeling outputs generated by existing sea level rise modeling tools.

Examples of Choosing Scenarios with Existing Sea Level Rise Modeling Tools

For California, there are two primary methods for identifying sea level rise scenarios, based on two of the currently available SLR mapping tools: CoSMoS (Our Coast Our Future) and Coastal Resilience Ventura (The Nature Conservancy). The type of tool available for sea level rise mapping in a planning area can be a deciding factor for which scenarios to use in the analysis. The Coastal Commission recommends using as many scenarios as necessary to fully analyze the potential impacts to coastal resources, human health, and safety rather than a specific tool or number of scenarios. Examples for choosing scenarios based on the tools available are described below.

Example 1: Identify SLR amounts, then relate to likely time period(s) of occurrence

This method involves first examining different amounts of sea level rise and storm events, and second, looking at the **2018 OPC SLR Guidance** projections to determine the range of years during which those impacts could potentially occur. For example, the Our Coast Our Future CoSMoS-based tool provides sea level rise maps for 9 different amounts in 25 cm (0.8 ft) intervals, three different storm scenarios (annual, 20-year, and 100-year), and a king tide scenario. With this tool, users can first evaluate different amounts of sea level rise and storms, determine how different amounts of sea level rise and storm situations affect the planning area, and then determine when the increased water level is likely to occur based on the **OPC Guidance projections. The CosMoS tool is currently available from Point Arena (in Mendocino County) through the Mexico border, and an expansion throughout the rest of the state is planned for 2018/2019**. The NOAA Sea Level Rise and Coastal Flooding Impacts viewer similarly provides maps for different amounts of sea level rise (in this case, in 1-ft increments), but does not include impacts from storms, erosion or waves. A methodology for adding in these additional impacts is described in Appendix B.

Example 2: Choose applicable years, then identify high, intermediate, and low scenarios

For this method, planners pick specific years, determine the range of sea level rise amounts that could occur by that year, and examine the consequences of three or more sea level rise amounts within that range. For example, the Coastal Resilience Ventura Tool (The Nature Conservancy) provides maps showing inundation, flooding, wave impact zone, and erosion risk zones with low, medium, and high sea level rise scenarios for the years 2030, 2060, and 2100. For local governments within Ventura County, planners may choose to evaluate scenarios according to the 2030, 2060, and 2100 time periods. The model provides maps for both flooding and erosion.

Expected outcomes from Step 1: *Upon completing this step, a range of regionally- or locally-relevant sea level rise projections for the time periods of concern should be established. Based on the range of projections, planners will have identified a low, high, and one or more intermediate projections. These projections are the sea level rise scenarios that will be carried through the rest of the planning process.*

Step 2 – Identify potential physical sea level rise impacts in LCP planning area/segment

The next step is to identify the physical hazards and impacts (referred to comprehensively as sea level rise impacts) associated with current and future sea level. As described in Section C of Chapter 3 of this Guidance, broad categories of sea level rise impacts may include inundation, flooding, wave impacts, erosion, and saltwater intrusion. In this step, planners should analyze these physical impacts and their various sub-components in order to understand current and future local hazard conditions. The analysis should answer the following basic questions:

- What are the existing hazard conditions that threaten the planning area?
- What is the projected change in hazard conditions due to locally appropriate sea level rise projections and planning horizons of concern?

This analysis should include the following topics, as applicable:

- Local Water Conditions (See Appendix B for a detailed methodology)
  - Current tidal datum[30] and future inundation
  - Water level changes from storm surge, atmospheric pressure, the Pacific Decadal Oscillation (PDO), the El Niño Southern Oscillation (ENSO), and/or other basin-wide phenomena
  - Wave impacts and wave runup, including wave runup from a 100-year storm, and based on tides, other water level changes, and future beach and bluff erosion
  - Flooding from extreme events such as storms with intervals greater than 100 years, tsunamis, *etc.*
- Shoreline change (See Appendix B for more information)
  - Current shoreline erosion rates. For future cliff and dune erosion rates, modify historic erosion rates, to account for the influence of sea level rise (*e.g.*, work by the Pacific Institute – Heberger *et al*. 2009; Revell *et al*. 2011). If possible, modify long-term beach erosion rates to account for changes in El Niño frequency, storm intensity, sediment supply or changing transport conditions. Analyzing wetland responses to sea level rise may require site-specific analyses of various physical and biological factors as described in Heberger *et al.* 2009.
  - Sedimentation rates
- Water quality
  - Current and future saltwater intrusion areas

[30] Tidal datums are based on the latest National Tidal Datum Epoch (NTDE) published by NOAA and are the mean of the observed sea levels over a 19-year period. The latest published epoch is 1983-2001. This tidal epoch can be considered equivalent to the year 2000 baseline for the **OPC projections**.

- Current and potential future coastal water pollution issues due to inundation of toxic soils, rising water tables, and increases in nonpoint source pollution

Use existing models, tools, reports, historic records, and other materials (Table 5) to develop or double check the identified hazard areas. Document the current and future hazard areas in the Land Use Plan using maps, GIS products, graphics, tables, charts, figures, descriptions, or other means. This process should be repeated for each planning horizon and/or sea level rise scenario defined in Step 1.

Expected outcomes from Step 2: *Upon completing this step, the potential current and future impacts to the planning area from sea level rise hazards should be identified based on sea level rise projections. These should include impacts from the high, low, and intermediate sea level rise scenarios for the planning horizon(s) of concern. Maps, GIS layers, graphics, figures, charts, tables, descriptions, or another system should be developed to communicate the impacts of current and future hazards.*

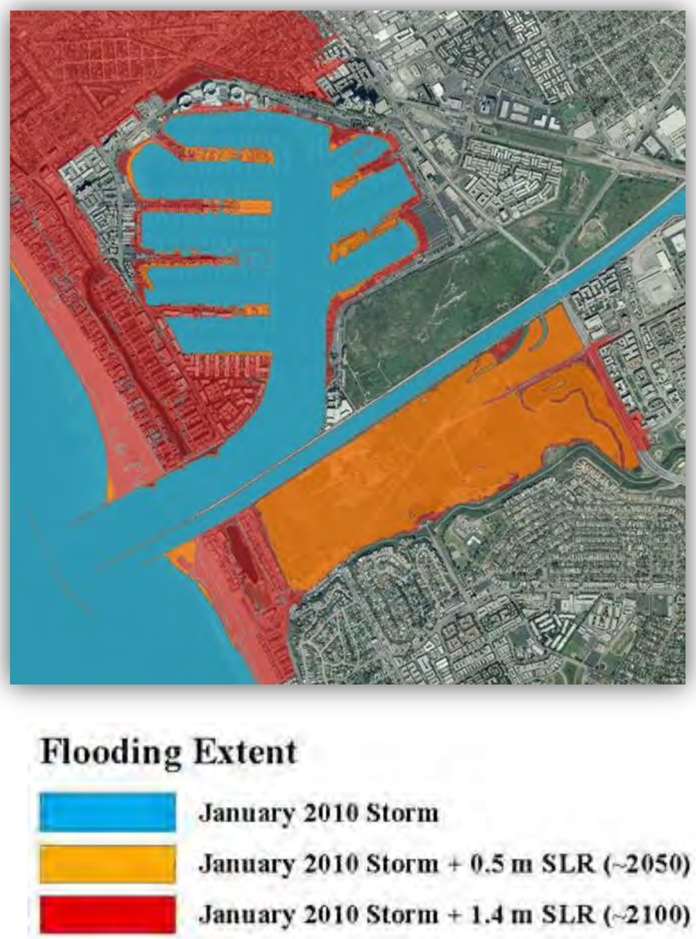

Figure 11. Example of analysis of SLR impacts. Flooding hazards predicted from the CoSMoS hindcast of the January 2010 storm, with and without sea level rise (SLR) scenarios, in the region of Venice and Marina del Rey, CA. (*Source*: Barnard *et al*. 2014).

Resources for Sea Level Rise Mapping

Table 5 includes a list of sea level rise mapping tools. The tools vary in their complexity: some are considered "bathtub models," because they show future inundation with simple rise in sea level (and no changes to the shoreline caused by other forces). Others include factors like erosion, storms, and fluvial inputs. These tools provide a useful first look at possible sea level rise impacts, but may need to be supplemented with additional, site- or topic-specific analyses, depending on the region. See Appendix B for additional information on determining hazard impacts and tools for mapping sea level rise.

Table 5. Sea Level Rise Mapping Tools

Tool	Description	Link
Statewide		
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels with a slider bar. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	NOAA Office for Coastal Management, http://coast.noaa.gov/digitalcoast/tools/slr
Cal-Adapt – Exploring California's Climate	**Represents inundation location and depth for the San Francisco Bay, the Sacramento-San Joaquin River Delta and California coast resulting from different increments of sea level rise coupled with extreme storm events. Incorporates real, time series water level data from past (near 100 year) storm events to capture the dynamic effect of storm surges in modeling inundation using a three dimensional hydrodynamic model (per Radke, 2017).**	http://cal-adapt.org/sealevel/
Pacific Institute Sea Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise, population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report *The Impacts of Sea-Level Rise on the California Coast* visit: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/

Climate Central Surging Seas	Overlays sea level rise data with socio-economic information and ability to analyze property values, population, socio-economic status, ethnicity, and income or areas at risk. Can compare exposure across the state or a county.	http://sealevel.climatecentral.org/ssrf/california
Coastal Storm Modeling System (CoSMoS); tool hosted by Our Coast Our Future	**Currently available for Point Arena to the Mexico border, with a statewide expansion anticipated in 2018/2019. The Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that allows detailed predictions of coastal flooding due to both future sea level rise and storms, and integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat)**	https://walrus.wr.usgs.gov/coastal_processes/cosmos/ http://data.pointblue.org/apps/ocof/cms/
TNC Coastal Resilience	**An online mapping tool showing potential impacts from sea level rise and coastal hazards designed to help communities develop and implement solutions that incorporate ecosystem-based adaptation approaches. Available statewide with more detailed modelling for Monterey Bay, Santa Barbara, Ventura, and Santa Monica.**	http://maps.coastalresilience.org/california/
Humboldt Bay Sea Level Rise Adaptation Project	This project is a multi-phased, regional collaboration. Phase I produced the *Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment* which describes current shoreline conditions and vulnerabilities under the current tidal regime. Phase II included hydrodynamic modeling to develop vulnerability maps of areas surrounding Humboldt Bay vulnerable to inundation from existing and future sea levels. Phase II produced the *Humboldt Bay Sea Level Rise Modeling Inundation Mapping Report* and the *Humboldt Bay Sea Level Rise Conceptual Groundwater Model*.	All reports are available at: http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project

Step 3 – Assess potential risks from sea level rise to coastal resources and development in LCP planning area/segment

After sea level rise impacts are identified and mapped in Step 2, the next Step is to determine whether sea level rise poses any risks, or potential problems, for coastal resources and development in the LCP planning area (refer to Chapter 4 for a description of the potential consequences of sea level rise for coastal resources). Next, assess whether the LCP planning area's current and planned land uses are appropriate or consistent with Coastal Act or LCP policies given those impacts, or if those land uses should be revised. This step requires an understanding of several characteristics of the coastal resources and development typically found within various land use types. (Much of this information can be produced in a vulnerability assessment, an analysis that is commonly conducted in the planning and climate change adaptation field. See Appendix C for a list of recent sea level rise vulnerability assessments.) Account for potential impacts to vulnerable, low-income communities and consider coastal development and resources, including but not limited to:

- Existing and planned development
- Coastal-dependent development and uses such as harbors, wharfs, ports, marinas, and commercial and recreational fishing areas and facilities
- Critical infrastructure[31] such as wastewater treatment plants, transportation infrastructure, and some power plants and energy transmission infrastructure
- Public accessways, beaches and other recreation areas, and the California Coastal Trail
- State Highway 1, 101, and other state and local roads that provide access to the coast
- Wetlands, environmentally sensitive habitat area (ESHA), and other coastal habitats and sensitive species
- Agricultural areas
- Cultural sites and archaeological or paleontological resources
- Visitor-serving development and uses

Conduct the following tasks for each planning horizon (*e.g.*, the years 2030, 2050, and 2100, or other planning horizons):

1. For the planning horizon of interest, determine what development and coastal resources may be subjected to the sea level rise impacts expected for that time period. Map the coastal resources and development that lie within the sea level rise impact areas for the given time period. (Remember to address the wide range of resources listed above, including both natural resources and development.)

[31] Critical infrastructure can vary widely from community to community. For planning purposes, a jurisdiction should determine criticality based on the relative importance of its various assets for the delivery of vital services, the protection of special populations, and other important functions.

2. Determine if sea level rise impacts are a problem or benefit for each resource, and if so, when and to what degree the resource will be impacted. In some instances, sea level rise may result in the creation of new habitat areas that could help to alleviate impacts from the loss of similar habitat in other locations. However, it is more likely, especially in heavily urbanized areas, that sea level rise will result in a net loss of habitat unless steps are taken to preserve these systems.

   To accomplish this, consider a wide range of characteristics of each resource, including the following. The questions listed under each characteristic might help guide the consideration of each of these characteristics. These questions are meant to be suggestions rather than a standardized approach, and planners may use scientific literature, best professional judgment, or a variety of other resources to gain a conceptual understanding of the important resources and vulnerabilities in their jurisdictions.

   a. **Exposure.** Will sea level rise impacts affect the resource/development at all?
      i. Are coastal resources and community assets exposed to sea level rise impacts?
      ii. Is the resource already exposed to hazards such as waves, flooding, erosion, or saltwater intrusion? If it is, will sea level rise increase hazard exposure?

   b. **Sensitivity.** If resources are exposed, to what degree will coastal resources/development be affected by sea level rise impacts? A simple way to think about this concept is to consider *how easily affected* the resource or development is in regard to sea level rise impacts.
      i. How quickly will the resource respond to the impact from sea level rise?
      ii. Will the resource/development be harmed if environmental conditions change just a small amount? What are the physical characteristics of resource/asset (*e.g.*, geology, soil characteristics, hydrology, coastal geomorphology, topography, bathymetry, land cover, land use)? Do any of those characteristics make the resource especially sensitive?
      iii. Are there thresholds or tipping points beyond which sensitivity to sea level rise increases?

   c. **Adaptive Capacity.** How easily can the resource successfully adapt to sea level rise impacts?
      i. How well can the resource/development accommodate changes in sea level?
      ii. Is rate of change faster than the ability of the resource/development to adapt?
      iii. How easily can development be modified to cope with flooding, inundation, and/or erosion? Can structures be elevated or relocated?

iv. Are there adaptation efforts already underway? Are there any factors that limit the success of adaptation efforts?

v. Do beaches, wetlands and other coastal habitats have room to migrate inland? What is the overall health of existing wetlands and coastal habitats?

vi. Are there any other climate change-related impacts to consider? Are there any non-climate stressors that could impair ability to adapt to sea level rise?

vii. Is there potential for habitat creation as a result of sea level rise?

viii. What are the options to protect, redesign (*e.g.*, elevate), or relocate inland any existing public accessways, recreational beaches, and segments of the Coastal Trail to cope with rising sea levels? Is lateral access compromised with sea level rise?

d. **Consequences.** When sea level rise and/or sea level rise adaptation measures have impact(s) upon a resource, what are the economic, ecological, social, cultural, and legal consequences?

i. How severely could each resource be affected? At what scale?

ii. Are there cumulative consequences?

iii. Are there ripple effects, or secondary consequences to consider?

iv. Will human responses cause further adverse impacts?

e. **Land Use Constraints.** Given the location of sea level rise impacts and the resources currently located in those areas, should the types and intensities of land use be altered to minimize hazards and protect coastal resources?

i. What is the current pattern of development? Is the area largely developed or does it have significant areas of undeveloped land?

ii. Is the area served by infrastructure that is vulnerable to sea level rise impacts?

iii. Are large areas of land under common ownership or is land mostly subdivided into smaller lots in separate ownership?

iv. What conditions does the land use type, development, or resource require to either exist or fulfill its intended purpose?

v. Is it a coastal-dependent use? What is its ideal proximity to the coast?

vi. For new development, what is the expected lifespan? Is it economically feasible to locate it in a sea level rise impact area for a certain period of time before it is removed or relocated?

vii. For existing development, what are the options available to minimize hazards to the development and protect coastal resources? Note that in certain situations, the Coastal Act allows existing structures to be protected (Coastal Act Section 30235). What are the coastal resource impacts of such protection, and are there feasible alternatives that avoid shoreline armoring, such as options to provide incentives to property owners to relocate or remove at-risk structures?

viii. For a natural resource or habitat, what conditions does it require to persist?

ix. Where would resources/development ideally be located after sea level rise causes environmental conditions to shift?

x. What changes to existing LCP requirements or other land use restrictions are necessary to maximize opportunities for avoiding hazards or relocating threatened existing development?

After going through the questions listed above, and others that may be relevant to the planning exercise, synthesize the information and determine where sea level rise impacts currently pose problems for coastal resources, what problems may develop over time as sea level rises, and how urgent the problems are. Create maps illustrating the location and extent of vulnerable land uses, such as critical facilities, wastewater infrastructure, and State Highway 1 and other coastal access roadways. This information can also be summarized in narrative form. The analysis should identify resources and development likely to be impacted by sea level rise at various periods in the future, and thus the issues that need to be resolved in the LCP planning process.

Remember that these assessments are not static; existing risks will change and new risks will arise with changes in a community, the emergence of new threats, new information, and the implementation of adaptation actions. For this reason, the analysis should be updated as needed to reflect changes in sea level rise projections, changes in land use patterns, or new threats.

Expected outcomes from Step 3*: Descriptions of the characteristics that influence risk, including exposure, sensitivity, and adaptive capacity of each coastal resource to sea level rise impacts under each sea level rise scenario identified in Step 1 at the selected planning horizons, along with the expected consequences of those impacts for the resource and broader community. Maps of resources and/or land uses at risk could be produced.*

Example for Step 3

To illustrate the process described in Step 3, consider a hypothetical planning area that includes multiple coastal resources and land use types, including a coastal wetland, bluff-top residential development with a fronting beach, and a wastewater treatment facility, that need to be addressed in the planning process. After Steps 1 and 2, portions of the planning area are found to be subject to current and future sea level rise impacts.

Step 3.1: Map the coastal resources (in this case the wetland, development, and wastewater treatment facility) for the range of time periods and sea level rise projections.

Step 3.2

a. **Exposure**

- *Wetland:* The wetland is highly exposed to flooding and inundation from sea level rise. By the year 2030, portions of the wetland will trap sediment at a rate such that the elevation keeps pace with sea level rise. By 2050, a portion of the wetland will become inundated and converted to open water, and by 2100 the entire area will be converted to open water. The wetland will be completely lost by this time period if it is not able to move inland.
- *Bluff-top Residential Development:* Houses in the residential development are not exposed to sea level rise impacts in 2030. However, a high rate of retreat along the fronting beach and bluff will put front-line houses in danger of being undermined by the year 2050, and the entire development may be lost by 2100.
- *Wastewater Treatment Facility:* Given that the wastewater treatment plant is set back somewhat from the water, it will not be exposed to impacts from sea level rise until 2050. By 2050, however, portions of the infrastructure will be exposed to impacts from elevated water levels due to 100-year storm events and El Niño occurrences. By 2100, significant portions of the facility will be exposed to flooding as the surrounding area is eroded and inundated.

b. **Sensitivity**

- *Wetland:* The wetland has high sensitivity to changes in sea level because its functioning is highly-dependent on local physical parameters such as water flow, tidal fluctuation, sediment supply, and water quality. Although it currently has good sediment supply, good water quality, and a number of other characteristics, small changes in sea level rise by 2050 may alter the function of the wetland. In addition, there are concerns that beyond 2050 the wetland will not be able to keep up with accelerated sea level rise, thus increasing sensitivity to further changes in sea level.
- *Bluff-top Residential Development:* The residential development has moderate to high sensitivity to longer-term sea level rise changes. By 2050, the front-line houses will no longer be safe enough for occupancy. Moreover, infrastructure such as roads, sewage systems, and power networks may be damaged as the bluff-face erodes.
- *Wastewater Treatment Facility:* The facility is moderately sensitive to sea level rise. Flooding and erosion from sea level rise could cause damage of the facility, pumps and

other equipment, but the facility was initially built to withstand a high degree of storm and related impacts.

c. **Adaptive Capacity**

- *Wetland:* Unlike many wetlands in the State of California, this particular wetland has a moderate-high adaptive capacity because it has the ability to both accumulate sediment and grow upwards, and, given that the land upland of the wetland is preserved as open space, it can migrate inland. However, by 2050, a part or all of the existing wetland area could be converted to open water if the wetland is not able to migrate inland or accumulate sediment at a rate that keeps pace with sea level rise. In this case, for example, a public trail will need to be relocated to allow inland migration of the new intertidal zone. Additionally, adaptive capacity may be reduced if pollution increases (*e.g.*, as a result of damage to adjacent development) and disrupts the normal functioning of the wetland.
- *Bluff-top Residential Development:* The residential development has a moderate adaptive capacity. As houses become threatened over time, a scenario of managed retreat would allow houses to be removed incrementally and eventually be relocated to safer areas. The feasibility of managed retreat can depend upon lot sizes, ownership patterns, land use restrictions in the safer areas, and the availability of public or private financing. In addition, a protective structure such as a seawall would minimize threats to the residence due to erosion, though if the development is protected by shoreline structures, the fronting beach will eventually be lost.
- *Wastewater Treatment Facility:* The wastewater treatment facility has a very low adaptive capacity. It is large and has expensive infrastructure so it cannot be elevated, and relocation is costly and difficult. In order to be protected in its current location, new structures will need to be built.

d. **Consequences**

- *Wetland:* In many situations, the loss of wetland area is a high risk since wetlands provide flood protection, water quality enhancement, and essential habitat for fish and bird species. However, in this case, wetland migration is not restricted by inland development, so the risks for this wetland are slight to moderate, depending upon the suitability of the inland area for establishment of wetland plants and potential changes in water temperature and water quality. In the short term, the wetland will likely continue to function at normal levels. However, if it eventually can't keep up with sea level rise or if there are barriers to migration, loss of the habitat will result in a loss of important ecosystem services.
- *Bluff-top Residential Development:* The housing development has medium to high risk through 2100. The option to either relocate houses or protect them with a seawall means that they could continue to exist. Importantly, a system of managed retreat will allow for the continued existence of the fronting beach and all of its social, economic, and environmental benefits, whereas the construction of a seawall will result in the loss of the beach and these benefits.

- *Wastewater Treatment Facility:* Given its low adaptive capacity and high sensitivity to higher levels of sea level rise, the wastewater treatment facility is at high risk. Loss or damage to the facility could result in serious social, economic, and environmental consequences. Flooding of the facility and surrounding areas will cause damage to infrastructure and loss of facility function. This could lead to discharge of untreated sewage, which would have adverse impacts to water quality and could impair the health of nearshore ecosystems. Sea level rise could also cause outflow pipes to back up with seawater, leading to inland flooding and additional water quality problems. However, efforts to protect the structure may have unintended consequences including loss of surrounding habitat areas.

e. **Land Use Constraints (discussed further in Step 4)**

- *Wetland:* The high adaptive capacity of the wetland means that minimizing risk to this resource may be accomplished by ensuring that there is space available for it to move into. Land use policies designed to protect areas inland of the current wetland area will be necessary.
- *Bluff-top Residential Development:* The area in question will eventually become incompatible with the current use. Development will not begin to be exposed to sea level rise impacts until 2050, but it is important to start planning now about how best to address the risks to the houses. Managed retreat would necessitate identifying feasible locations into which houses could be moved or a plan to abandon and remove houses. Such a plan might include a Transfer of Development Rights program in which homes are encouraged in less hazardous areas. If a managed retreat strategy is not in place, existing structures may qualify for shoreline protection. Shoreline protection would likely exacerbate beach erosion, degrade public access, impair shoreline habitat, and alter visual character.
- *Wastewater Treatment Facility:* The biggest risk in this scenario is to the wastewater treatment facility. It should be determined how likely it is that the facility will be able to be protected throughout the rest of its expected lifespan under even the highest sea level rise scenarios. It may be that the wastewater treatment facility becomes an incompatible use under future conditions. If so, plans should be made to relocate at-risk portions of the facility, as feasible, or to phase out the facility.

Note that this is a simplified example used to demonstrate the process described in Step 3. Decisions about how to address various challenges presented by sea level rise will be more complex than those illustrated above and may require prioritizing the different resources based on Coastal Act requirements taking into account the goals and circumstances of the community and the various characteristics of each resource. An understanding of the exposure, sensitivity, adaptive capacity, consequences, and land use constraints for the particular resources and scenarios will need to be kept in mind as planners move into Step 4 to identify possible adaptation strategies. Updated LCP policies and ordinances should be considered to support strategy implementation over the long term.

Step 4 – Identify LCP adaptation strategies to minimize risks

Whether as part of a new LCP or as part of an amendment to update an existing LCP, coastal planners should work with the Coastal Commission and relevant stakeholders at all steps, but particularly to evaluate potential options and adaptation strategies to address the sea level rise impacts identified in Step 2 and the risks to coastal resources identified in Step 3. Planners will then develop new or revised land use designations, policies, standards, or ordinances to implement the adaptation strategies in the LCP.

An LCP as certified by the Commission should already have land use policies, standards, and ordinances to implement Coastal Act Chapter 3 policies, including policies to avoid and mitigate hazards, and to protect coastal resources. However, in older LCPs, many of these policies may not address changing conditions adequately enough to protect coastal resources over time as sea level rises. Similarly, policies to protect resources and address coastal hazards may not reflect new techniques that can be utilized to adaptively manage coastal resources in a dynamic environment. As such, the LCP should be evaluated to identify the land use designations, policies, or ordinances that need to be amended. An LCP update may need to include a variety of adaptation measures depending on the nature and location of the vulnerability. In addition, local governments may need to add new "programmatic" changes to address sea level rise, such as transfer of development credit programs, regional sediment management programs, or a land acquisition program.

In Steps 1-3, planners will have analyzed several possible sea level rise scenarios, and this analysis will have revealed valuable information about areas and specific coastal resources that are especially vulnerable to sea level rise hazards under possible scenarios. The results should show areas that are particularly resilient to future change and trigger points at which sea level hazards will become particularly relevant to certain areas. Step 3d (identifying the *Consequences* of sea level rise impacts) and Step 3e (considering the *Land use constraints*) will be particularly useful in thinking through what resources are particularly vulnerable and what the local priorities may be.

In Step 4, planners should weigh information from the previous steps, keeping in mind the hazard avoidance and resource protection policies of the Coastal Act, and begin identifying, choosing, and/or developing adaptation strategies to be included in a new or updated LCP. The options available to minimize risks from sea level rise are dependent upon the specifics of the local community, and will vary widely depending on whether the area is an urban, fully-developed waterfront, or a rural, undeveloped coastline. In undeveloped areas, the options may be clear: strictly limit new development in sea level rise hazard zones.

However, in urban areas, sea level rise can present unprecedented challenges, and the options are less clear. The Coastal Act allows for protection of certain existing structures. However, armoring can pose significant impacts to coastal resources. To minimize impacts, innovative, cutting-edge solutions will be needed, such as the use of living shorelines to protect existing infrastructure, restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs. Strategies will need to be tailored to the specific needs of each community based on the resources at risk, should be evaluated for resulting impacts to coastal resources, and should be developed through a public process, in close consultation with the Coastal Commission and in line with the Coastal Act.

Adaptation strategies should be selected based upon the local conditions, the results of the scenario-based analysis, and Coastal Act requirements, taking into account the particular goals of the local community. If certain adaptation strategies should be implemented when conditions reach pre-identified trigger points, those caveats should be included in the LCP. Similarly, LCP adaptation policies should be developed and implemented in such a way as to be flexible and adaptive enough that they can be changed or updated as conditions change or if sea level rise impacts are significantly different than anticipated. Additionally, many adaptation strategies should be implemented in a coordinated way through both the LCP and individual CDPs. For example, current land uses that will conflict with future conditions may be amended through updated zoning designations in an LCP. In turn, zoning designations could carry out specific policies or requirements regarding new development or redevelopment that need to be addressed in a CDP to ensure that projects are resilient over time. Planners are encouraged to work with Coastal Commission staff to ensure compliance with the Coastal Act and to coordinate and share information with other local partners including those in charge of emergency management, law enforcement, and related services, and those identified in Figure 10 as applicable and feasible.

A key issue that should be addressed in the LCP is the evaluation of strategies to minimize hazards related to existing development. Under the Coastal Act, certain improvements and repairs to existing development are exempt from CDP requirements. Non-exempt improvements and any repairs that involve the replacement of 50% or more of a structure, however, generally require a CDP and must conform to the standards of the relevant Local Coastal Program or Coastal Act.[32] Redevelopment, therefore, should minimize hazards from sea level rise. For existing structures currently sited in at-risk locations, the process of redeveloping the structure may require the structure to be moved or modified to ensure that the structure and coastal resources are not at risk due to impacts from sea level rise. As described in Guiding Principle 6, sequential renovation or replacement of small portions of existing development should be considered in total. LCPs should include policies that specify that multiple smaller renovations that amount to alteration of 50% or more of the original structure should require a Coastal Development Permit, and require that the entire structure to be brought into conformance with the standards of the Local Coastal Program or Coastal Act.[33]

[32] Section § 13252(b) of the Commission's regulations states that "unless destroyed by natural disaster, the replacement of 50 percent or more of a single family residence, seawall, revetment, bluff retaining wall, breakwater, groin or any other structure is not repair and maintenance under Coastal Act Section 30610(d) but instead constitutes a replacement structure requiring a Coastal Development Permit."

[33] In addition, for existing structures located between the first public road and the sea or within 300 feet of the inland extent of a beach, improvements that increase the height or internal floor area by more than 10% normally require a CDP. (Cal. Code Regs., tit. 14, §§13250(b)(4), 13253(b)(4).) Depending upon the location of the structure, smaller improvements may also require a CDP. (Cal. Code Regs., tit. 14, §§ 13250(b), 13253(b).)

General Adaptation Strategies:

Chapter 7 describes a number of adaptation policies and strategies and is organized by resource type to allow users to easily identify the types of policies that may be relevant to local resource vulnerabilities. However, there are a number of adaption strategies or related actions that apply to a variety of resources or that may be generally useful when adopting or updating an LCP. Some of these adaptation strategies and actions are broadly described below.

- **Update resource inventory and maps**: An important first step for addressing sea level rise hazards and vulnerabilities in a new or updated LCP will be to compile a set of maps that clearly show the current locations of the range of coastal resources present in an LCP jurisdiction (*e.g.*, beaches and public accessways; agricultural land, wetlands, ESHA, and other coastal habitats; energy, wastewater, transportation, and other critical infrastructure; and archaeological and paleontological resources), as well as existing land use designations, and hazard areas. It may also be helpful to map possible future conditions based on the analysis done in Steps 1-3. Doing so will help planners begin to identify possible land use and zoning changes and other adaptation strategies that will be necessary to meet hazard avoidance and resource protection goals.
- **Update land use designations and zoning ordinances**: One of the most common methods of regulating land use is through zoning designations and ordinances, and updating these policies is one of the most fundamental ways of responding to sea level rise impacts. Planners may address particular vulnerabilities and local priorities by updating land use designations and zoning ordinances to protect specific areas and/or resources. For example, areas that are particularly vulnerable to sea level rise impacts can be designated as hazard zones and specific regulations can be used to limit new development and/or to encourage removal of existing development in such zones. Similarly, open areas can be designated as conservation zones in order to protect and provide upland areas for wetland and habitat migration or for additional agricultural land.
- **Update siting and design standards**: Updated siting and design standards may go hand in hand with updated land use designations and zoning ordinances in that specific standards may be required for development or projects in certain zones. For example, development in hazard zones may require additional setbacks, limits for first floor habitable space, innovative stormwater management systems, special flood protection measures, mitigation measures for unavoidable impacts, relocation and removal triggers and methodologies, and so on.
- **Establish methods to monitor local changes from sea level rise**: Add policies that establish actions to conduct long-term sea level rise monitoring and research on areas of key uncertainties, areas sensitive to small changes in sea level rise, or areas with high sea level rise risk.
- **Research and data collection**: Support research to address key data gaps and better utilize existing information. Local governments may find it useful to collaborate with local, regional, and state partners to pursue new research to better understand the factors controlling sea level rise, baseline shoreline conditions, ecosystem responses to sea level rise, potential impacts and vulnerabilities, and the efficacy of adaptation tools. Related efforts may include monitoring programs designed to track trends in local shoreline

change, flooding extent and frequency, or water quality. Monitoring of the results of various adaptation strategies and protective structures could be included as part of a Coastal Development Permit for projects in hazard zones.

- **Outreach and education**: Education and outreach efforts involve formal instruction and provision of information to stakeholders, and can help generate support for planning and action implementation. It is important to coordinate with partners and include all relevant stakeholders in these processes, particularly those that are typically isolated, such as low-income or underserved communities. For many people, sea level rise is a new issue. Information on sea level rise science and potential consequences may motivate stakeholders to take an active role in updating the LCP for sea level rise issues, or in the vulnerability and risk assessment efforts. Additionally, education efforts regarding the risks of sea level rise as well as possible adaptation strategies may encourage people to take proactive steps to retrofit their homes to be more resilient or to choose to build in less hazardous areas.

As stated above, a more extensive and detailed list of possible adaptation strategies can be found in Chapter 7. The list should neither be considered a checklist from which all options need to be added to an LCP, nor is it an exhaustive list of all possible adaptation strategies. Sea level rise adaptation is still an evolving field and decision makers will need to be innovative and flexible to respond to changing conditions, new science, and new adaptation opportunities. The important point is to analyze current and future risks from sea level rise, determine local priorities and goals for protection of coastal resources and development, and identify what land use designations, zoning ordinances, and other adaptation strategies can be used to meet those goals within the context of the Coastal Act.

Expected outcomes from Step 4*: Identified sections of the LCP that need to be updated, a list of adaptation measures applicable to the LCP, and new policies and ordinances to implement the adaptation measures.*

Step 5 – Draft updated or new LCP for certification with the Coastal Commission

Once potential adaptation strategies have been identified, LCP policies that address sea level rise should be incorporated into a new LCP or LCP amendment. For jurisdictions with a certified LCP, adaptation measures will be implemented through development of amendments to the certified LCPs. For jurisdictions that currently do not have a certified LCP, the sea level rise policies will be part of the development of a new LCP. In areas without a certified LCP, the Coastal Commission generally retains permitting authority, and the standard of review for development is generally Chapter 3 of the California Coastal Act.

As noted in Step 4, sea level rise has the potential to affect many types of coastal resources in an LCP planning area/segment, and it is likely that policies throughout the LCP will need to be revised or developed to address impacts from sea level rise. Two major types of updates to the LCP will likely be needed to address sea level rise:

1. New or revised policies/ordinances that apply to all development in the planning area. For example, policies such as "All new development shall be sited and designed to minimize risks from sea level rise over the life of the structure."
2. Updated land use and zoning designations, as well as programs to facilitate adaptive community responses, to reduce risks to specific coastal resources. For example, the LCP could modify the zoning of undeveloped land located upland of wetlands from residential to open space in order to provide the opportunity for wetlands to migrate inland, and protect wetlands for the future.

Local government staff should work closely with Coastal Commission staff and relevant stakeholders, including ensuring there is opportunity for public input, to develop the new LCP or LCP amendments. Once the updates and plans are complete, local governments will submit to the Commission for certification. The Commission may either certify or deny the LCP or LCP amendment as submitted, or it may suggest modifications. If the Commission adopts suggested modifications, the local government may adopt the modifications for certification or refuse the modifications and resubmit a revised LCP for additional Commission review. For more information on updating LCPs, see https://www.coastal.ca.gov/rflg/.

Expected outcomes from Step 5*: Certified/updated LCP with policies and land use designations that address sea level rise and related hazards and ensure protection of coastal resources to the maximum extent feasible.*

Step 6 – Implement LCP and monitor and revise as needed

Upon certification of the updated LCP, sea level rise adaptation strategies will be implemented through the certified implementing ordinances and related processes and actions (*e.g.*, local review of CDPs, proactive action plans). Additionally, an important component of successful adaptation is to secure funds for implementation, regularly monitor progress and results, and update any policies and approaches as needed. Sea level rise projections should be re-evaluated and updated as necessary.

- **Secure resources for implementation:** There are a number of different sources of funds available to help local governments implement adaptation strategies. For example, the Coastal Commission, the Ocean Protection Council, and the Coastal Conservancy have grant programs designed to support local adaptation efforts (see Chapter 1 for additional details on each of these programs).

  As described previously there may also be overlap between LCP planning and Local Hazard Mitigation planning. FEMA's Hazard Mitigation Assistance (HMA) grant programs provide significant opportunities to reduce or eliminate potential losses to State, Indian Tribal government, and local assets through hazard mitigation planning and project grant funding. Currently, there are three programs: the Hazard Mitigation Grant Program (HMGP); Pre-Disaster Mitigation (PDM); and Flood Mitigation Assistance

(FMA)[34]. Cal OES administers the HMA and FMA programs. More information can be found at http://www.caloes.ca.gov/cal-oes-divisions/recovery/disaster-mitigation-technical-support/404-hazard-mitigation-grant-program or the FEMA HMA Web site at https://www.fema.gov/hazard-mitigation-assistance.

A list compiled by Cal OES of additional funding options for hazard mitigation can be found in Appendix E. The Commission recognizes that funding opportunities are constantly evolving, that demand for funding is increasing, and that there is a significant need for the development of additional funding opportunities.

- **Identify key resources to monitor:** Certain species can be indicators of whether sea level rise is affecting an ecosystem. For instance, the presence of certain plant species can indicate the salinity of soils. Also, monitoring plans should reflect the outcome of the scenario-based analysis of sea level rise. Some adaptation measures might be earmarked for implementation when a certain amount of sea level rise (or a particular sea level rise impact) occurs. Monitoring programs should ensure that these triggers are recognized and responded to at the appropriate time.

- **Periodically Update LCPs:** Local governments should try to review their vulnerability and risk assessments on a regular basis as significant new scientific information becomes available and propose amendments as appropriate. Given the evolving nature of sea level rise science, policies may need to be updated as major scientific advancements are made, changing what is considered the best available science. Modify the current and future hazard areas on a five to ten year basis or as necessary to allow for the incorporation of new sea level rise science, monitoring results, and information on coastal conditions. Regular evaluation of LCPs is important to make sure policies and adaptation strategies are effective in reducing impacts from sea level rise.

Expected outcomes from Step 6*: Plan to monitor the LCP planning area for sea level rise and other impacts and for effectiveness of various adaptation strategies that are implemented; plan to revise the LCP when conditions change or science is updated.*

This six-step process discussed in this chapter is illustrated in the flowchart below (Figure 12). Notice that the process is circular. Because sea level rise science will be refined and updated in the future, planners should periodically repeat this six-step process to update and improve their LCPs.

For additional resources and examples of ways to incorporate sea level rise into the LCP, see Appendix C.

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[34] Each HMA program was authorized by separate legislative action, and as such, each program differs slightly in scope and intent.

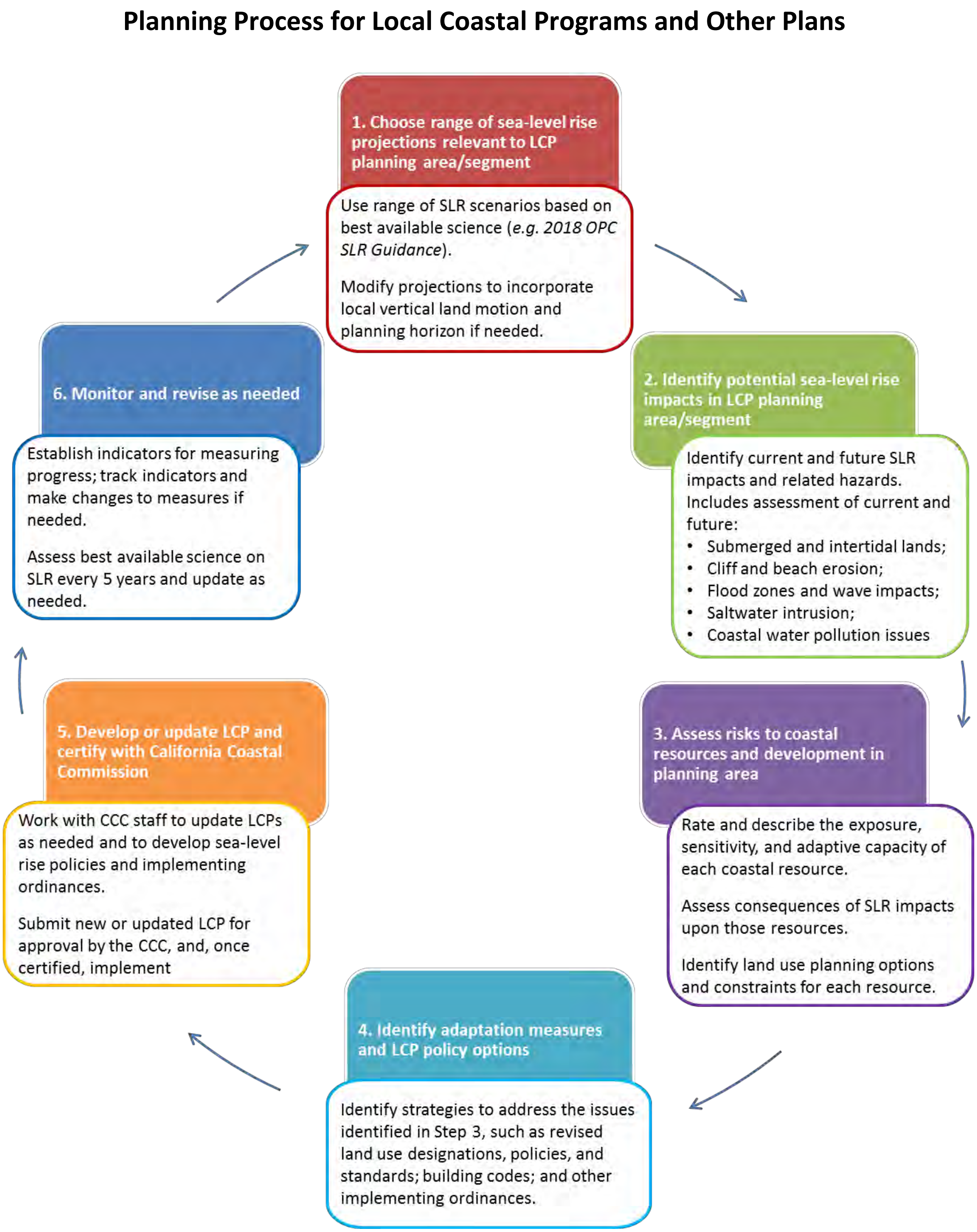

Figure 12. Flowchart for addressing sea level rise in Local Coastal Programs and other plans

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Chapter 6

Addressing Sea Level Rise in Coastal Development Permits

Development in the coastal zone generally requires a Coastal Development Permit (CDP).[35] In areas of retained jurisdiction and areas without a certified Local Coastal Program (LCP), the Commission is generally responsible for reviewing the consistency of CDP applications with the policies of Chapter 3 of the Coastal Act (Public Resources Code Sections 30200-30265.5).[36] In areas with a certified LCP, the local government is responsible for reviewing the compliance of CDP applications with the requirements of the certified LCP and, where applicable, the public access and recreation policies of the Coastal Act. Certain local government actions on CDP applications are appealable to the Commission. On appeal, the Commission also applies the policies of the certified LCP and applicable public access and recreation policies of the Coastal Act.[37] The Commission and local governments may require changes to the project or other mitigation measures in order to assure compliance with Coastal Act policies or LCP requirements by both minimizing risks to the development from coastal hazards and avoiding impacts to coastal resources.

The Coastal Act, the LCP, and the CDP Application cover the broad range of information and analyses that must be addressed in a CDP application. This CDP guidance focuses only on sea level rise and those conditions or circumstances that might change as a result of changing sea level. It does not address other Coastal Act or LCP requirements.

Adopting or updating LCPs as recommended in this Guidance should facilitate subsequent review of CDPs. LCPs can identify areas where close review of sea level rise concerns is necessary and where it is not. If kept up to date, they can also provide information for evaluation at the permit stage and specify appropriate mitigation measures for CDPs to incorporate.

Sea level rise will be important for some, but not all, of the projects reviewed through the CDP process. Locations currently subject to inundation, flooding, wave impacts, erosion, or saltwater intrusion will be exposed to increased risks from these coastal hazards with rising sea level and will require review for sea level rise effects. Locations close to or hydraulically connected to these at-risk locations, will themselves be at risk as sea level rises and increases the inland extent

[35] Coastal Act Section 30106 defines "Development" to be, "on land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice Act of 1973 (commencing with Section 4511)."

[36] The Commission retains CDP jurisdiction below mean high tide and on public trust lands.

[37] Local governments may assume permitting authority even without a fully certified LCP (*see* Public Resources Code, §§ 30600(b), 30600.5), but only the City of Los Angeles has done so. Any action on a CDP application by a local government without a fully certified LCP may be appealed to the Commission. (Public Resources Code, § 30602.)

of these hazards. The following box provides some of the general situations for which sea level rise will need to be included in the project analysis.

General Situations when sea level rise should be considered in the project analysis include when the project or planning site is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding or erosion from waves or tides
- Currently in a location protected by constructed dikes, levees, bulkheads, or other flood-control or protective structures
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply

Many of the projects reviewed through the CDP application process already examine sea level rise as part of the hazards analysis. Such examination will need to continue, and these guidelines offer direction and support for a thorough examination of sea level rise and its associated impacts based on current climate science, coastal responses to changing sea level, and consequences of future changes.

To comply with Coastal Act Section 30253 or the equivalent LCP section, projects will need to be planned, located, designed, and engineered for the changing water levels and associated impacts that might occur over the life of the development. In addition, project planning should anticipate the migration and natural adaptation of coastal resources (beaches, access, wetlands, *etc.*) due to future sea level rise conditions in order to avoid future impacts to those resources from the new development. As LCPs are updated to reflect changing conditions and to implement sea level rise adaptation strategies, it will be important that CDPs are also conditioned and approved in ways that similarly emphasize an adaptive approach to addressing sea level rise hazards. Such coordination between LCP and CDP adaptation policies and strategies will help ensure that coastal development and resources are resilient over time.

Steps for Addressing Sea Level Rise in Coastal Development Permits

The steps presented in Figure 13 and described in more detail below, provide general guidance for addressing sea level rise in the project design and permitting process for those projects where sea level rise may be contribute to or exacerbate hazards or impact coastal resources.

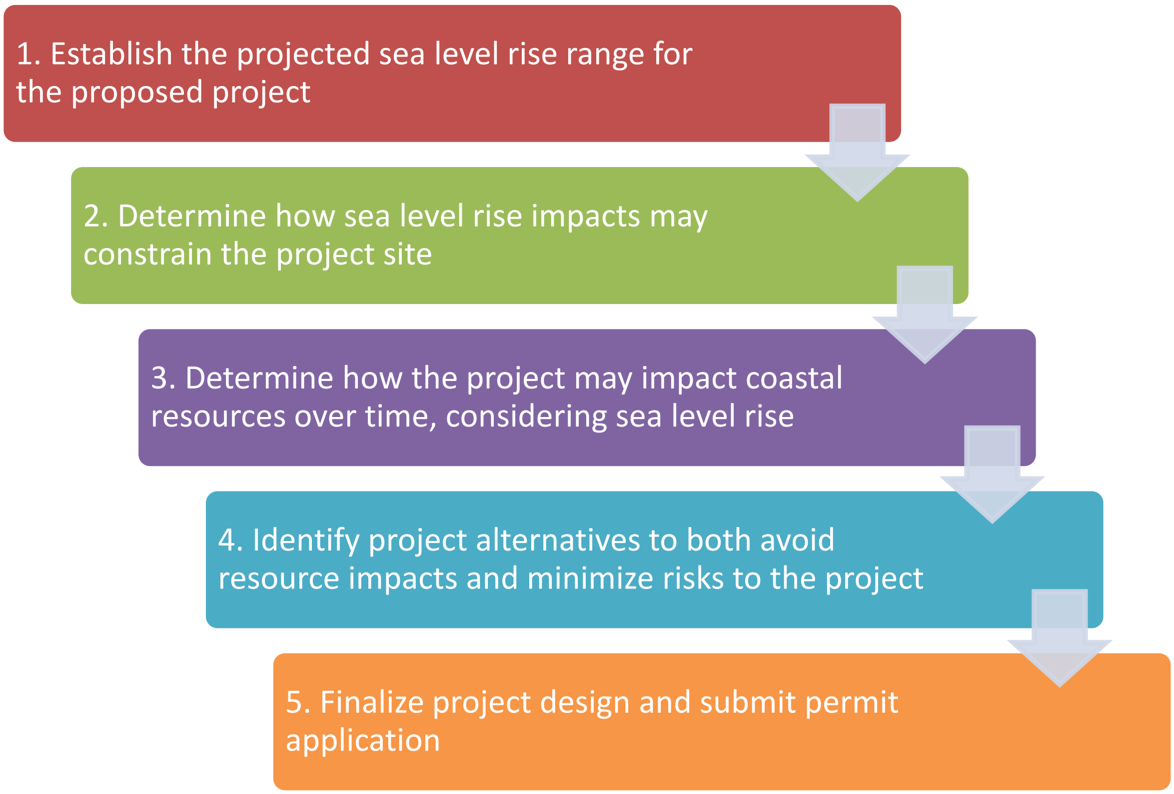

Figure 13. Process for addressing sea level rise in Coastal Development Permits

The goal of these steps is to ensure that projects are designed and built in a way that minimizes risks to the development and avoids impacts to coastal resources in light of current conditions and the changes that may arise over the life of the project. Many project sites and proposed projects may raise issues not specifically contemplated by the following guidance steps or the permit filing checklist at the end of this section. It remains the responsibility of the project applicant to adequately address these situations so that consistency with the Coastal Act and/or LCP may be fully evaluated. There are many ways to evaluate and minimize the risks associated with sea level rise, and the Commission understands that different types of analyses and actions will be appropriate depending on the type of project or planning effort.

Throughout the CDP analysis, applicants are advised to contact planning staff (either at the Commission or the local government, whichever is appropriate) to discuss the proposed project, project site, and possible resource or hazard concerns. The extent and frequency of staff coordination may vary with the scale of the proposed project and the constraints of the proposed project site. Larger projects and more constrained sites will likely necessitate greater coordination with local government and Commission staff.

Use scenario-based analysis

This process recommends using various sea level rise scenarios for the analysis of possible resource changes and site risks associated with sea level rise. Given the uncertainty about the magnitude and timing of future sea level rise, a scenario-based analysis will examine the consequences of a range of situations rather than basing project planning and design upon one sea level rise projection.

One approach for scenario-based analysis is to start with the highest possible sea level rise. If a developable area can be identified that has no long-term resource impacts, and is at no or low-risk from inundation, flooding, and erosion, then there may be no benefit to undertaking additional analysis for sea level rise and the project can continue with the rest of the analyses that are part of the Coastal Act or LCP (such as impacts to coastal habitats, public access, and scenic and visual qualities, and other issues unrelated to sea level rise).

If the site is constrained under a high sea level rise scenario, analysis of other, lower sea level rise amounts can help determine thresholds for varying impacts to coastal resources and types and extent of site constraints that need to be considered during project planning. The analysis of lower and intermediate sea level rise projections are used to better understand the timing and probability of the constraints. For further description of scenario-based analysis, see Chapter 3 of this Guidance.

Step 1 – Establish the projected sea level rise range for the proposed project

A projected sea level rise range should be obtained from the best available science, such as the **2018 OPC SLR Guidance** or an equivalent resource. These projections should cover the expected life of the proposed project, as the ultimate objective will be to assure that the project is safe from coastal hazards, without the need for shoreline protection or other detrimental hazard mitigation measures, as long as it exists.

- **Define Expected Project Life**: The expected project life will help determine the amount of sea level rise to which the project site could be exposed while the development is in place. Importantly, the point of this step is not to specify exactly how long a project will exist (and be permitted for), but rather to identify a project life time frame that is typical for the type of development in question so that the hazard analyses performed in subsequent steps will adequately consider the impacts that may occur over the entire life of the development.

  Some LCPs include a specified design life for new development. If no specified time frame is provided, a more general range may be chosen based on the type of development. For example, temporary structures, ancillary development, amenity structures, or moveable or expendable construction may identify a relatively short expected life such as 25 years or less. Residential or commercial structures will likely be around for some time, so a time frame of 75 to 100 may be appropriate. A longer time frame of 100 years or more should be considered for critical infrastructure like bridges or industrial facilities. Resource protection or enhancement projects such as coastal habitat conservation or restoration projects should also consider longer time frames of 100 years or more, as these types of projects are typically meant to last in perpetuity.[38]

- **Determine Sea Level Rise Range:** Using the typical project life identified above, the project analysis should identify a range of sea level rise projections based on the best available science that may occur over the life of the project. **At present, the 2018 OPC SLR Guidance is considered to be the best available science** (Table 6; Appendix G), though an equivalent resource may be used provided that it is peer-reviewed, widely accepted within the scientific community, and locally relevant[39].

  As explained in Chapter 3, the 2018 OPC SLR Guidance recommends evaluating different scenarios depending on the type of project and the level of risk associated with the development type. These projections scenarios include:

  1. ***Low risk aversion scenario:* may be used for projects that would have limited consequences or have a higher ability to adapt, such as sections of unpaved coastal trail, public accessways, and other small or temporary structures that are easily removable and would not have high costs if damaged.**
  2. ***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.**
  3. ***Extreme risk aversion (H++):* should be used for projects with 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. In the Coastal Commission's jurisdiction, this could include new wastewater treatment plants, power stations, highways, or other critical infrastructure.**

  In general, the Coastal Commission recommends taking a precautionary approach by evaluating the higher sea level rise projections. If constraints are identified with the high sea level rise scenario, a low sea level rise scenario and/or one or more intermediate rise scenarios should also be used. **For critical infrastructure, development with a very long project life, or 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, the analysis should consider the "extreme risk aversion" scenario. These values should each be carried forward through the rest of the steps in this chapter.**

[38] Determining an anticipated life for restoration activities or other related projects is somewhat more complex than for typical development projects because these activities are typically meant to exist in perpetuity. As such, assessing sea level rise impacts may necessitate analyzing multiple different time frames, including the present, near future, and very long term depending on the overall goals of the project. For restoration projects that are implemented as mitigation for development projects, an expected project life that is at least as long as the expected life of the corresponding development project should be considered.

[39] **More detailed refinement of sea level rise projections is not considered necessary at this time, as variations from the nearby tide gauges will often be quite small, and may be insignificant compared to other sources of uncertainty. However, the Coastal Commission recognizes that other studies exist with localized data, for example those completed in the Humboldt Bay region, which may also be appropriate for use.**

Table 6. **Sea Level Rise Projections for the San Francisco Tide Gauge[40] (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.

Expected outcomes from Step 1*: A proposed or expected project life and corresponding range of sea level projections—including the high, the low, and one or more intermediate sea level rise projections—that will be used in the following analytic steps.*

[40] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Step 2 – Determine how physical impacts from sea level rise may constrain the project site

The Coastal Act requires that development minimize risks from coastal hazards. Sea level rise can both present new hazards and exacerbate hazards that are typically analyzed in CDP applications. In this step, project applicants determine the types and extent of sea level rise impacts that may occur now and into the future.

As described in Chapter 3 of the Guidance, impacts associated with sea level rise generally include erosion, inundation, flooding, wave impacts, and saltwater intrusion. An assessment of these impacts is often required as part of a routine hazards assessment or the safety element of the LCP. Therefore, information in the local LCP can provide an initial determination of potential hazards for the project in question, if available. However, proposed development will often need a second, site-specific analysis of hazards to augment the more general LCP information.

Analyze relevant sea level rise impacts for each sea level rise scenario.

A CDP application for new development in a hazardous area should include reports analyzing the anticipated impacts to a project site associated with each sea level rise scenario identified in Step 1. Generally, the analyses pertinent to sea level rise include geologic stability, erosion, flooding/inundation, wave runup, and wave impacts, and these analyses are described in detail below. Depending on the site, however, different analyses may be required. Applicants should work with planning staff (Coastal Commission or local government staff) to perform a pre-application submittal consultation to determine what analyses are required for their particular project. Analysis of those hazards that will not be altered by sea level rise (such as the location of faults, fire zones, *etc.*) should be undertaken at the same time as the assessment of sea level rise affected hazards so a complete understanding of hazard constraints can be used for identification of safe or low-hazard building areas. After the submission of the CDP application, any additional analyses that are required will be listed in an application filing status review letter.

The professionals who are responsible for technical studies of geologic stability, erosion, flooding/inundation, wave runup, and wave impacts should be familiar with the methodologies for examining the respective impacts. However, the methodologies do not always adequately examine potential impacts under rising sea level conditions, as established by best available science. Appendix B goes through the various steps for incorporating the best available science on sea level rise into the more routine analyses, which are summarized below. The analyses should be undertaken for each of the sea level rise scenarios identified in Step 1.

- **Geologic Stability:** The CDP should analyze site-specific stability and structural integrity without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caisson foundations) that would substantially alter natural landforms along bluffs and cliffs. Geologic stability can include, among others, concerns such as landslides, slope failure, liquefiable soils, and seismic activity. In most situations, the analyses of these concerns will be combined with the erosion analysis (below) to fully establish the safe developable area.

- **Erosion:** Both bluff erosion and long-term shoreline change will increase as the time period increases. Thus, some estimate of project life is needed to determine expected bluff and shoreline change, and to fully assess the viability of a proposed site for long-term development. The CDP application should include an erosion analysis that establishes the extent of erosion that could occur from current processes, as well as future erosion hazards associated with the identified sea level rise scenarios over the life of the project. If possible, these erosion conditions should be shown on a site map, and the erosion zone, combined with the geologic stability concerns, can be used to help establish locations on the parcel or parcels that can be developed without reliance upon existing or new protective devices (including cliff-retaining structures, seawalls, revetments, groins, buried retaining walls, and caissons) that would substantially alter natural landforms along bluffs and cliffs.
- **Flooding and Inundation:** The CDP application should identify the current tidal datum and include analysis of the extent of flooding or inundation that potentially could occur from the identified sea level rise scenarios, and under a range of conditions that could include high tide, storm surge, water elevation due to El Niños, Pacific Decadal Oscillations, a 100-year storm event, and the combination of long-term erosion and seasonal beach erosion. If possible, this information and resulting flood zones should be shown on a site map.
    - **Flood Elevation Certificate**: If a site is within a FEMA-mapped 100-year flood zone, building regulations, in implementing the federal flood protection program, require new residences to have a finished floor elevation above Base Flood Elevation (BFE; generally 1 ft).[41] The CDP application should include a flood elevation certificate prepared by a registered land surveyor, engineer, or architect, demonstrating that the finished floor foundation of the new structure will comply with the minimum FEMA guidelines and building standards. However, at this time, the Flood Certificate does not address sea level rise related flooding. In addition, designing to meet FEMA requirements may be in conflict with other resource constraints, such as protection of visual resources, community character, and public access and recreation. Thus, in general, a certificate is not adequate to address Coastal Act and LCP standards for demonstrating that future flood risk or other impacts to coastal resources have been minimized.
- **Wave Runup and Wave Impacts:** Building upon the analysis for flooding, the CDP application should include analysis of the wave runup and impacts that potentially could occur over the anticipated life of the project from a 100-year storm event, combined with

[41] FEMA's proposed "Revised Guidelines for Implementing Executive Order 11988, Floodplain Management" (released for public review and comment on January 30, 2015) will modify the Federal Flood Risk Management Standard, in compliance with EO 13960, to address the need for federal agencies to include climate change considerations in floodplain management. It recommends that the elevation and flood hazard area be established by (i) using climate-informed science, (ii) adding 2 feet (for non-critical actions) or 3 feet (for critical actions) of freeboard to the Base Flood Elevation, or (iii) including the area subject to the 0.2% annual chance of flood. These Revised Guidelines could lead to future changes in the elevation required for Flood Elevation Certificates for new development.

the identified sea level rise scenarios, and under a range of conditions that could include high tide, storm surge, water elevation due to El Niño events, Pacific Decadal Oscillations, and the combination of long-term erosion and seasonal beach erosion. If possible, this information and resulting wave runup zones should be shown on a site map or site profile.

- **Other Impacts**: Any additional sea level rise related impacts that could be expected to occur over the life of the project, such as saltwater intrusion should be evaluated. This may be especially significant for areas with a high groundwater table such as wetlands or coastal resources that might rely upon groundwater, such as agricultural uses.

Expected outcomes from Step 2*: Detailed information about the sea level rise related impacts that can occur on the site and changes that will occur over time under various sea level rise scenarios. High risk and low risk areas of the site should be identified. The scenario-based analyses should also provide information on the potential effects of sea level rise, such as coastal erosion, that could occur over the proposed development life, without relying upon existing or new protective devices.*

Step 3 – Determine how the project may impact coastal resources, considering the influence of sea level rise upon the landscape over time

The Coastal Act requires that development avoid impacts to coastal resources. Sea level rise will likely cause some coastal resources to change over time, as described in Chapters 3 and 4. Therefore, in this step, applicants should analyze how sea level rise will affect coastal resources now and in the future so that alternatives can be developed in Step 4 to minimize the project's impacts to coastal resources throughout its lifetime.

This section discusses only those resources that might change due to rising sea level or possible responses to rising sea levels. As in Step 2, each sea level rise scenario (high, low, and intermediate values) should be carried through this step. A complete CDP application will need to assess possible impacts to all coastal resources – including public access and recreation, water quality, natural resources (such as ESHA and wetlands), agricultural resources, natural landforms, scenic resources, and archaeological and paleontological resources. Analysis of those resources that will not be affected by sea level rise should be undertaken at the same time as the assessment of the sea level rise affected resources so a complete map of resource constraints can be used for identification of a resource-protective building area.

3.1 Analyze coastal resource impacts and hazard risks for each sea level rise scenario

Analysis of resource impacts will require information about the type and location of the resources on or in proximity to the proposed project site and the way in which the proposed project will affect such resources initially and over time. The following discussion of each resource will help identify the key impacts to each that might result from either sea level rise or the proposed development. If coastal resources will be affected by sea level rise, such as changes to the area and extent of a wetland or riparian buffer, these changes must be considered in the analysis. Much of the following discussion recommends analysis of impacts from current and future inundation, flooding, erosion, and from the ways in which the project proposes to address such impacts. Appendix B provides guidance on how to undertake this analysis and includes lists of suggested resources that can provide data, tools, or other resources to help with these analyses. This analysis should be repeated for each sea level rise scenario identified in Step 1. Also, it may be important for local planners to coordinate and share information with other local partners – including those in charge of emergency management, law enforcement, and related services – in order to identify risks and vulnerabilities. Information on the following coastal resources is included. To skip to a section, click on the links below:

- New Development (addressed in Step 2, above)
- Public Access and Recreation
- Coastal Habitats
- Natural Landforms
- Agricultural Resources
- Water Quality and Groundwater
- Scenic Resources

Public Access and Recreation: Public access and recreation resources include lateral and vertical public accessways, public access easements, beaches, recreation areas, public trust lands,[42] and trails, including the California Coastal Trail. These areas may become hazardous or unusable during the project life due to sea level rise and/or due to the proposed project. Approaches to identify potential risks to public access and recreation include:

- Identify all public access locations on or near the proposed project site and, if possible, map these resources in relation to the location of the proposed project. The analysis should also identify existing public trust areas in relation to the proposed project
- Determine whether any access locations or public trust lands will be altered or impacted by sea level rise and/or the proposed project for the identified sea level rise scenarios. Such impacts could result from flooding, inundation, or shoreline erosion, or from proposed project elements. At a minimum, establish the extent of likely and/or possible changes to public access and recreation and to public trust lands.
- If any access locations will be altered by sea level rise and/or the proposed project, map or otherwise identify the potential changes to the location of these access resources for the identified sea level rise scenarios.
- Identify whether there are locations on the proposed project site that can support development without encroachment onto the existing or future locations of these access locations, and without impacts otherwise to public access and recreation. Overlay with

[42] The State Lands Commission has oversight of all public trust lands and many local governments are trustees of granted tidelands. The State Lands Commission or other appropriate trustee should be contacted if there is any possibility that public trust lands might be involved in the proposed project. As a general guide, public trust lands include tide and submerged lands as well as artificially filled tide and submerged lands.

development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Coastal Habitats (ESHA, wetlands, *etc.*): Coastal habitats, especially those that have a connection to water, such as beaches, intertidal areas, and wetlands, can be highly sensitive to changes in sea level. Ways to identify potential resource impacts associated with the project include:

- Identify all coastal habitats and species of special biological or economic significance on or near the proposed project site and, if possible, map these resources in relation to the location of the proposed project.
- Determine whether any coastal habitats will be altered or affected by sea level rise and/or the proposed project over the proposed life of the project. Such impacts could result from flooding, inundation, shoreline erosion, or changes to surface or groundwater conditions (see discussion below on water quality). At a minimum, use the identified sea level rise scenarios to establish the extent of likely and/or possible changes to coastal habitats.
- If any coastal habitats will be altered by sea level rise and/or the proposed project, map or otherwise identify potential changes to the location of these coastal resources for the identified sea level rise scenarios.
- Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these coastal habitats, and without other impacts to coastal habitats. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Natural Landforms: Natural landforms can include coastal caves, rock formations, bluffs, terraces, ridges, and cliffs. Steps to identify natural landforms at risk include:

- Identify all natural landforms on or near the proposed project site and, if possible map these resources in relation to the location of the proposed project.
- Determine whether any natural landforms will be altered or impacted by sea level rise and/or the proposed project for the identified sea level rise scenarios. Such impacts could result from flooding, inundation or shoreline erosion. At a minimum, use the identified sea level rise scenarios to establish the zone of likely and/or possible changes to natural landforms.
- If any natural landforms will be altered by sea level rise and/or the proposed project, map or otherwise identify the likely changes to location of these coastal resources for the identified sea level rise scenarios.
- Identify locations of the proposed project site that can support development without encroachment onto the existing or future locations of these natural landforms and without other impacts to such landforms. Bluffs and cliffs can often require additional analysis for slope stability to determine the setback from the eroded bluff face that can safely support development. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

Agricultural Resources: Agricultural resources may be affected by sea level rise through changes to surface drainage and the groundwater table. Other changes can result from flooding, inundation or saltwater intrusion. If agricultural lands are protected by levees or dikes, they can be affected by changes to the stability or effectiveness of these structures. Steps to identify risks to agricultural resources include:

- Identify whether the proposed project site is used for or zoned for agricultural uses, contains agricultural soils, or is in the vicinity of or upstream of lands in agricultural use.
- Identify surface water drainage patterns across the site or from the site to the agricultural use site.
- If any drainage patterns are closely linked to and potentially influenced by the elevation of sea level, examine changes in drainage patterns with rising sea level on the proposed site or the agricultural use site.

Water Quality and Groundwater: Sea level rise may cause drainages with a low elevation discharge to have water back-ups. It may also cause a rise in the groundwater table. Both of these changes could alter on-site drainage and limit future drainage options. If the proposed site must support an on-site wastewater treatment system, or if drainage and on-site water retention will be a concern, consider the following, as appropriate:

- Identify surface water drainage patterns across the site.
- Examine changes with rising sea level of any drainage patterns that are closely linked to and likely influenced by the elevation of sea level. At a minimum, use the identified sea level rise scenarios to establish the zone of likely changes to drainage patterns.
- Identify the elevation of the groundwater table. Since groundwater can fluctuate during periods of rain and drought, attempt to identify the groundwater zone.
- Estimate the likely future elevation of the groundwater zone, due to sea level rise. At a minimum, use the identified sea level rise scenarios to establish the zone of likely changes to groundwater.
- Evaluate whether changes in groundwater will alter the proposed site conditions.

Scenic Resources: Visual and scenic resources include views to and along the ocean and scenic coastal areas. Development modifications to minimize risks from sea level rise could have negative consequences for scenic resources, including creating a structure that is out of character with the surrounding area, blocks a scenic view, or alters natural landforms. Steps to identify impacts to scenic resources, including any impacts from possible adaptation measures, include:

- Identify all scenic views to and through the proposed project site from public vantage points such as overlooks, access locations, beaches, trails, the Coastal Trail, public roads, parks, and if possible, map these views and view lines in relation to the location and maximum allowable elevation of the proposed project.
- Identify locations of the proposed project site that can support development and avoid or minimize impacts to scenic views from current and future vantage points. Overlay with development constraints (fault zones, landslides, steep slopes, property line setbacks, *etc.*) and with other coastal resource constraints.

3.2 Synthesize and assess development and resource constraints

After completing the detailed analysis of each coastal resource, the applicant should summarize the potential resource impacts under each sea level rise scenario identified in Step 1. This set of results, when combined with potential impacts to those coastal resources not affected by sea level rise, should give the applicant valuable information about the degree of risk posed to each coastal resource and to the development itself. If practical, for each sea level rise scenario, applicants should produce a constraints map illustrating the location and the extent of resource impacts that could occur over the life of the development. Based on the analysis of resource impacts and potential hazard risks over the life of the development, the applicant should develop an overlay identifying the development and resource constraints.

3.3 Identify areas suitable for development

The final part of this step is to identify the locations of the project site that could support some level of development without impacts to coastal resources and without putting the development at risk.

***Expected outcomes from Step 3**: Upon completing this step, the applicant should have detailed information about the types of coastal resources on the project site and the level of risk that sea level rise poses to each resource under each sea level rise scenario, including resource locations and the extent of resource impacts that could occur over the life of the proposed project. This step should also provide an overlay of all development and resource constraints, and clearly identify the locations on the proposed project site that could support some level of development without impacts to coastal resources and without putting the development at risk.*

Step 4 – Identify project alternatives that avoid resource impacts and minimize risks to the project

By this step, applicants should have developed a set of factors based on the sea level rise hazards identified in Step 2, potential resource impacts identified in Step 3, and other site conditions (such as archaeological resources or fault lines) to identify the buildable areas that avoid both risk from coastal hazards and impacts to coastal resources. Hazard and resource avoidance is usually the preferred option, and, in many cases, applicants may find that the site is safe from sea level rise hazards for all the identified sea level rise scenarios and no further identification of project alternatives would be necessary in order to address sea level rise concerns.

For some cases, the site constraints may require consideration of project alternatives that fit with the available buildable area, without the use of protective structures. In these cases, one of the alternatives may be to replace what was initially being considered for the site. In other cases, development that is safe from hazards and is resource protective may be possible if certain adaptation strategies are used to modify the project over time and as the potential hazard areas increase or move closer to the project. For these cases, the possible adaptation measures would be included as part of the proposed project, along with necessary monitoring and triggers for implementing the adaptation options. In still other cases, hazard minimization may be the only feasible option for development on hazard constrained-sites. In all cases, projects must be sited and designed to address all applicable Coastal Act and LCP requirements, including any new requirements within LCPs that have been updated to adapt to sea level rise.

The results from the analysis of sea level rise scenarios should factor into the decisions made in this step. In particular, after looking at the results from Steps 2 and 3 as a whole, applicants can better decide the project changes, types of adaptation strategies, and design alternatives that would be most appropriate given the degree of risk posed by possible sea level rise and how long the development might be free from risk. The applicant also might identify triggers (*e.g.*, a certain amount of sea level rise) when certain adaptation measures should be implemented to reduce risk and/or impacts to coastal resources.

Importantly, land divisions and lot line adjustments in high hazard areas can change hazard exposure and should therefore be undertaken only when they can be shown to not worsen or create new vulnerability. In particular, no new lots or reconfigured lots with new development potential should be created if they cannot be developed without additional shoreline hazard risks.

Strategies to Avoid Resource Impacts and Minimize Risks

The best way to minimize risks to development and coastal resources is to avoid areas that are or will become hazardous as identified by the sea level rise scenarios analysis in the previous steps. Such avoidance often includes changes to the proposed project to bring the size and scale of the proposed development in line with the capacity of the project site. However, if it is not feasible to site or design a structure to completely avoid sea level rise impacts, the applicant may need to modify or relocate the development to prevent risks to the development or to coastal resources. Some changes, such as the use of setbacks, may be necessary at the outset of the project. Other changes, such as managed retreat or added floodproofing, may be useful as adaptive strategies that can be used after the initial project completion. Considerations involved in choosing and designing an appropriate adaptation strategy may include those listed below. See Chapter 7 for more information on specific adaptation measures. For a list of guidebooks, online clearinghouses, and other sea level rise adaptation resources, see Appendix C.

- **Assess Design Constraints:** Determine whether there are any significant site or design constraints that might prevent future implementation of possible sea level rise adaptation measures. Some project locations may be constrained due to lot size, sea level related hazards, steep slopes, fault lines, the presence of wetlands or other ESHA, or other constraints such that no safe development area exists on the parcel. Ideally, such parcels would be identified during the LCP vulnerability analysis, and the land use and zoning designations would appropriately reflect the constraints of the site. However, in some cases development may need to be permitted even if it cannot avoid all potential hazards. As stated above, care should be taken in these cases to avoid resource impacts and minimize risks as much as possible by developing and implementing a sea level rise adaptation plan for the proposed development. In creating this plan, it is important to identify any design constraints that will limit the ability to implement adaptation strategies in the future, as described below.

- **Identify Adaptation Options:** Identify possible adaptation strategies (such as those found in Chapter 7) for the proposed project, and evaluate each adaptation option for efficacy in protecting the development. Also, evaluate the consequences from each proposed adaptation measure to ensure it will not have adverse impacts on coastal and sensitive environmental resources, including visual impacts and public access.

  For example, an option that is often considered for sea level rise is to elevate the development or the structures that are providing flood protection. However, elevated structures will change the scenic quality and visual character of the area. Also, elevation of the main development may be of little long-term utility to the property owner if the supporting infrastructure, such as the driveways, roads, utilities or septic systems are not also elevated or otherwise protected. Elevation of existing levees or dikes can provide flood protection for an area of land and all the development therein. However, the foundation of the levee or dike must have been designed to support the additional height or else it may have to be expanded and the increased footprint of the foundation could have impacts on intertidal area, wetlands, or other natural resources. Thus, the long-term options for adaptation should be considered as part of any permit action, to ensure that current development decisions are not predetermining resource impacts in the future.

- **Ensure Sea Level Rise Design Flexibility:** If the likelihood of impacts is expected to increase with rising sea level, it may be necessary to design the initial project for some amount of sea level rise but to also include design flexibility that will allow future project changes or modifications to prevent impacts if the amount of sea level rise is more than anticipated in the initial design. Changes and modifications could include the use of foundation elements that will allow for building relocations or removal of portions of a building as it is threatened or reserving space to move on-site waste treatment systems away from eroding areas or areas that will be susceptible to a rising water table or increased flooding.

- **Develop Project Modifications**: Highly constrained sites may not be able to support the amount of development that an applicant initially plans for the site. Even a small building footprint may be at risk from flooding or erosion under high sea level rise scenarios. In such cases, it will be important to work closely with the appropriate planning staff to develop a project option that can minimize hazards from the identified sea level rise scenarios for as long as possible, and then incrementally retreat once certain triggers are met. Some examples of triggers could be that erosion is within some distance of the foundation, or monthly high tides are within some distance of the finished floor elevation. The time period for relocation or removing the structure would be determined by changing site conditions but relocation would most likely occur prior to the time period used in Step 1 to determine long-term site constraints.

- **Plan for Monitoring:** Develop a monitoring program or links to other monitoring efforts to ensure that the proposed adaptation measures will be implemented in a timely manner. Following a monitoring protocol and requirements for evaluating sea level rise impacts to coastal habitats over time can help to identify the triggers that would lead to revising project life, other project modifications or additional adaptation efforts.

***Expected outcomes from Step 4**: This step may involve an iterative process of project modifications and reexamination of impacts, leading to one or more alternatives for the project site. The alternative that will minimize risks from coastal hazards and avoid or minimize impacts to coastal resources should be identified. Possible adaptation options could be identified and analyzed, if appropriate. If the site is very constrained, modifications to the expected project life might be suggested.*

Step 5 – Finalize project design and submit CDP application

After Step 4, the applicant should have developed one or more project alternatives and identified a preferred alternative. The alternatives should include adaptation strategies to minimize impacts if hazards cannot be avoided entirely. The CDP application step involves the following:

1. **Work with the planning staff to complete the CDP application**. Depending upon the proposed project and extent of prior interactions with the planning staff, the initial submittal may be the first time the planner has been provided with information about the general project or the preferred alternative. Once a proposed project is submitted, the coastal planner will need to become familiar with the project location, area around the project site, the proposed actions and the studies and analyses that have been undertaken in support of the application. The planner will review the application for completeness to ensure that there is sufficient information to analyze the project for all appropriate LCP or Coastal Act Chapter 3 policies. If analysis for sea level rise concerns is needed, the planner will also check that analyses for sea level rise risks have been included in the submittal. Much of the information developed in Steps 1-4 will be useful for the application process. The Suggested Filing Checklist for CDP Applications (located at the end of this chapter) covers the typical information that might be included in a CDP application necessary for planning review of the sea level rise aspects of the proposed project. Applicants who are unfamiliar with the permit process should consult the local government website, Coastal Commission website, or contact the appropriate district office for instructions on how to complete a CDP application.

   The review of an application might involve an iterative process, wherein planning staff requests more information about the proposed project, project alternatives, analysis of the hazards or identification of potential resource impacts to help in the review for compliance with the LCP or the Coastal Act. At the same time, planning staff may request that some of the technical staff review the submitted material to ensure that there is sufficient information in all technical information and analyses to support a decision on the proposed project. This process may be repeated until the application provides the studies, analysis and project review necessary for planning review.

2. **Submit a complete CDP application.** Once a complete application has been accepted, the planning staff will do a more thorough review and analysis of the potential hazards and resource impacts associated with the proposed project. Ideally, the planner will have requested all necessary project information at the filing stage. In some instances,

additional information may be needed after the application has been accepted. This is normally limited to clarifications of some of the information or further details about some of the possible, but not preferred alternatives. During this stage in the CDP application process, the planner may identify necessary project modifications that were not part of the initial application, or identify various conditions that will be needed if the project is to be approved. Chapter 7 includes many of the possible project modifications and permit conditions that might be used to address sea level rise concerns and potential resource impacts.

During the project analysis, the planning staff will review all submitted material, discussing the proposed project with other staff members, and obtaining further technical review. Working with their supervisors and managers, they will also develop a staff recommendation and prepare a staff report that supports the proposed recommendation. Please consult the Coastal Commission website (http://www.coastal.ca.gov/cdp/cdp-forms.html) or contact your district office for instructions on how to complete a CDP application.

3. **Permit action.** Once the proposed project has been through planning review and a staff recommendation has been prepared, the proposed project will be brought to hearing before either the local planning commission or the California Coastal Commission. The outcome of the hearing process will be project approval, approval with conditions, or denial. Based on the regulatory decision, the project may be constructed, or additional modifications and condition requirements may have to be met.
4. **Monitor and revise.** CDP approvals may include conditions that require monitoring. Applicants should monitor the physical impacts of sea level rise on the project site, provide reports and updates to planning staff and introduce adaptive changes to the project in accordance with the permit and permit conditions.

Expected outcomes from Step 5*: This step, combined with supporting documentation from the previous steps, should provide a basis for evaluating the proposed project's hazard risks and impacts that can result from sea level rise. Such an analysis will provide one of the bases for project evaluation and complements the other resource evaluations and analyses that are part of a complete CDP application.*

Planning Process for Coastal Development Permits

1. Establish the projected sea-level rise range for the proposed project

- Determine time period of concern using expected project life.
- Use range of SLR scenarios based on best available science (*e.g. 2018 OPC SLR Guidance*).
- Modify projections to incorporate local vertical land motion and planning horizon if needed.

2. Determine how sea-level rise impacts may constrain the project site

Using locally relevant SLR projections, determine site- or project-specific hazards or impacts for the time period of concern, including current and future hazard impacts. Consider:

- Geologic Stability and Erosion
- Flooding and Inundation
- Wave Impacts
- Other Impacts

3. Determine how the project may impact coastal resources over time, considering SLR

Determine how the project may impact coastal resources (below) considering how SLR may alter the resources over the expected lifetime of the project.

- Public Access and Recreation
- Coastal Habitats
- Agriculture
- Water Quality
- Archaeological/Paleontological resources
- Scenic Resources

4. Identify project alternatives to both avoid resource impacts and minimize risks to the project

- Ideally, locate the project in a site that avoids conflicts with natural resources and SLR impacts
- Alternatively, minimize the likelihood that the project will come into contact with hazards, and design an adaptation strategy for unavoidable impacts.
- Modify project if impacts cannot be avoided
- Summarize these alternatives

5. Finalize project design and submit permit application

Complete the CDP application. Submit the application. Receive permit action. Monitor and revise project as needed.

Figure 14. Flowchart for steps to address sea level rise in Coastal Development Permits

Suggested Filing Checklist for Sea Level Rise Analysis

- Proposed/Expected Project Life
- Sea Level Rise Projections used in Impacts Analyses
- Impacts Analyses (possibly from Vulnerability Assessment)
  - Structural and Geologic Stability
    - Identify current tidal datum
    - Perform Geotechnical Report and Erosion Analysis
    - Identify blufftop setback and safe building area
    - Show setback, safe building area and proposed project footprint (site maps)
  - Erosion Amount over Expected Project Life
    - Perform Coastal Processes Study and Erosion Analysis
    - Quantify total erosion amount for proposed project site
    - Show retreat along with proposed project footprint (site maps)
  - Flooding and Inundation Risks
    - Perform Coastal Processes Study and Wave Runup Analysis
    - Quantify flood elevation and flooding extent
    - Show flood extent with proposed project footprint (site map)
    - Show flood elevation on site profile, with proposed project elevation
    - Provide Flood Certificate if in FEMA designated 100-year Flood Zone
  - Tipping points for sea level rise impacts, specific to proposed project site
- Impacts to coastal resources (possibly from Environmental Assessment) for current conditions and changes due to sea level rise and related impacts
  - Public Access and Recreation
    - Show access resources and future changes (site maps)
  - Water Quality, surface and groundwater
    - Provide surface drainage patterns and runoff and future changes (site maps)
    - Provide zone of groundwater elevation
  - Coastal Habitats
    - Provide wetland delineation, ESHA determination, if appropriate
    - Provide boundary determinations or State Lands review, if appropriate
    - Show all coastal habitats and future changes (site maps)
  - Agricultural Resources
    - Show agricultural resources and future changes (site maps)
  - Natural Landforms
    - Show all natural landforms and future changes (site maps)
  - Scenic Resources
    - Show views from public access and future changes due to access changes
  - Overlay all coastal resources to establish areas suitable for development (site maps)
- Analysis of Proposed Project and Alternatives
  - Provide amount(s) of sea level rise used in project planning and design
  - Provide analysis of the proposed project and alternatives
  - Identify proposed current and future adaptation strategies
  - Show avoidance efforts (site map)
  - Identify hazard minimization efforts that avoid resource impacts (site maps)

Example for Addressing Sea Level Rise in Coastal Development Permits

To illustrate the process described in this chapter for how to address sea level rise in the CDP process, consider three example projects: a wetland restoration project, a new bluff-top residential development with a fronting beach, and a new wastewater treatment facility. These three examples will follow each of the recommended CDP steps, showing how the guidance could be applied in specific situations. Note that these are simplified examples used to demonstrate the process described in this chapter. Decisions about how to address various challenges presented by sea level rise will be more complex than those illustrated below, and the Coastal Commission encourages applicants to coordinate with staff as necessary and feasible throughout the process.

Step 1: Establish the projected sea level rise range for the proposed project

- *Wetland Restoration Project:* Sea level rise projection ranges should be chosen based on the goals of the project. For example, if wetland restoration efforts are intended as mitigation for a development project, the lifetime for the wetland restoration should be, at a minimum, the lifetime of the development project. For wetland restoration projects in which the desired outcome is the protection of the wetland in perpetuity, sea level rise ranges should be projected over a minimum of 100 years, with consideration of the intervening years as well as the even longer term for ongoing adaptive management.
- *Bluff-top Residential Development:* The lifetime of the project is assumed to be at least 75 years, unless the LCP specifies a different time period. High, low, and intermediate sea level rise projection ranges are established, appropriate for the proposed area over the assumed 75-year project life.
- *Wastewater Treatment Facility:* Wastewater treatment facilities are normally critical infrastructure. For this example, a minimum life of 100 years is assumed, unless the LCP specifies a different time period. High, low, and intermediate sea level rise projections ranges are established, appropriate for the proposed area over the assumed 100-year or longer project life.

Step 2: Determine how impacts from sea level rise may constrain the project site

- *Wetland Restoration Project:* Current topography of the wetland area is mapped, current barriers to inland migration are identified, and an analysis of erosion and flooding potential (and subsequent effects to wetland extent) is performed for various sea level rise scenarios. Potential changes to groundwater are evaluated. Potential changes in sediment flows or other physical properties as a result of changing conditions are examined. It is determined that in this case, open space exists behind the wetland to allow for inland migration over time.
- *Bluff-top Residential Development:* The average long-term beach and bluff retreat rate, erosion rate due to various sea level rise scenarios, and erosion potential from 100-year storms and other extreme events are determined. Beach and bluff erosion will vary with sea level rise rates. The geologic stability of the bluff over the life of the development is analyzed assuming that no protective structure (such as a seawall) either exists or will be built.

- *Wastewater Treatment Facility:* Erosion and flooding potential over the lifetime of the facility under both a low and a worst-case scenario sea level rise projection are analyzed, as are current and future wave runup and storm impacts for 100-year storms. The geologic stability of the site over the life of the facility is analyzed assuming that no protective structure either exists or will be built. Potential damage to infrastructure (for example corrosion due to saltwater intrusion) is examined.

Step 3: Determine how the project may impact coastal resources, considering the influence of sea level rise upon the landscape over time

- *Wetland Restoration Project:* Coastal resources present in the proposed project site are mapped and sea level rise impacts to these resources are analyzed over the lifetime of the project. It is unlikely that the project will have any adverse impacts on coastal resources. Barriers to wetland migration are examined and it is determined in this case that enough open space currently exists to allow for the wetland to migrate inland over time. The few barriers that exist can be modified in the future, if necessary. This will allow for continued maintenance of habitat area and ecosystem services.
- *Bluff-top Residential Development:* Maps are developed that identify scenic viewsheds, the bluff extent, and adjacent coastal habitats including the fronting beach, and descriptions of each are provided. Opportunities for public access are identified. Impacts to each of these resources as a result of sea level rise are analyzed, as are impacts that would result from the development project. It is determined that the development has the potential to result in the loss of a fronting beach if a protective structure is installed. However, development setbacks are designed to ensure that no such structure is planned over the lifetime of the development under any sea level rise scenario.
- *Wastewater Treatment Facility:* Maps are developed that identify coastal resources in the area and impacts to these resources resulting from sea level rise are analyzed. As with the bluff-top development, any protective structure would have detrimental effects to the fronting beach, but no such structure is determined to be necessary. Any potential impacts to adjacent habitat areas or to water quality as a result of damage to infrastructure (for example sewage outflow or backup of seawater into the system) are examined under the range of sea level rise projections for the life of the facility.

Step 4: Identify project design alternatives that avoid resource impacts and minimize risks to the project

- *Wetland Restoration Project:* In this example, there are no concerns related to detrimental impacts to coastal resources as a result of this project. Natural barriers will be removed through grading and contouring of the land to ensure that the wetland has the ability to migrate inland with sea level rise and that hydrologic function will be maintained. Inland areas are protected into the future to ensure the space will be open for migration. Additionally, a plan is included to monitor changes in sea level, sediment dynamics, and overall health of the wetland so that adaptive management options can be applied as needed.

- *Bluff-top Residential Development:* The optimal site for a bluff-top residential development is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative locations on the project sites should be identified and examined. If no such location exists, efforts should be made to minimize hazards and impacts to resources, or the project should be denied. Minimization efforts may include: building with an extra setback from the bluff-face, developing a managed retreat plan, and designing buildings to be easily relocated. If the safe building envelope will not be sufficient for a reasonable-sized building, local governments could consider allowing reduced setbacks on portions of the site located away from the bluff face (*e.g.*, side or front yard setbacks), reduced off-street parking, additional height on safe portions of the site, or other development that doesn't require shore protection. No seawall is planned as such a device would result in the loss of the fronting beach. A plan to monitor rates of erosion at various places along the bluff as well as any impacts to adjacent resources is developed, and erosion rates/scenarios that would trigger the need for retreat are identified.
- *Wastewater Treatment Facility:* The optimal site for a wastewater treatment facility is one that avoids the hazards identified in Step 2 and impacts to coastal resources identified in Step 3 over the life-time of the project. If the proposed site does not avoid risks, alternative sites should be identified and examined. If no such site exists, efforts should be made to minimize hazards and impacts to resources. Minimization efforts may include: building the facility further back from the beach, elevating outflow pipes, and adding one-way valves to prevent backflow of sea-water into the system. A plan to monitor erosion rates along the beach as well as wave and storm impacts and any impacts to coastal resources caused by the facility is developed.

Step 5: Finalize project design and submit CDP application

- *Wetland Restoration Project:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes likely options for adaptive management to maintain wetlands and key monitoring needed to examine ongoing wetland function.
- *Bluff-top Residential Development:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes analyses of hazard and resource risks and any plans for adaptive project designs and proposed monitoring.
- *Wastewater Treatment Facility:* The best site and design option is chosen and presented to the Commission or local government for the permit process. Application includes analyses of hazards and resource risk and plans for site monitoring.

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Chapter 7

Adaptation Strategies

Chapters 5 and 6 provide guidance on the sequential processes for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs). This chapter describes some of the specific adaptation strategies to consider in these planning and development review processes. Given the range of impacts that could occur as a result of sea level rise, and the uncertainties surrounding projections of sea level rise over the lifetimes of many coastal projects, communities, planners, coastal managers and project applicants will need to use adaptation strategies to effectively address coastal hazard risks, and protect coastal resources over time.

As described in Chapters 5 and 6, adaptation strategies should be chosen based on the specific risks and vulnerabilities of a region or project site and the applicable Coastal Act and LCP requirements, with due consideration of local priorities and goals. Adaptation strategies may involve modifications to land use plans, regulatory changes, project modifications, or permit conditions that focus on avoidance or minimization of risks and the protection of coastal resources.

Some adaptation strategies may require land use plans or proposed projects to anticipate longer-run impacts now, such as assuring that critical infrastructure is built to last a long time without being put in danger, or rezoning hazardous areas as open space. Other adaptation strategies may build adaptive capacity into the plan or project itself, so that future changes in hazard risks can be effectively addressed while ensuring long-term resource protection. In most cases, especially for LCP land use and implementation plans, multiple adaptation strategies will need to be employed. For projects, adaptation strategies may be addressed through initial siting and design and through conditions that provide for specific adaptation over time.

The next sections provide an overview of the general categories of adaptation options, followed by a description of various specific adaptation strategies organized by type of coastal resource, as outlined in Chapter 3 of the California Coastal Act.

The adaptation options described in this chapter are intended to provide guidance for potential LCP and permitting strategies. Not all strategies listed here will be appropriate for every jurisdiction, nor is this an exhaustive list of options. However, as described in Chapters 5 and 6, all local governments and all project applicants should analyze the possible effects of sea level rise and evaluate how the strategies in this chapter, or additional supplemental strategies, could be implemented in LCPs or CDPs to minimize the adverse effects of sea level rise.

General Adaptation Categories

There are a number of options for how to address the risks and impacts associated with sea level rise. Choosing to "do nothing" or following a policy of "non-intervention" may be considered an adaptive response, but in most cases, the strategies for addressing sea level rise hazards will require proactive planning to ensure protection of coastal resources and development. Such proactive adaptation strategies generally fall into three main categories: protect, accommodate, and retreat.

For purposes of implementing the Coastal Act, no single category or even specific strategy should be considered the "best" option as a rule. Different types of strategies will be appropriate in different locations and for different hazard management and resource protection goals. The effectiveness of different adaptation strategies will vary across both spatial and temporal scales. In many cases, a hybrid approach that uses strategies from multiple categories will be necessary, and the suite of strategies chosen may need to change over time. As discussed later in the document, the legal context of various options will also need to be considered in each situation and ultimately, adaptive responses will need to be consistent with the Coastal Act. Nonetheless, it is useful to think about the general categories of adaptation strategies to help frame the consideration of land use planning and regulatory options in specific communities and places along the coast.

Protect: Protection strategies refer to those strategies that employ some sort of engineered structure or other measure to defend development (or other resources) in its current location without changes to the development itself. Protection strategies can be further divided into "hard" and "soft" defensive measures or armoring. "Hard" armoring refers to engineered structures such as seawalls, revetments, and bulkheads that defend against coastal hazards like wave impacts, erosion, and flooding. Such armoring is a fairly common response to coastal hazards, but it can result in serious negative impacts to coastal resources, particularly as sea level rises. Most significantly, hard structures form barriers that impede the ability of natural beaches and habitats to migrate inland over time. If they are unable to move inland, public recreational beaches, wetlands, and other habitats will be lost as sea level continues to rise. This process is commonly referred to as "passive erosion," which is the narrowing of beaches due to the fact that the back of the beach on an eroding shoreline has been fixed in place (Flick *et al*. 2012). Other detrimental impacts may include negative visual impacts or interference with other ecosystem services.


Figure 15. Photo depicting passive erosion. (*Left*) Passive erosion in front of a revetment at Fort Ord, illustrating the loss of beach where the development prevents the shoreline from migrating landward. The beach continues to migrate inland on either side of the revetment. (*Right*) Recovery of the beach following removal of the revetment and blufftop structure. (*Source: California Coastal Records Project*).

"Soft" armoring refers to the use of natural or "green" infrastructure like beaches, dune systems, wetlands, and other systems to buffer coastal areas. Strategies like beach nourishment, dune management, or the construction of "living shorelines" capitalize on the natural ability of these systems to protect coastlines from coastal hazards while also providing benefits such as habitat, recreation area, more pleasing visual impacts, and the continuation or enhancement of ecosystem services. The engineering of green infrastructure is a somewhat newer concept in some cases, and because of this, the effectiveness of different strategies in different types of environments is not necessarily well-known or tested. In cases in which natural infrastructure might not be completely effective or may not be preferred, a hybrid approach using both hard and natural infrastructure could be considered. As described in Principle 10 of this Guidance and in the *Safeguarding California* plan (CNRA 2014), priority should be given to options that protect, enhance, and maximize coastal resources and access, including giving full consideration to innovative nature-based approaches such as living shoreline techniques or managed/planned retreat. Although the Coastal Act clearly provides for potential protection strategies for "existing development", it also directs that new development be sited and designed to not require future protection that may alter a natural shoreline.

Accommodate: Accommodation strategies refer to those strategies that employ methods that modify existing developments or design new developments to decrease hazard risks and thus increase the resiliency of development to the impacts of sea level rise. On an individual project scale, these accommodation strategies include actions such as elevating structures, retrofits and/or the use of materials meant to increase the strength of development, building structures that can easily be moved and relocated, or using extra setbacks. On a community-scale, accommodation strategies include any of the land use designations, zoning ordinances, or other measures that require the above types of actions, as well as strategies such as clustering development in less vulnerable areas or requiring mitigation actions to provide for protection of natural areas even as development is protected. As with protection strategies, some accommodation strategies could result in negative impacts to coastal resources. Elevated structures may block coastal views or detract from community character; pile-supported structures may, through erosion, develop into a form of shore protection that interferes with coastal processes, blocks access, and, at the extreme, results in structures looming over or directly on top of the beach.

Figure 16. Photo depicting "managed retreat" and restoration. Surfers' Point Managed Shoreline Retreat project in which the parking lot was moved back and beach area was restored. (*Aerial composite by Rick Wilborne (February 28, 2013); photo courtesy of Surfrider Foundation*)

Retreat: Retreat strategies are those strategies that relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. These strategies include land use designations and zoning ordinances that encourage building in more resilient areas or gradually removing and relocating existing development. Acquisition and buy-out programs, transfer of development rights programs, and removal of structures where the right to protection was waived (*i.e.*, via permit condition) are examples of strategies designed to encourage managed retreat.

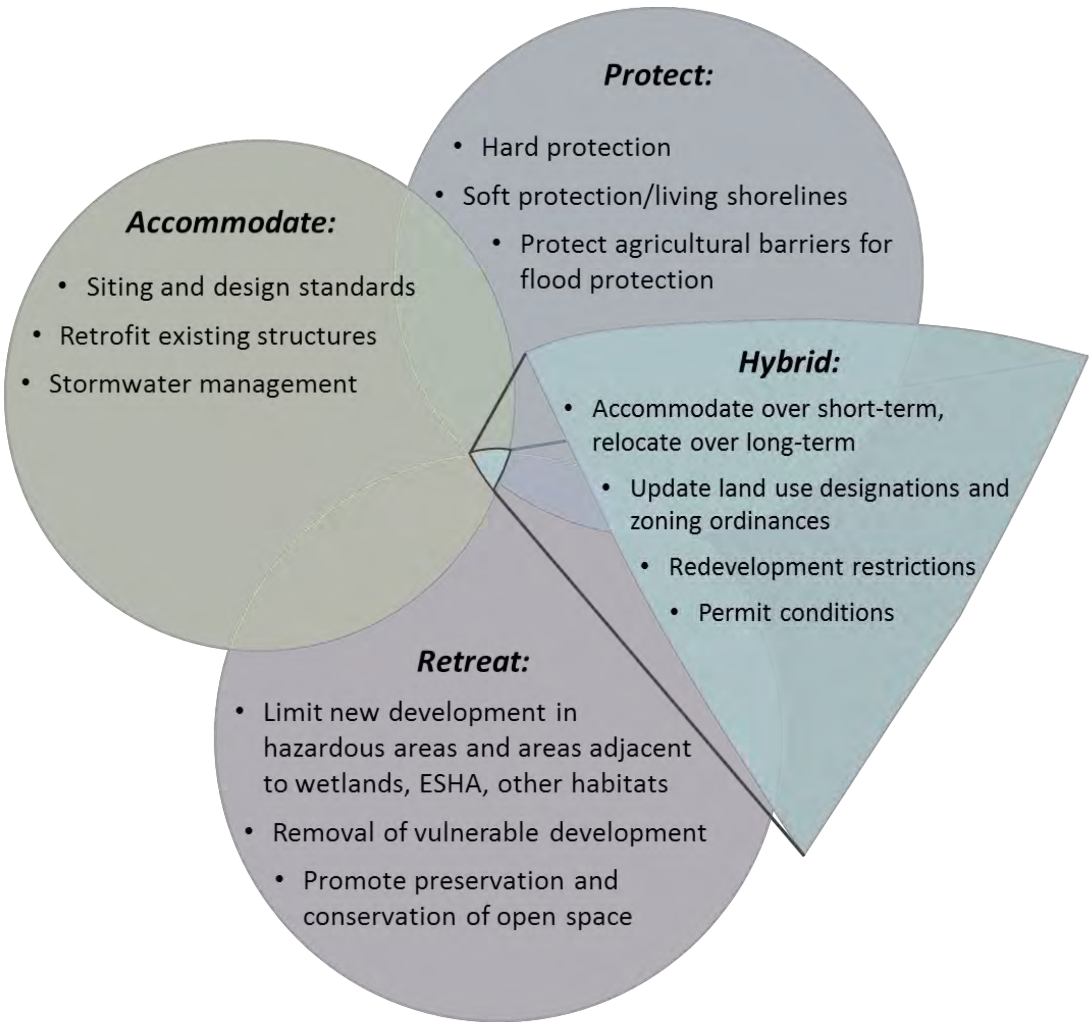

Figure 17. Examples of general adaptation strategies

SPECIFIC ADAPTATION STRATEGIES

The following sections, organized by category of coastal resource, present measures that local governments and coastal planners should consider including in their LCPs or individual CDPs. The purpose of this organization is to allow coastal managers and project applicants to easily find strategies that will help address the specific resource vulnerabilities identified in Steps 1-3 of the LCP and CDP processes laid out in Chapters 5 and 6. In the development of LCP policies, local governments should use adaptation measures that best implement the statewide resource protection and hazard policies of the Coastal Act at the local level given the diverse geography and conditions of different areas.

As part of identifying adaptation strategies, local governments should carefully examine the potential impacts to coastal resources that could occur from various adaptation strategies. Some adaptation strategies will need to be implemented incrementally over time as conditions change, and many strategies will need to be implemented through both the LCP and CDP to be effective. For each issue area, there is a description of potential impacts that could occur due to sea level rise and a list of adaptation tools or actions to minimize impacts. To skip to a topic, click on the links below.

A. Coastal Development and Hazards
B. Public Access and Recreation
C. Coastal Habitats, ESHA, and Wetlands
D. Agricultural Resources
E. Water Quality and Supply
F. Archaeological and Paleontological Resources
G. Scenic and Visual Resources

The lists in these sections should be considered neither checklists from which all options need to be used, nor exhaustive lists of all possible adaptation strategies. Sea level rise adaptation is an evolving field, and policy language, cost considerations, effectiveness of various strategies, and other topics are continuing to be developed. Planners, applicants, and partners will need to think creatively and adaptively respond to changing conditions, new science, and new adaptation opportunities, and the Coastal Commission will continue to support and collaborate on these efforts.

Additionally, sea level rise planning may involve a number of trade-offs among various competing interests, and no single adaptation strategy will be able to accomplish all planning objectives. Economic and social implications of various adaptation options will likely play into the planning process at the local level. The important point is to analyze current and future risks from sea level rise, determine local priorities and goals for protection of coastal resources and development in light of Coastal Act requirements, and identify what land use designations, zoning ordinances, and other adaptation strategies can be used to meet those goals.

A. Coastal Development and Hazards

The Coastal Act requires that new development be sited and designed to be safe from hazards and to not adversely impact coastal resources (Coastal Act Sections 30235 and 30253). The main goals that relate to hazards and coastal development are:

- Update land use designations, zoning maps, and ordinances to account for changing hazard zones
- Include sea level rise in hazard analyses and policies
- Plan and locate new development to be safe from hazards, not require protection over its entire lifespan, and be protective of coastal resources
- Incorporate sea level rise adaptation into redevelopment policies
- Encourage the removal of development that is threatened by sea level rise
- Use "soft" or "natural" solutions as a preferred alternative for protection of existing endangered structures
- Limit bluff and shoreline protective devices to protect existing endangered structures
- Require special considerations for critical infrastructure and facilities
- Protect transportation infrastructure

Chapter 3 of the Guidance covers the impacts to coastal development that might result from sea level rise. Certified LCPs should already have policies and standards to assure that coastal development is safe over its anticipated lifetime and that it does not adversely impact other coastal resources. However, LCP policies and standards may need to be updated in light of new knowledge and to consider sea level rise hazards. Adaptation options have been developed to support the development goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Update land use designations, zoning maps, and ordinances to account for changing hazard zones

A.1 Establish mapped hazard zones or overlays: Update land uses and zoning requirements to minimize risks from sea level rise in identified hazard zones or overlay areas. For example, limit new development in current and future sea level hazard zones and encourage removal of existing development when threatened.

A.1a **Identify zones that require a more rigorous sea level rise hazards analysis**: Specify areas where a closer analysis of sea level rise is necessary at the permit application stage to avoid or minimize coastal hazards and impacts to coastal resources. Ensure that the most up-to-date information on sea level rise is incorporated in such analyses.

Goal: Include sea level rise in hazard analyses and policies

A.2 Update policies to require sea level rise to be included in hazard analyses and management plans: LCP policies should include requirements to analyze projected sea level rise. Consider specific projection scenarios to be analyzed. (See Chapter 3 of the Guidance for a description of scenario planning.) LCPs could also specify which analyses are required for various types of projects/development (see Step 2 of Chapters 5 and 6 or Appendix B for suggested analyses).

A.2a **Site-specific evaluation of sea level rise**: Update policies, ordinances, and permit application requirements to include a required site-specific evaluation of coastal hazards due to sea level rise over the full projected life of any proposed development. Analyses should be conducted by a certified Civil Engineer or Engineering Geologist with expertise in coastal processes.

A.2b **Incorporate wave runup zones and sea level rise in coastal flood hazard maps:** Develop coastal flood maps that include areas that will be subject to wave action and flooding due to sea level rise. These maps may be able to rely upon existing flood maps, such as the FEMA Flood Insurance Rate Maps, for current flood areas and base conditions, but should be augmented to include future conditions, including sea level rise, likely to occur through the life of proposed new development.

A.2c **Incorporate sea level rise into calculations of the Geologic Setback Line**: Update geotechnical report requirements for establishing the Geologic Setback Line (bluff setback) to include consideration of bluff retreat due to sea level rise in addition to historic bluff retreat data, future increase in storm or El Niño events, and any known site-specific conditions. The report should be completed by a licensed Geotechnical Engineer or an Engineering Geologist.

A.2d **Include sea level rise in wave runup, storm surge, and tsunami hazard assessments**[43]: Sea level rise should be included in wave runup analyses, including storm event and tsunami hazard assessments. This should include evaluating tsunami loads/currents on maritime facilities and coastal structures. Since tsunami wave runup can be quite large, sea level rise projections of only a few inches may not have a large impact on these assessments. However, for time periods or scenarios where sea level rise projections are large (perhaps 1 ft or more), it would be appropriate to include sea level rise because it could change the results to a significant degree.

[43] Tsunami evacuation maps are based upon current sea level conditions and they will need to be updated with changes in sea level.

A.3 Establish shoreline management plans to address long-term shoreline change due to sea level rise: Create policies that require a management plan for priority areas that are subject to sea level rise hazards, and incorporate the plan into the larger LCP if applicable. Similar to an LCP, shoreline management plans generally include the short and long term goals for the specified area, the management actions and policies necessary for reaching those goals, and any necessary monitoring to ensure effectiveness and success. Incorporate strategies necessary to manage and adapt to changes in wave, flooding, and erosion hazards due to sea level rise.

Goal: Plan and locate new development to be safe from hazards, not require protection over its entire lifespan, and be protective of coastal resources

A.4 Limit new development in hazardous areas: Restrict or limit construction of new development in zones or overlay areas that have been identified or designated as hazardous areas to avoid or minimize impacts to coastal resources and property from sea level rise impacts.

A.5 Cluster development away from hazard areas: Concentrate development away from hazardous areas. Update any existing policies that cluster development to reflect additional hazard zones due to sea level rise.

A.5a **Concentration of development/smart growth**: Require development to concentrate in areas that can accommodate it without significant adverse effects on coastal resources. This strategy is applicable for community wide planning through an LCP, but may also apply to CDPs for subdivisions or for larger developments involving large or multiple lots.

A.5b **Transfer of Development Rights programs (TDR)**: Restrict development in one area ("sending area") and allow for the transfer of development rights to another area more appropriate for intense use ("receiving area"). LCPs can establish policies to implement a TDR program to restrict development in areas vulnerable to sea level rise and allow for transfer of development rights to parcels with less vulnerability to hazards. A TDR program can encourage the relocation of development away from at-risk locations, and may be used in combination with a buy-out program.

A.6 Develop adequate setbacks for new development: Ensure structures are set back far enough inland from the beach or bluff edge such that they will not be endangered by erosion (including sea level rise induced erosion) over the life of the structure, *without the use of a shoreline protective device*. When used to address future risk, setbacks are normally defined by a measurable distance from an identifiable location such as a bluff edge, line of vegetation, dune crest, or roadway. Establish general guidance and criteria for setbacks in LCPs that consider changes in retreat due to sea level rise. Require detailed, site-specific analyses through LCPs and CDPs to determine the size of the setback, taking into consideration sea level rise and establish the expected life of the structure (for example, the time period over which the setback should be effective).

Figure 18. Photo depicting a development setback in Pismo Beach. (*Source:* California Coastal Records Project)

A.7 **Limit subdivisions in areas vulnerable to sea level rise**: Prohibit any new land divisions, including subdivisions, lot splits, lot line adjustments, and/or certificates of compliance that create new beachfront or blufftop lots unless the lots can meet specific criteria that ensure that when the lots are developed, the development will not be exposed to hazards or pose any risks to protection of coastal resources.

A.8 **Update development siting, code, and design standards to avoid, minimize, or reduce risks from coastal hazards and extreme events**: Establish and implement building codes and standards for building siting and construction that avoid or minimize risks from flooding and erosion and increase resilience to extreme events within sea level rise hazard zones. Such standards and applicable building code provisions should be included in LCPs as additional development controls in areas that are identified in the LCP as hazard areas, and applied in specific projects through a CDP.

A.8a **Update flood protection measures to incorporate both FEMA and Coastal Act requirements:** Require new development located in areas subject to current or future flood/wave action to be sited and designed to be capable of withstanding such impacts in compliance with both FEMA and Coastal Act requirements. For example, ensure that implementation of adaptation measures such as elevation of habitable areas, break-away walls, *etc*. will be consistent with both LCP and FEMA provisions.

A.8b **Limit basements and first floor habitable space**: Where applicable, in areas likely to be subject to current or future flood/wave action, revise residential building standards to prohibit habitable space at elevations subject to wave/flood risk. Specifically address potential impacts of basements on long-range adaptation options such as landward relocation or removal.

A.8c **Evaluate impacts from flood protection measures:** Require new development that must be located in areas likely subject to current or future flood/wave action or elevated groundwater to evaluate potential impacts to adjacent or nearby properties from all proposed structural flood protection measures to ensure that these measures will not create adverse direct and/or cumulative impacts either on-site or off-site.

A.9 Analyze options for removal when planning and designing new development: Design options should not place an undue burden on future property owners or coastal resources. For new development in high hazard areas or resource-constrained areas where managed retreat might be an appropriate option at some time in the future, ensure that foundation designs or other aspects of the development will not preclude future incremental relocation or managed retreat. Foundation and building elements, such as deepened perimeter foundations, caissons or basements, may be difficult to remove in the future, or their removal may put adjacent properties at risk. Alternative design options should be considered, and employed if site conditions allow.

A.9a **Develop a plan to remove or relocate structures that become threatened:** Require new development authorized through a CDP that is subject to wave action, erosion, or other hazards to be removed or relocated if it becomes threatened in the future.

A.9b **Identify triggers for incremental removal of structures on constrained lots**: When a lot is not large enough to accommodate development that avoids coastal hazards for the expected life of the development, develop a project option that minimizes hazards from the identified sea level rise scenarios for as long as possible, and then requires incremental retreat once certain triggers are met.

Triggers for relocation or removal of the structure would be determined by changing site conditions such as when erosion is within a certain distance of the foundation; when monthly high tides are within a certain distance of the finished floor elevation; when building officials prohibit occupancy; or when the wetland buffer area decreases to a certain width.

A.9c **Avoid shoreline protection for new development:** Require CDPs for new development in hazardous locations to include as a condition of approval a waiver of rights to future shoreline protection that would substantially alter natural landforms or cause other adverse coastal resource impacts.

A.9d **Limit the use of foundations or basements that can interfere with coastal processes:** In locations where foundation or building elements, such as deepened perimeter foundations, caissons or basements may be exposed to wave action through rising sea level or erosion, require analysis of less extensive foundation or building options.

A.9e **Develop triggers for foundation and structure removal:** If no less damaging foundation alternatives are possible, ensure that the foundation design allows for incremental removal as the foundation elements become exposed, and develop pre-established triggers, for example when the bluff edge or shoreline comes within a certain distance of the foundation, for incremental or complete removal that will avoid future resource impacts.

Figure 19. Photo depicting eroding bluff and exposed caissons in Encinitas, CA. (*Photograph by Lesley Ewing*)

A.10 Ensure that current and future risks are assumed by the property owner: New development should be undertaken in such a way that the consequences from development in high hazard areas will not be passed on to public or coastal resources. Recognize that over time, sea level rise will cause the public trust boundary to move inland. Establish standards, permit conditions, and deed restrictions that ensure that current and future risks are assumed by the property owner. Consider policies that would encourage or require property owners to set aside money, such as in the form of a bond, as a contingency if it becomes necessary to modify, relocate, or remove development that becomes threatened in the future.

A.11 Real estate disclosure: Require sellers of real estate to disclose permit conditions related to coastal hazards, or property defects or vulnerabilities, including information about known current and potential future vulnerabilities to sea level rise, to prospective buyers prior to closing escrow.

Goal: Incorporate sea level rise adaptation into redevelopment policies

A.12 Avoid the expansion or perpetuation of existing structures in at-risk locations: On an eroding shoreline, the seaward portions of an existing structure may become threatened as the setback or buffer zone between the structure and the mean high tide line or bluff edge is reduced due to erosion of the beach or bluff. When the seaward portion of the structure no longer meets the standards or setback that would be required for new development, it becomes a "non-conforming" structure for purposes of redevelopment policies and regulations. The following should be considered, as consistent with the Coastal Act, FEMA policies, and other relevant standards, to address existing non-conforming development to avoid the need for shoreline or bluff protective devices and associated impacts to coastal resources.

A.12a **Update non-conforming structure policies and definitions**: Develop policies and regulations to define non-conforming development in the area between the sea and the first coastal roadway or other known hazard zones to avoid perpetuating development that may become at risk and require a new protective device or extend the need for an existing protective device.

A.12b **Limit redevelopment or upgrades to existing structures in at risk locations**: Use redevelopment policies or regulations to limit expansions, additions, or substantial renovations of existing structures in danger from erosion. Require removal of non-conforming portions of the existing structure, when possible, when a remodel or renovation is proposed.

A.12c **Limit foundation work within the geologic setback area:** To facilitate removal of non-conforming portions of an existing structure, use LCP regulations and CDPs to limit new or replacement foundations or substantial improvements, other than repair and maintenance, to the existing foundation when located seaward of the Geologic Setback line. Approve significant new foundation work only when it is located inland of the setback line for new development and when it will not interfere with coastal processes in the future.

A.12d **Limit increases to existing non-conformities:** Use LCP regulations and CDPs to allow non-exempt repair and maintenance and modifications only if they do not increase the size or degree of non-conformity of the existing structure. For shoreline or blufftop development, any decrease in the existing non-conforming setback would increase the degree of non-conformity.

A.12e **Limit additions to non-conforming structures:** Use LCP regulations and CDPs to acknowledge that additions to existing structures should be considered new development that must conform to the standards for new development including but not limited to avoiding future protective devices. Consider limitations on the size of additions unless non-conforming portions of the structure are removed.

A.12f **Address existing protection of non-conforming structures:** Use LCP regulations and CDP conditions to put current and future property owners on notice that if there is currently shoreline or bluff protection for an existing structure, the structure is likely at-risk and improvements to that structure in its current location may be limited. Also, consider acknowledging that any rights to retain the existing protective device(s) apply only to the structure that existed at the time the protective device was constructed or permitted.

A.13 Redevelopment of existing structures: Define "redevelopment" as, at a minimum, replacement of 50% or more of an existing structure. Other options that may be used to define what constitutes redevelopment or a replacement structure could include 1) limits on the extent of replacement of major structural components such as the foundation or exterior walls, or 2) improvements costing more than 50% of the assessed or appraised value of the existing structure. The redevelopment definition should take into consideration existing conditions and pattern of development, potential impacts to coastal resources, and the need for bluff or shoreline protective devices if the structure remains in its current, non-conforming location.

A.13a **Require redevelopment to meet the standards for new development:** Use LCPs and CDPs to require that renovations meeting the threshold for redevelopment should not be approved unless the entire structure meets the standards for new development, including but not limited to a waiver of right to protection. Specify that if any existing non-conforming elements are permitted to remain, those non-conforming elements are not subject to rights to protection pursuant to Coastal Act Section 30235.

A.13b **Include cumulative improvement or additions to existing structures in the definition of redevelopment:** Use LCP regulations to acknowledge that demolition, renovation, or replacement of less than 50% (or less) of an existing structure constitutes redevelopment when the proposed improvements would result cumulatively in replacement of more than 50% of the existing structure from an established date, such as certification of the LUP.

A.14 Remove existing shoreline protective devices: On properties with existing shoreline protective devices, use regulations to require removal of the protective device when the structure requiring protection is redeveloped or removed. If removal is not possible, require a waiver of any rights to retain the protective device to protect any structure other than the one that existed at the time the protective device was constructed or permitted.

Goal: Encourage the removal of development that is threatened by sea level rise

A.15 Use Rolling Easements: The term "rolling easement" refers to the policy or policies intended to allow coastal lands and habitats including beaches and wetlands to migrate landward over time as the mean high tide line and public trust boundary moves inland with sea level rise. Such policies often restrict the use of shoreline protective structures (such as the "no future seawall" limitation sometimes used by the Commission), limit new development, and encourage the removal of structures that are seaward (or become seaward over time) of a designated boundary. This boundary may be designated based on such variables as the mean high tide line, dune vegetation line, or other dynamic line or legal requirement. Despite the term "rolling easements," not all of the strategies related to rolling easements actually involve the use of recorded easements.

A.16 Develop an incentive program to relocate existing development at risk: Provide incentives to relocate development out of hazardous areas and to acquire oceanfront properties damaged by storms, where relocation is not feasible. Consider creating a relocation fund through increased development fees, *in lieu* fees, or other funding mechanisms.

A.17 Transfer of Development Rights programs (TDR): See Strategy A.5b above.

A.18 Acquisition and buyout programs: Acquisition includes the acquiring of land from the individual landowner(s). Structures are typically demolished or relocated, the property is restored, and future development on the land is restricted. Such a program is often used in combination with a TDR program that can provide incentives for relocation. Undeveloped lands are conserved as open space or public parks. LCPs can include policies to encourage the local government to establish an acquisition plan or buyout program to acquire property at risk from flooding or other hazards.

Goal: Use "soft" or "natural" solutions as a preferred alternative for protection of existing endangered structures

A.19 Require the use of green infrastructure as a preferred alternative: Under appropriate shoreline conditions, require or encourage development to use "soft" or "natural" solutions or "living shorelines" as an alternative to the placement of hard shoreline protection in order to protect development or other resources and to enhance natural resource areas. Examples of soft solutions include vegetative planting, dune restoration, and sand nourishment.

A.19a **Establish a beach nourishment program and protocols**: New policies may be needed to address increased demand or need for beach nourishment with sea level rise. Policies within an LCP may identify locations where nourishment may be appropriate; establish a beach nourishment program and protocols for conducting beach nourishment; establish criteria for the design, construction, and management of the nourishment area; and/or establish measures to minimize adverse biological resource impacts from deposition of material, such as sand compatibility specifications, timing or seasonal restrictions, and identification of environmentally preferred locations for deposits. Beach nourishment programs should also consider how nourishment options may need to change over time as sea level rises.

A.19b **Dune management**: Establish management actions to maintain and restore dunes and natural dune processes. Dunes provide buffers against erosion and flooding by trapping windblown sand, storing excess beach sand, and protecting inland areas, and they also provide habitat. This is likely most effective for areas with some existing dune habitat and where there is sufficient space to expand a foredune beach for sand exchange between the more active (beach) and stable (dune) parts of the ecosystem. LCPs can identify existing dune systems and develop or encourage management plans to enhance and restore these areas, including consideration of ways that the system will change with rising sea level. CDPs for dune management plans may need to include periodic reviews so the permitted plans can be updated to address increased erosion from sea level rise, and the need for increased sand retention and replenishment.

Figure 20. Photo depicting dune restoration at Surfer's Point, Ventura. (*Photograph courtesy of Surfrider Foundation*)

A.19c **Regional Sediment Management (RSM) programs**: Develop a Regional Sediment Management (RSM) program including strategies designed to allow the use of natural processes to solve engineering problems. To be most effective, RSM programs include the entire watershed, account for effects of human activities on sediment, protect and enhance coastal ecosystems, and maintain safe access to beaches for recreational purposes. LCPs can support development of an RSM program and its implementation, and the program should be periodically updated to address on-going changes from sea level rise. Natural boundaries for RSM may overlap within several LCPs, so regional cooperation may be needed for best implementation. Individual actions such as a beach nourishment project would be accomplished through a CDP. Many coastal RSM programs have already been developed and can be used as a resource. See the *Coastal Sediment Management Workgroup* website (and Appendix C) for more information.

A.19d **Maintenance or restoration of natural sand supply**: Adjustment of the sediment supply has been one of the ways natural systems have accommodated changes from sea level. Maintenance or restoration of sediment involves identifying natural sediment supplies and removing and/or modifying existing structures or actions that impair natural sand supply, such as dams or sand mining. LCPs could include policies and implementing standards that support nature-based responses to sea level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to prohibit sand mining, regulate sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea level rise and may identify and designate high priority areas for restoring natural processes. These actions and policies can also be implemented through a Regional Sediment Management (RSM) program.

A.19e **Beneficial reuse of sediment through dredging management**: Dredging involves the removal of sediment from harbor areas to facilitate boat and ship traffic or from wetland areas for restoration. Dredging management actions and plans may need to be updated to account for elevated water levels. Policies can be developed with an LCP and/or carried out through a CDP to facilitate delivery of clean sediment extracted from dredging to nearby beaches or wetland areas where needed. Beneficial reuse of sediment in this way can be coordinated through a Regional Sediment Management (RSM) program and/or through coordination with other jurisdictions.

Goal: Allow bluff and shoreline protective devices only to protect existing endangered structures

A.20 Use hard protection only if allowable and if no feasible less damaging alternative exists: "Hard" coastal protection is a broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. In some cases, caissons and pilings may also be considered hard shoreline protective devices. Due to adverse effects on shoreline sand supply and beach area available for public use, such protective devices should be avoided when feasible. Under current law, shoreline protection for existing structures in danger from erosion may be allowed if coastal resource impacts are avoided or minimized and fully mitigated where unavoidable.

A.20a **Retention of existing shoreline protection**: On intensely developed, urbanized shorelines, if the removal of armoring would put existing development at risk and not otherwise result in significant protection or enhancement of coastal resources, it may be appropriate to allow properly designed shoreline armoring to remain for the foreseeable future, subject to conditions that provide for potential future removal in coordination with surrounding development. However, the proper short term responses, longer term adaptation measures, and mitigation of on-going resource impacts should be determined through updated context-specific LCP planning and consideration of the existing rights and responsibilities of development in the area (see strategies A.21 – A.25).

A.21 Require monitoring of the structure: Require periodic monitoring of the shoreline protective device to examine for structural damage, excessive scour, or other impacts from coastal hazards and sea level rise. Ensure that the structures remain within the initial footprint and that they retain functional stability.

A.22 Conditional approval of shoreline protective device: Use LCP regulations and permit conditions to require monitoring of impacts to shoreline processes and beach width both at the project site and the broader area and/or littoral cell as feasible, and provide for such actions as removal or modification of armoring in the future if it is no longer needed for protection or if site conditions change.

A.22a **Limit the authorization of shoreline protective devices to the development being protected:** Use LCP regulations and CDP conditions to require permits for bluff and shoreline protective devices to expire when the currently existing structure requiring protection is redeveloped, is no longer present, or no longer requires a protective device, whichever occurs first. Prior to expiration of the permit, the property owner should apply for a Coastal Development Permit to remove the protective device, or to modify or retain it if removal is not feasible at that time.

A.22b **Require assessment of impacts from existing pre-Coastal Act or permitted shoreline armoring:** Use LCP regulations and permit conditions to specify that expansion and/or alteration of a pre-Coastal Act or legally permitted bluff or shoreline protective device requires a new CDP and the review should include an assessment of changes to geologic site and beach conditions including but not limited to, changes in beach width relative to sea level rise, implementation of any long-term, large scale sand replenishment or shoreline restoration programs, and any ongoing impacts to public access and recreation from the existing device.

A.22c **Reassess impacts and need for existing armoring over time:** Use LCP regulations and CDPs to provide for reassessment of the impacts from protective devices at specific trigger points, including when substantial improvement or redevelopment of the structure requiring protection is proposed, or when existing armoring is being modified or expanded. Reassessment should consider the effect any significant improvement to a structure requiring protection will have on the length of time the protective device will remain, and if the existing armoring is still required, acknowledge that it is authorized to protect the existing structure only. The CDP review should assess existing site conditions and evaluate options to modify, replace, or remove the existing device in a manner that would eliminate or mitigate any identified impacts that may be occurring on public access and recreation, scenic views, sand supply, and other coastal resources, if feasible.

A.23 Require mitigation for impacts of shoreline protective devices: For unavoidable public resource impacts from shoreline structures permitted under the Coastal Act, require mitigation of resource impacts over the life of the structure as a condition of approval for the development permit. For example, require landowners to pay mitigation fees and/or complete other mitigation actions for the loss of sandy beach and other adverse impacts on public access and recreation due to shoreline protection devices. Importantly, mitigation measures should be planned in such a way that sea level rise will not impair their efficacy over time. Other mitigation measures could include acquisition of other shoreline property for public recreational purposes, construction of public access and recreational improvements along the shoreline, and/or easements to protect lateral access along the shoreline in areas where seawalls eliminate sandy beach.

A.23a **Reassess mitigation over time as necessary:** Impacts of shoreline structures, including to shoreline and sand supply, public access and recreation, ecosystem values, and other relevant coastal resources, should be fully mitigated. Where reassessment of an approved structure is authorized, phasing of necessary mitigation may be appropriate.

A.24 Limit retention of existing shore protection: On lots with existing pre-Coastal Act or permitted armoring, consider requiring a waiver of rights to retain such protection for any structures other than the structure that existed at the time the armoring was constructed or permitted.

A.25 Removal of shoreline protection structures: The removal of shoreline protection structures can open beach or wetland areas to natural processes and provide for natural responses to sea level rise. LCPs can specify priority areas where shoreline protection structures should be removed if they are no longer needed or in a state of great disrepair, including areas where structures threaten the survival of wetlands and other habitats, beaches, trails, and other recreational areas. Once these priority areas have been identified, assessment of potential re-siting of structures and removal of armoring could be required by a CDP as redevelopment occurs.

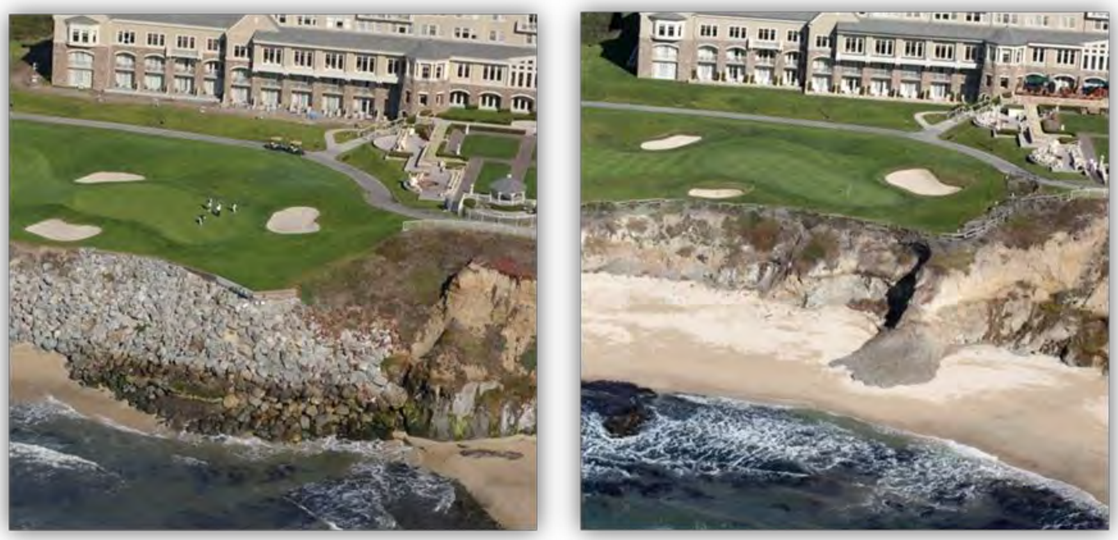

Figure 21. Photo depicting removal of shoreline protective structure. Removal of rock revetment restores access and allows natural bluff erosion at the Ritz Carlton in Half Moon Bay. (*Source:* California Coastal Records Project)

A.25a **Remove shoreline protective structures located on public lands:** Over time, sea level rise will cause the public trust boundary to move inland. If the structures as originally approved were located on uplands but that land becomes subject to the public trust in the future, the State Lands Commission or any local government or other entity acting as trustee for public trust lands could require the structures to be removed. The Commission or local governments could approve permit conditions to ensure permittees obtain authorization to retain or remove structures if they ever become located on public trust lands. Removal might also be accomplished through non-regulatory means such as offering incentives for removal to property owners or by incorporating removal of public structures into Capital Improvement Plans.

Goal: Require special considerations for critical infrastructure and facilities

A.26 Plan ahead to preserve function of critical facilities: Addressing sea level rise impacts to critical facilities and infrastructure will likely be more complex than for other resources and may require greater amounts of planning time, impacts analyses, public input, and funding. To address these complexities, establish measures that ensure continued function of critical infrastructure, or the basic facilities, service, networks, and systems needed for the functioning of a community. Programs and measures within an LCP could include identification of critical infrastructure that is vulnerable to SLR hazards, establishment of a plan for managed relocation of at-risk facilities, and/or other measures to ensure functional continuity of the critical services provided by infrastructure at risk from sea level rise and extreme storms. Repair and maintenance, elevation or spot-repair of key components, or fortification of structures where consistent with the Coastal Act may be implemented through CDPs.

A.26a **Develop or update a long-term public works plan for critical facilities to address sea level rise**: Develop a long-term management plan to address the complexities of planning for sea level rise that incorporates any potential maintenance, relocation, or retrofits and structural changes to critical facilities to accommodate changes in sea level, and obtain Coastal Commission certification.

A.27 Apply high sea level rise projections for siting and design of critical facilities: Given the planning complexities, high costs, and potential impacts resulting from damage, there is reason to be particularly cautious when planning and designing new critical facilities and/or retrofitting existing facilities. Ensure that critical facilities are designed to function even if the highest projected amounts of sea level rise occur and that sites with hazardous materials are protected from worst-case scenario sea level rise impacts.

A.27a **Design coastal-dependent infrastructure to accommodate worst case scenario sea level rise**: Include policies that would require proposals and/or expansion plans to address sea level rise for coastal dependent infrastructure that must necessarily be sited in potentially hazardous areas, such as industrial, energy, and port facilities. Such facilities should be designed to withstand worst case future impacts while minimizing risks to other coastal resources through initial siting, design, and/or inclusion of features that will allow for future adaptation.

A.28 Site and design wastewater disposal systems to avoid risks from sea level rise: Wastewater treatment and disposal systems are particularly challenging in that they are often located in areas that will be impacted by sea level rise. Ensure that these systems are not adversely affected by the impacts of sea level rise over the full life of the structure and ensure that damage to these facilities would not result in impacts to water quality or other coastal resources. Avoid locating new facilities in hazardous areas if possible. If complete avoidance is not possible, minimize elements of the system that are in hazardous areas (for example, locate the main facility on higher ground and only place pump stations in potentially hazardous areas), and design any facilities in hazardous areas to withstand worst-case scenario sea level rise impacts.

Goal: Protect transportation infrastructure

A.29 Identify priorities for adaptation planning and response: Carry out vulnerability analyses to identify chronic problem areas that are highly subject to erosion, wave impacts, flooding, or other coastal hazards or that maybe become so in the near future. Coordinate with Caltrans and local public works/transportation agencies to address high priority areas and increase monitoring efforts of chronic problem areas.

A.30 Add policies to address impacts to transportation routes: If transportation facilities are at risk from sea level rise, coordinate with Caltrans and local public works/transportation agencies to establish new alternative transportation routes or a plan to ensure continued alternative transportation and parking is available that allows for continued access to beaches and other recreation areas.

A.30a **Integrate LCP/land use planning processes with transportation planning processes:** Updates and changes to LCPs and other land use planning efforts should be jointly planned, evaluated, and implemented with Coordinated System Management Plans, Regional Transportation Plans, and other transportation planning efforts to ensure that long-term land use and access goals and needs are aligned.

A.31 Allow for phased implementation of realignment and relocation projects: In some cases it may be necessary to make incremental changes in transportation networks so that access to and along the coast can be maintained while also addressing coastal hazards over the long-term. For example, a phased approach may allow for interim shoreline protection to maintain an existing road alignment while future realignment plans are evaluated and pursued. Such phased approaches should be coordinated with Caltrans and local public works/transportation agencies and aligned with long-term LCP planning and adaptation goals. Individual projects will be implemented through CDPs.

Figure 22. Photo depicting planned retreat for major public infrastructure. The Piedras Blancas Highway 1 Realignment will move nearly 3 miles (5km) of Highway 1 500 ft (152 m) inland. (*Source:* California Coastal Records Project)

A.32 Plan and design transportation systems to accommodate anticipated sea level rise impacts: Ensure that transportation networks are designed to function even if the highest projected sea level rise amounts occur. Efforts to realign, retrofit, and/or protect infrastructure should be coordinated with Caltrans, local public works/transportation agencies, and LCP planning efforts, and individual projects will be implemented through CDPs.

A.32a **Retrofit existing transportation infrastructure as necessary:** In instances where relocation is not an option, repair damage and/or retrofit existing structures to better withstand sea level rise impacts. For example, use stronger materials, elevate bridges or sections of roadways, and build larger or additional drainage systems to address flooding concerns.

A.32b **Build redundancy into the system:** Provide alternate routes, as possible, to allow for access to and along the coast in instances in which sections of roadways may become temporarily impassible as a result of coastal hazards. Ensure that alternate route information is provided to residents and visitors to coastal areas.

A.33 Incorporate sea level rise considerations into Port Master Plans and other port activities: Ensure that ports and related infrastructure are designed to function given anticipated sea level rise. In some cases, this may mean initially designing structures to accommodate projected sea level rise impacts. Other options may include planning for and ensuring capacity for future adaptive actions.

A.33a **Retrofit existing port infrastructure as necessary**: Given the coastal-dependent nature of many port structures, it may not be feasible to site or relocate development to avoid hazards. In these instances it may be more appropriate to include efforts to accommodate and withstand sea level rise during actions to repair or retrofit existing structures. Options may include using more robust designs or materials or elevating structures.

A.33b **Minimize resource impacts that may result from future use of shoreline protective structures**: If existing, coastal-dependent port structures require shoreline protective structures, minimize resource impacts as feasible and consistent with Chapter 3 and/or Chapter 8 of the Coastal Act, as applicable, by encouraging inland expansion of protective devices rather than further fill of coastal waters.

A.33c **Ensure that linkages to overland transportation networks are able to adapt to sea level rise impacts**: Coordinate with relevant stakeholders to ensure that linkages between port infrastructure and overland transportation networks will be resilient to future sea level rise impacts.

A.33d **Ensure that lessees and other parties understand sea level rise risks and vulnerabilities**: Coordinate with lessees and other stakeholders to ensure that they understand the risks associated with development in hazard areas as well as the responsibilities that come with such development.

B. Public Access and Recreation

One of the highest priorities in the Coastal Act is the mandate to maximize public access and recreational opportunities to and along the coast. The main goals and Coastal Act policies (Sections 30210, 30220, 30221, 30213) that relate to public access and recreation are to:

- Maximize public access and recreational use by protecting beaches and other coastal areas suitable for such use
- Protect lower cost visitor and recreational facilities and accessways

Chapter 3 of the Guidance covers the impacts to public access and recreation that might result from sea level rise or the interaction of sea level rise with development patterns. Certified LCPs should already have policies and standards to assure that existing public access and visitor serving amenities are protected and that maximum public access is both planned for and provided with new development when warranted. However, LCP policies and standards may need to be updated to consider sea level rise hazards. Adaptation options have been developed to support the access goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Maximize public access and recreational use by protecting beaches and other coastal areas

B.1 **Incorporate sea level rise into a comprehensive beach management strategy**: Update or develop a new comprehensive beach management strategy to address loss of beach areas, including loss of lateral access, or changes in beach management due to sea level rise. Establish a program to minimize loss of beach area through, as may be appropriate, a beach nourishment program; restoring sand and sediment supply to the littoral cell; removal, adjustments, or maintenance to shoreline protection structures; use of man-made structures such as terminal groins or artificial reefs to retain sediment; or other actions.

B.1a **Develop a sediment management and sand replenishment strategy**: Identify natural sediment supplies and remove and/or modify existing structures or actions that impair natural sand supply, such as dams or sand mining. LCPs could include policies and implementing standards that support nature-based responses to sea level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to prohibit sand mining, regulate sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea level rise. These actions and policies can also be implemented through a Regional Sediment Management (RSM) program.

B.2 Plan ahead to replace loss of access and recreation areas: Identify replacement opportunities or otherwise plan ahead for how to replace recreation areas and accessways that will be lost due to inundation or damage associated with sea level rise. An LCP could designate and zone lands for this through, for example, a phased overlay or other regulatory measures that ensure that access and recreational areas are available in the future. Local governments may choose to provide additional incentives to encourage creation of new recreation areas or opportunities. Such incentives could include grant for protection new recreation areas or tax breaks for recreation related businesses.

B.2a **Protect existing open space adjacent to the coast**: Plan for future coastal recreational space and parkland by protecting open space adjacent to coastal habitats so that beaches and other habitats can migrate or so that there is open space available as parkland or other areas are lost.

B.2b **Plan for removal of structures that limit inland migration of beaches**: Seawalls and other development adjacent to beaches and other coastal habitats will impede the ability of these habitats to migrate inland and will therefore result in the inundation and eventual loss of these areas. Consideration should be given to removing and relocating these structures to ensure that beaches and other habitats are able to persist over time. Additional detail on removal of structures can be found above in the "Coastal Development and Hazards" section of this chapter.

Goal: Protect lower cost visitor and recreational facilities and accessways

B.3 Site and design access sites and facilities to minimize impacts: Add policies that require public access sites, segments of the CCT, and recreation and visitor-serving facilities to be sited and designed to avoid impacts from sea level rise, while maximizing public access and recreation opportunities. Examples of siting and design standards for development can be found in section A. Where facilities can be safely sited for the near term but future impacts are likely, require an adaptive management plan detailing steps for maintenance, retrofitting, and/or relocation.

B.3a **Require mitigation of any unavoidable impacts**: For unavoidable impacts to public access or recreation from shoreline armoring or other development, require mitigation of impacts through the addition of new public access, recreation opportunities, visitor-serving accommodations, or Coastal Trail segments, or payment of fees to fund such improvements. Importantly, mitigation measures should be planned in such a way that, if possible, sea level rise will not impair their efficacy over time.

B.4 Plan ahead to replace loss of visitor-serving and recreational facilities: Develop a plan to replace any visitor-serving facilities that are lost due to impacts from sea level rise, maximizing continued provision of affordable options and an appropriate mix of accommodations over time. For example, an LCP could include standards to re-site existing visitor-serving and recreational facilities when they become impacted by sea level rise and/or could identify and zone for future areas to be reserved for these functions.

B.5 **Add requirements for retrofit/relocation of public access and recreation sites at risk**: The LCP can add policies that require all new public access and recreation areas, sections of the CCT, visitor- serving accommodations, or related recreation facilities to be retrofitted or relocated if they become threatened from erosion, flooding, or inundation. For new facilities and public access sites, the CDP conditions of approval can specify how maintenance, retrofit, or relocation will take place. Policies and plans should be designed to be adaptive so that retrofits and or/relocations are implemented as sea level rise impacts occur.

B.5a **Retrofit or relocate recreation and visitor-serving facilities**: Consider options to retrofit existing recreation and visitor-serving facilities to better accommodate sea level rise impacts. Such retrofits could include use of different building materials and/or relocating facilities.

B.5b **Retrofit or relocate vertical accessways**: Consider options to retrofit existing accessways to reduce impacts from sea level rise. Such retrofits could include using different materials that can better withstand impacts, or re-orienting the layout or other features of accessways to lessen damage and other impacts. Also begin to plan for and identify triggers and options for relocating accessways over time as conditions change.

B.5c **Retrofit or relocate sections of the Coastal Trail**: Use boardwalks, bridges, and/or other design features to ensure continuity of the CCT in sections that are vulnerable to SLR hazards. Some sections may need to be relocated over time. An LCP could identify vulnerable sections of the CCT and establish a phased approach to relocate sections of the trail in such a way that is consistent with provisions of the Coastal Act and ensures that the CCT remains within sight, sound, or smell of the sea.

Goal: Foster efforts to better understand impacts of sea level rise

B.6 **Support research on impacts to recreation and public access**: Changes in sea level will affect wave conditions and sediment transport, but additional research is needed to understand how these changes will affect specific conditions for surfing and other recreation activities. While such research programs may be outside the scope of individual local jurisdictions, statements of support for the local issues that need to be addressed can help guide research agendas at the regional state or federal level. Or, such needs can serve to guide grant applications to undertake the needed projects within a jurisdiction. To the extent possible, add policies to promote research on sea level rise impacts to recreational activities like surfing or other coastal recreational uses in the LCP jurisdiction.

C. Coastal Habitats, ESHA, and Wetlands

The Coastal Act provides for the protection of both land and marine habitats. It mandates that ESHA and marine resources shall be protected against significant disruption of habitat value and shall be maintained, enhanced, and restored as feasible (Sections 30230, 30233, 30240, 30240(a), 30240(b)). The main goals and Coastal Act policies that relate to coastal habitats are to:

- Protect, enhance, and restore sensitive habitats
- Avoid significant disruption to sensitive habitats
- Avoid significant impacts to habitats from adjacent development
- Manage sediment in ways that benefit habitats

Chapter 3 of the Guidance covers the impacts to coastal habitats and resources that might result from sea level rise or the interaction of sea level rise with development patterns. Certified LCPs should already have policies and standards to ensure that ESHA, wetlands, and other coastal habitats and resources are protected to the maximum extent feasible. However, LCP policies and standards may need to be updated to consider sea level rise hazards. Adaptation options have been developed to support the habitat protection goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect, enhance, and restore sensitive habitats

C.1 Open space preservation and conservation: Preserve land for its ecological or recreational value. This may involve limiting or prohibiting development and any uses that conflict with ecological preservation goals. LCPs can establish transfer of development rights programs to offset reduced development potential and can develop open space management plans that evaluate and consider the impacts of sea level rise, extreme events, and other climate change impacts. LCPs can establish open space and conservation areas through land use designations and zoning, redevelopment restrictions, acquisition and easement programs, and setback and buffer requirements.

C.1a **Update policies to provide for new or restored coastal habitat**: Update policies to require new coastal habitat to be provided or for degraded areas to be restored to account for the expected loss of existing habitat that will occur when development blocks the necessary upland migration due to sea level rise. Use an adaptive management approach where applicable. Encourage policies that provide for conservation or restoration of multiple habitat types.

C.1b **Identify areas for public acquisition**: New or updated LCPs can establish a program to partner with state, federal, and non-profit organizations to acquire and protect natural resource areas for public use, including areas that could serve as refugia for species impacted by sea level rise, or areas that could be appropriate sites for coastal habitat creation or restoration.

C.1c **Establish conservation easements or other development restrictions to protect habitat**: Establish a formalized program to identify, acquire, and manage areas appropriate for some form of conservation protection. Easements or other strategies may be used to limit or restrict development on portions of a lot parcel that are most vulnerable to SLR impacts. The program might develop standard agreements to be used for easements and identify the entities that could hold the easements. A conservation easement program could be established on a community wide basis through an LCP and implemented on a parcel by parcel basis through individual CDPs.

C.1d **Require open space protection as a component of new development located adjacent to coastal habitats**: The LCP can require permit conditions for new development in certain areas that buffers around natural resource areas be protected through a conservation easement, deed restrictions, or other comparable mechanism.

C.1e **Use Rolling Easements**: See Strategy A.15 above.

C.1f **Transfer of Development Rights programs (TDR)**: See Strategy A.5b above.

Goal: Avoid significant disruption to habitats

C.2 **Use ecological buffer zones and/or increase the size of buffers**: Buffer zones are intended to protect sensitive habitats from the adverse impacts of development and human disturbance. An important aspect of buffers is that they are distinct ecologically from the habitat they are designed to protect. LCPs can establish requirements for ecological buffers and provide guidance on how to establish or adjust these buffers to accommodate sea level rise. CDPs should require buffers to be designed, where applicable, to provide "habitat migration corridors" that allow sensitive habitats and species to migrate inland or upland as sea level rises.

C.2a **Consider sea level rise buffer zones**: Update buffer zone policies to allow room for coastal habitats to migrate with changes in sea level. The size of the buffer needed to allow for migration will vary depending on the individual wetland or habitat type, as well as site-specific features such as natural or artificial topography and existing development. For instance, in flat areas, a larger buffer may be needed, but in steep areas, a smaller buffer may be acceptable.

C.3 **Avoid impacts to Marine Protected Areas**: Recognize the importance of the State's network of marine protected areas (MPAs) in protecting the diversity and abundance of marine life. Understand that planning and permitting decisions made on land could have impacts on these areas, particularly as conditions change with sea level rise, and avoid disruptions to these habitats as feasible and applicable.

C.4 **Protect specific ESHA functions:** Environmentally Sensitive Habitat Areas (ESHA) are areas that are critically important for the survival of species or valuable for maintaining biodiversity. These areas can include nursery grounds, spawning areas, or highly diverse areas. Where at risk from sea level rise, the LCP should establish measures to ensure the continued viability of the habitat areas, such as protection of migration zones, habitat corridors, and other applicable adaptation strategies, as listed below. ESHA that is not at risk from sea level rise should also be afforded special protection in the LCP to serve as refugia.

C.4a **Protect wildlife corridors, habitat linkages, and land upland of wetlands to allow habitat migration**: Preserve open areas that are adjacent to wetlands to allow for migration of these habitats as sea levels rise.

C.4b **Protect refugia areas**: Protect refugia, or areas that may be relatively unaltered by global climate change and thus can serve as a refuge for coastal species displaced from their native habitat due to sea level rise or other climate change impacts.

C.4c **Promote increased habitat connectivity to allow species movement**: Connectivity refers to the degree to which the landscape facilitates animal movement and other ecological flows. Roads, highways, median barriers, fences, walls, culverts, and other structures can inhibit movement of animals. Develop LCP policies that will enable identification of important animal movement corridors. Develop regulations to protect these corridors for present and future conditions, taking into account habitat shifts from climate change. In LCPs and through CDPs, require that new structures such as highways, medians, bridges, culverts, and other development are designed to facilitate movement of animals.

C.4d **Facilitate wetland and other habitat migration**: Reserve space for a "habitat migration corridor" or areas into which wetlands and other habitats could migrate as sea level rise induced inundation of existing wetland areas occurs. In the LCP, identify potential habitat migration corridors. These areas could be reserved for this purpose in an LCP through land acquisition, use designations, zoning buffers, setbacks, conservation easement requirements, and clustering development. LCPs should also consider developing a plan for acquisition of important habitat migration corridors.

Goal: Avoid significant impacts to habitats from adjacent development

C.5 Limit new development in areas adjacent to wetlands, ESHA, and other coastal habitats: Restrict the construction of new development in areas that are adjacent to wetlands, ESHA, and other coastal habitats in order to preserve buffers and open areas to allow for habitat migration.

C.5a **Cluster development away from coastal habitats**: Existing LCPs will likely have policies that already require clustering of development. To address sea level rise, these policies might need to be updated to include clustering development away from land where wetlands and other coastal habitats could migrate with sea level rise.

C.5b **Limit subdivisions**: Update subdivision requirements to require provision for inland migration of natural resource areas or to require lots to be configured in a way that allows such migration. Lot line adjustments may sometimes be appropriate if they facilitate locating physical development further away from hazards or sensitive resources.

Figure 23. Photo depicting the preservation and conservation of open space along an urban-rural boundary. North end of Pismo Beach from 1972 (*left*) to 2002 (*right*). (*Source:* California Coastal Records Project)

Goal: Manage sediment in ways that benefit habitats

C.6 **Identify opportunities for Regional Sediment Management**: Sediment supplies will be important for the long-term sustainability of many beaches and wetland areas. Strategies to maintain or restore natural sediment supplies and to coordinate sediment removal efforts with opportunities for reuse can provide multiple benefits to coastal ecosystems. See Strategy A.19c above for more detail on RSM programs.

C.6a **Restore natural sediment sources to wetlands**: Restoration of natural hydrodynamic systems will help to ensure the ability of wetlands to persist with sea level rise by ensuring that sediment is available for wetland accretion. Such actions may include restoring natural channels in streams and waterways that have been armored or channelized. Organizing and coordinating such efforts may be accomplished through a Regional Sediment Management Plan.

C.6b **Identify opportunities for beneficial reuse of sediment to support wetland restoration**: Consider facilitating the delivery of clean, dredged sediment to areas where former wetlands have subsided or to areas where existing wetlands are or may become sediment-limited as sea levels rise.

Goal: Incorporate sea level rise into habitat management actions

C.7 **Include sea level rise in site-specific evaluations**: Update policies to require site-specific biological evaluations and field observations of coastal habitat to include an evaluation of vulnerability to sea level rise where appropriate. Such an evaluation should consider both topographic features as well as habitat and species sensitivities (for example, sensitivity to inundation and saltwater intrusion).

C.8 Incorporate sea level rise in restoration, creation, or enhancement of coastal habitats: Update policies to require site-specific biological evaluations and field observations of coastal habitat to include an evaluation of vulnerability to sea level rise. Such an evaluation should consider both topographic features as well as habitat and species sensitivities (for example, sensitivity to inundation and saltwater intrusion). Habitat restoration, creation, or enhancement projects should be designed to withstand impacts of sea level rise and adapt to future conditions. As applicable, the LCP should contain policies to ensure restoration and management techniques account for future changes in conditions. CDPs for restoration projects should incorporate sea level rise and provisions to ensure habitats can adapt with changing future conditions.

C.9 Update habitat management plans to address sea level rise: Add policies stating that the effects of sea level rise should be addressed in management plans for coastal habitats. For example, plans should evaluate the full range of sea level rise impacts to coastal habitats, and develop a strategy for managing coastal habitats given changing sea level rise conditions. Existing management plans may need to be updated to add new monitoring and restoration requirements to address sea level rise. The strategies listed below are examples of strategies that could be included in habitat management plans.

C.9a **Use an adaptive management approach in ecosystem management, restoration, or design**: Habitat management plans and/or other habitat projects should establish an adaptive management approach, with clearly defined triggers for adaptive actions. Such an approach would allow for and ensure that coastal habitats are able to migrate and transition with changes in sea level.

Figure 24. Photo depicting habitat protection at Salinas River State Beach. Dunes are roped off to protect Snowy Plover nesting habitat. (*Source:* California Coastal Records Project)

C.10 Pursue strategies to protect ecosystem function under a range of future sea level rise or climate change scenarios: The LCP and/or habitat management plans can recommend coastal habitat management strategies that strive to protect ecosystem function in the future. Strategies include protecting a wide range of ecosystem types, protecting refugia, protecting wildlife and habitat corridors, and establishing methods to monitor ecosystem change over time.

C.10a **Update monitoring requirements for coastal habitats**: As part of the LCP and/or habitat management plans, consider establishing a monitoring protocol and requirements for evaluating sea level rise impacts to coastal habitats over time. Such a protocol would also help identify triggers at which additional adaptation options are necessary.

D. Agricultural Resources

Agriculture is a priority use within the Coastal Act, which mandates that the maximum amount of prime agricultural land shall be protected and maintained (Sections 30231, 30241, 30242). The main goals and Coastal Act policies that relate to agriculture are to:

- Protect the maximum amount of prime agricultural land
- Limit conversion of lands suitable for agriculture to non-agricultural uses
- Minimize impacts to water quality that could result from agricultural practices
- Promote water conservation efforts

Chapter 3 of the Guidance describes the impacts to agricultural resources that may result from sea level rise. Certified LCPs should already have policies and standards to ensure that agricultural resources are protected to the maximum extent feasible. However, LCP policies and standards may need to be updated to address sea level rise hazards. Adaptation options have been developed to support the agricultural protection goals of the Coastal Act through both LCP policies and CDP conditions, and the following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect the maximum amount of prime agricultural land

D.1 Identify and designate areas suitable for agricultural production to replace agricultural production areas that could be lost to sea level rise: Identify any non-sensitive open or developed areas, both within and outside of the Coastal Zone, which could potentially be used to replace agricultural land that is lost to sea level rise. Update LCP designations and/or policies to protect these identified areas for agricultural production and, as applicable, to provide for their conversion to agricultural use. Encourage and support regional coordination as feasible and applicable.

D.1a **Establish SLR-specific agricultural protection program:** Establish a formal program to identify, acquire, incentivize, and manage areas appropriate for new/renewed agricultural use and/or for protection of current and/or future agricultural uses. Such program should target key areas and properties where agricultural conversion threats are highest, and should dovetail with existing agricultural protection programs. Easements and other legal restrictions may be used as part of such program to help limit or restrict development in areas where agricultural land and production are most vulnerable to sea level rise impacts. The program might develop standard language and/or legal documents that can be used for easements or other property restrictions. The program should be flexible enough to be able to be implemented on both a large scale (*e.g.*, though LCP policies and programs) as well as on a smaller scale (*e.g.*, through the CDP process).

D.2 Protection, maintenance, and adaptation of dikes and levees: Repairing and maintaining existing flood barriers such as dikes and levees may be a cost-effective way to continue to protect agricultural areas. While some repair and maintenance activities are exempt from the need for a CDP, the repair and maintenance exemption does not apply to repair and maintenance work that is located within an ESHA, within any sand area, within 50 feet of the edge of a coastal bluff or ESHA, or within 20 feet of coastal waters. LCPs could identify opportunities for these kinds of actions and ensure that they are appropriately permitted, with consideration to the environmental protection and restoration goals of the Coastal Act. While landowners have the right to repair and maintain existing legal levees in their current configurations, the Commission and local governments administering LCPs have the authority to regulate, via the CDP process, the proposed methods of repair and maintenance. To raise, reconfigure, enlarge, or widen levees is not repair and maintenance and requires a Coastal Development Permit. Such activities may not be consistent with the Coastal Act or certified LCP, such as in cases involving wetland fill impacts. However, where there are opportunities to restore marine resources and the biological productivity of wetlands and estuaries, it may be possible to permit a dike/levee reconstruction project that provides for substantial restoration.

Goal: Limit conversion of lands suitable for agriculture to non-agricultural uses

D.3 Limit conversion of agricultural land to other developed land uses: Develop policies to assure maximum environmentally feasible protection of rural agricultural land, open space, and other coastal resources, including areas that may be considered non-prime agricultural land at this time. Anticipate areas that could become more difficult to farm and identify strategies to avoid or mitigate the potential impacts.

Goal: Minimize impacts to water quality that could result from agricultural practices

D.4 Include sea level rise in water quality protection policies: Where needed, coordinate with regional water quality control boards to add policies to reduce water pollution from runoff should agricultural lands become flooded or inundated due to sea level rise.

D.4a **Minimize water quality impacts from flooding of agricultural lands**: Agricultural practices that are designed to minimize water quality impacts, such as those designed to minimize runoff, may need to be updated or enhanced to ensure water quality protection if sea level rise results in more frequent flooding of agricultural lands.

D.4b **Add policies to address saltwater intrusion**: Add policies to protect water supply for priority coastal agriculture, including policies to address saltwater intrusion, such as limits on groundwater withdrawal or diversification of water supplies. Strategies to pump freshwater and/or highly treated wastewater into aquifers to reduce saltwater intrusion should be minimized in areas with limited freshwater resources.

Goal: Promote water conservation efforts

D.5 Maximize water conservation to protect priority agricultural water supplies: Saltwater intrusion and other climate change impacts may result in reduced water availability. LCP policies should be updated to establish or enhance standards related to water conservation and/or to identify opportunities for water recycling, dual plumbing systems, and the like. For more information on options such as relocating wells and reducing pumping in sensitive aquifers, see the following section on Water Quality and Water Control Management.

D.6 Identify alternate water sources for agriculture: Establish a program to identify alternate water sources for agriculture.

E. Water Quality and Supply

The main water quality protection policy of the Coastal Act requires minimizing the adverse effects of wastewater discharges, runoff, and groundwater depletion in order to protect the biological productivity and quality of coastal waters, as described in Section 30231. The main goals related to water quality include:

- Control runoff and stormwater pollution
- Minimize adverse effects of wastewater discharges and entrainment
- Prevent depletion of groundwater supplies from saltwater intrusion
- Improve long-term water quality through research

Chapter 3 of the Guidance covers the impacts to coastal waters from increased runoff, wastewater discharge and saltwater intrusion into groundwater sources from sea level rise. Adaptation options have been developed to limit the amount of pollutants that enter coastal waters through runoff or discharges.

Goal: Control runoff and stormwater pollution

E.1 **Update water quality Best Management Practices (BMPs)**: Evaluate and update BMPs to account for changes in water quality and supply issues due to sea level rise, as applicable. Updates could include practices to provide greater infiltration/inflow of rainwater, increased stormwater capture and/or water recycling programs, the use of low impact development, improved maintenance procedures for public sewer mains, policies to address impaired private sewer laterals, and other proactive measures.

E.2 **Include sea level rise in stormwater management plans and actions**: Control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff. LCPs should include sea level rise and extreme storms in stormwater management plans and actions. CDPs for stormwater infrastructure should consider sea level rise.

E.2a **Increase capacity of stormwater infrastructure**: Actions to reduce impacts from higher water levels could include widening drainage ditches, improving carrying and storage capacity of tidally-influenced streams, installing larger pipes and culverts, adding pumps, converting culverts to bridges, creating retention and detention basins, and developing contingency plans for extreme events. Encouraging and supporting these types of efforts upstream may also be important.

E.2b **Use green stormwater infrastructure to the maximum extent feasible**: Employ natural, on-site drainage strategies to minimize the amount of stormwater that flows into pipes or conveyance systems. These strategies include low impact development, green roofs, permeable pavements, bioretention (*e.g.*, vegetated swales, rain gardens) and cisterns. LCPs can include policies that require green infrastructure be used whenever possible *in lieu* of hard structures. Incorporate sea level rise and extreme storms into the design.

E.2c **Retrofit existing development with inadequate stormwater infrastructure**: Identify and prioritize development in low-lying or other at-risk areas with inadequate stormwater infrastructure and take steps to retrofit these systems to better accommodate sea level rise driven changes. Retrofits should incorporate the green infrastructure options detailed in strategy E.2c above as applicable.

Goal: Minimize adverse effects of wastewater discharges and entrainment

E.3 Add policies to address water quality risks from wastewater treatment plants, septic systems, and ocean outfalls: Consider establishing a program to retrofit, relocate, or eliminate ocean outfalls and other wastewater infrastructure deemed at risk. Alternatives include modifications to outfall lines, the use of green infrastructure, and redesign of waste and stormwater systems.

E.3a **Update siting and design policies**: Add policies to ensure that new ocean outfalls, wastewater treatment facilities, and other facilities that could negatively impact water quality if flooded or inundated, are sited and designed to minimize impacts from sea level rise. Avoid construction of new stormwater outfalls and direct stormwater to existing facilities with appropriate treatment and filtration where feasible. Where new outfalls cannot be avoided, plan, site, and design stormwater outfalls to minimize adverse impacts on coastal resources, including consolidation of existing and new outfalls where appropriate. Consolidate new and existing outfalls where appropriate.

E.3b **Retrofit, relocate, or eliminate outfalls deemed "at risk"**: An ocean outfall is a pipeline or tunnel that discharges municipal or industrial wastewater, stormwater, combined sewer overflows, cooling water, or brine effluents from desalination plants to the sea. LCPs should identify areas where sea level rise could affect flow of wastewater from outfalls and lead to backup and inland flooding, and plans should be made to retrofit, relocate, or eliminate these outfalls to prevent damage and impacts to water quality. Additionally, CDPs for new ocean outfalls should consider sea level rise in the design.

E.3c **Reduce or find alternatives for septic systems in hazardous areas**: Flooding, inundation, and changing groundwater dynamics may result in impacts to septic systems, which rely on leach fields for dispersal of wastewater, that could cause water quality impairments. Options to reduce the potential for these impacts by redesigning or eliminating septic systems in hazardous areas should be identified. New development that will rely on septic systems should be limited in hazardous areas.

Goal: Prevent depletion of groundwater supplies from saltwater intrusion

E.4 Groundwater Management: Plan and coordinate monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of fostering long-term sustainability of the resource. The LCP can add policies that specify limits or establish other standards for the use of groundwater and sensitive aquifers. These policies should be made in accordance with other regional water planning efforts, such as Integrated Regional Water Plans as well as relevant state water policies. CDPs involving the use of groundwater should address groundwater management issues.

E.4a **Add policies to address saltwater intrusion into aquifers**: Consider adding policies that establish a long-term strategy for addressing saltwater intrusion in aquifers, including limiting development that would use sensitive aquifers as applicable. For some areas of the state, additional information is needed on the site-specific impacts of sea level rise on aquifers. For these areas, the LCP could identify the local information needs and promote the establishment of a research program to increase understanding of the vulnerability of coastal aquifers.

E.4b **Limit groundwater extraction from shallow aquifers**: Groundwater extraction from shallow aquifers can increase susceptibility to saltwater intrusion. Regulating development to limit or prevent extraction and avoid overdraft from vulnerable aquifers can reduce the impacts of saltwater intrusion and preserve fresh groundwater supplies. LCPs or CDPs can add restrictions to the use of aquifers susceptible to saltwater intrusion and can encourage measures to recharge shallow aquifers that are depleted.

E.4c **Relocate wells and water intake facilities**: Identify opportunities to relocate wells and water intake facilities away from hazards and/or areas where saltwater intrusion may be a problem.

E.4d **Restrict development of new wells in sensitive areas**: Require new water wells to be sited away from areas where saltwater intrusion could occur.

E.4e **Limit development that relies on vulnerable water supplies**: Limit or restrict new development in areas that are dependent on water supplies that are or will become susceptible to saltwater intrusion.

E.4f **Ensure adequate long term water supplies:** When siting and designing new development, ensure that adequate and sustainable water sources are available for the lifetime of the development and suitable for the intended use of the development, considering potential impacts of sea level rise and saltwater intrusion upon groundwater supplies.

Goal: Improve long-term water quality through research

E.5 Identify research and monitoring needs to more precisely understand local issues: Research programs may be established to analyze the particular local challenges related to water quality and supply as a result of sea level rise. Opportunities for innovative solutions to these challenges should be identified.

E.5a **Clearly define areas at risk**: The LCP should include an updated inventory of potential pollutant sources due to sea level rise, including toxic waste sites, ocean outfalls and wastewater treatment facilities at risk of inundation, as well as aquifers and wells at risk of saltwater intrusion. Policies may also be added to prioritize low-lying contaminated sites for remediation and restoration.

F. Archaeological and Paleontological Resources

The Coastal Act provides for the protection of archaeological and paleontological resources, stating in Section 30244 that:

> "Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required."

Chapter 3 of the Guidance discusses the impacts to archaeological and paleontological resources that might result from sea level rise. Certified LCPs should already have policies and standards to ensure that these resources are protected to the maximum extent feasible, however, such policies and standards may need to be updated to consider sea level rise hazards. The following strategies cover a range of options for addressing the identified goals of the Coastal Act.

Goal: Protect archaeological and paleontological resources

F.1 Add policies to protect archeological and paleontological resources from sea level rise: Add policies to require site-specific evaluation of potential sea level rise impacts to archeological and paleontological resources on a development site. The LCP can also add requirements that a monitoring program and plan be established as a condition of approval for development located on a site with artifacts vulnerable to sea level rise. Adaptation or protection strategies used may depend on the significance of the archaeological resources in question.

F.1a **Consult with relevant tribes for guidance:** If resources are at risk, the appropriate entity or Native American tribe(s) should be contacted to develop a coordinated management plan for artifacts. See, for example, the *California Natural Resources Agency Final Tribal Consultation Policy* for additional guidance.

F.1b **Coordinate with the State Historic Preservation Officer (SHPO):** In line with the provisions of the Coastal Act, work with the State Historic Preservation Officer to identify actions to protect archaeological and paleontological resources.

G. Scenic and Visual Resources

The scenic value of the coast is a resource of public importance. As noted in Section 30251 of the Coastal Act, development shall be sited and designed to:

> "Protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural landforms…and to restore and enhance visual quality in visually degraded areas."

As stated in Chapter 3 of the Guidance, some options to address rising sea levels, such as elevating structures or utilizing seawalls or bluff retention devices, have the potential to alter or degrade the visual character of an area. Certified LCPs should already have policies and standards to ensure scenic and visual resources are protected to the maximum extent feasible, but these may need to be updated to consider sea level rise hazards. Coastal regions with scenic overlays or designated scenic corridors, or those areas designated as scenic in the California Coastal Preservation and Recreation Plan in particular should pay close attention to actions that could be used to minimize risks to development. The following adaptation options address some of the methods for protecting the scenic qualities of the coast.

Goal: Protect views to and along the ocean and scenic coastal areas

G.1 **Establish design standards to protect visual resources**: Update and/or add design standards to ensure that adaptation measures protect visual resources while minimizing hazards. Adaptation strategies such as shoreline armoring or elevation techniques should be designed such that the visuals are subordinate to, and in character with, the surrounding visual resources of an area.

G.1a **Establish standards for the use of caissons or other means of elevating structures:** Ensure that the use of caissons or other elevation techniques do not result in negative visual impacts. Develop policies regarding where elevation of structures may be allowable, and establish standards guiding the use of these techniques. Ensure that the appearance of caissons will not detract from the scenic character of an area if or when they become visible as a result of erosion or other processes.

G.1b **Maintain height limitations in scenic areas**: Avoid modifications to height limits in scenic areas and provide for options to modify roof-lines or elevate the lowest flood elevation for flood protection in a manner that is consistent with scenic character. In some cases it may be appropriate to update height limitations to allow for elevation in response to sea level rise hazards. However, such decisions will require trade-offs and will need to strike a balance in terms of adapting to sea level rise and protecting visual resources and community character in line with the requirements of the Coastal Act.

G.1c **Develop or redevelop property to be safe from hazards without impairing scenic resources**: Emphasize the use of adaptation strategies that will not impact visual resources. Such strategies may include short-term retrofits with plans for longer term relocation or removal.

G.1d **Establish new scenic communities**: Designate areas with significant visual resources that could be negatively impacted by adaptation responses (*e.g.*, due to seawalls or "spider" homes) as scenic communities with special protections. Establish standards in LCPs to specifically protect visual resources in these areas.

Figure 25. Photo depicting protection of visual resources and public access. A seawall visually blends in with the natural bluff while surfing access is also provided at Pleasure Point, Santa Cruz (2013). (*Source:* California Coastal Records Project)

Chapter 8

Legal Context of Adaptation Planning

Land use law is dynamic and must be interpreted and applied based on case-specific factors at the time of decision. Nonetheless, sea level rise and adaptation planning raise a number of important legal issues that coastal managers should consider as they develop and apply adaptation strategies.

This section includes discussion of the legal contexts for addressing:

- Seawalls and other shoreline protective devices
- The public trust boundary
- Potential private property takings issues

Seawalls and Other Shoreline Protective Devices

Section 30235 of the Coastal Act provides that seawalls and other forms of construction that alter natural shoreline processes "shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply." Despite other Coastal Act provisions that could often serve as the basis for denial of shoreline protective devices (for example, new development requiring shoreline protection can also conflict with Coastal Act policies requiring protection of public access and recreation, coastal waters and marine resources, natural landforms, and visual resources), the Coastal Commission has interpreted Section 30235 as a more specific overriding policy that requires the approval of Coastal Development Permits for construction intended to protect coastal-dependent uses[44] or existing structures if the other requirements of Section 30235 are also satisfied.[45] The Commission thus will generally permit a shoreline protective device if (1) there is an existing structure, public beach, or coastal-dependent use that is (2) in danger from erosion; and (3) the shoreline protection is both required to address the danger (the least environmentally-damaging, feasible alternative) and (4) designed to eliminate or mitigate impacts on sand supply.

In contrast to Section 30235, Coastal Act Section 30253 requires that "new development…assure stability and structural integrity, and neither create nor contribute significantly to erosion…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 Commission has long applied this policy to implement appropriate bluff-top and shoreline setbacks for new development. Such setbacks are based on an assessment of projected erosion and related hazards at the site for the life of the proposed development and help ensure that seawalls and other protective devices that could lead to adverse impacts would not be necessary in the future.

[44] Coastal-dependent uses are those that require a site on, or adjacent to, the sea to be able to function at all. (Public Resources Code, § 30101.)

[45] Some commenters argue that because shoreline armoring often conflicts with Coastal Act policies other than Section 30235, the Commission should evaluate proposed armoring under the conflict resolution provisions of the Act. (See Public Resources Code, § 30007.5, 30200(b).) Because the conflict resolution provisions require the Commission to resolve the conflict in a manner which on balance is the most protective of significant coastal resources, this approach could result in the more frequent denial of shoreline armoring, especially when it is intended to protect residential development or other uses that the Coastal Act does not identify as priority uses.

Additionally, from its earliest days, the Commission has also required that landowners "assume the risks" of developing along shoreline and coastal bluffs where risks of coastal hazards are present. Since at least the late 1990s, the Commission has approved many new developments with required deed restrictions that specifically prohibit any future construction of shoreline protection for these developments. These deed restrictions require that property owners waive any rights that may exist for a shoreline structure under Section 30235 and thus internalize the risks of building in an inherently hazardous location. This, in turn, will protect shoreline areas with natural resources or other access, recreational, or scenic value, including as required by Section 30253. If and when the approved development is threatened by erosion and becomes uninhabitable, these deed restrictions prevent the construction of a shoreline protective device and require property owners to remove the development, as well as clean up any debris that may result from erosion undermining the development.[46]

Read together, the most reasonable and straight-forward interpretation of Coastal Act Sections 30235 and 30253 is that they evince a broad legislative intent to allow shoreline protection for development that was in existence when the Coastal Act was passed, but avoid such protective structures for new development now subject to the Act. In this way, the Coastal Act's broad purpose to protect natural shoreline resources and public access and recreation would be implemented to the maximum extent when new, yet-to-be-entitled development was being considered, while shoreline development that was already entitled in 1976 would be "grandfathered" and allowed to protect itself from shoreline hazards if it otherwise met Coastal Act tests even if this resulted in adverse resource impacts. Such grandfathering of existing conditions is common when new land use and resource protection policies are put in place, and the existing development becomes "non-conforming."

Even still, in the case of Coastal Act Section 30235, existing development is only entitled to shoreline protection if it is in fact in danger, and the proposed shoreline protection is the least environmentally-damaging alternative to abate such danger. It may be that in certain circumstances existing development can be modified or feasibly relocated, or that other non-structural alternatives such as reducing blufftop irrigation or pursuing beach replenishment, may effectively address the risk to the development without the need for a shoreline protective device.

In practice, implementing Sections 30235 and 30253 has been challenging because many urban areas are made up of both developed and undeveloped lots. In addition, many developments in existence in 1976 have since been "redeveloped" through renovations, remodeling, additions, and complete demolition and rebuild. The reality of effective shoreline management is that the Coastal Act and LCPs must address and be applied to a wide variety of physical and legal circumstances that may not be addressed by a simple application of the clean Coastal Act distinction between existing development that may be entitled to shoreline protection and new development that is not. In some urban areas, for example, one may find intermingled shoreline developments that pre-date the Coastal Act, both with and without shoreline protection, post-Coastal Act developments approved by the Coastal Commission or local governments pursuant to an LCP that theoretically won't need shoreline protection (though some may have it), and

[46] This legal instrument is not an easement but it does provide for "planned retreat" into the future as a site erodes. Once a development is removed, a site may have potential for new development if it is once again set back and restricted against future shoreline protection device construction.

developments that may have pre-dated the Coastal Act but that were redeveloped pursuant to a coastal development permit. Moreover, some of the post-Coastal Act developments may have conditions that prohibit shoreline protection while adjacent properties may be eligible for or have a protective device because they pre-date the Act.

For purposes of implementing this Guidance, it is important that local governments, property owners, development applicants, and others take full advantage of available legal tools to mitigate hazards and protect resources, but to do so in way that considers the specific legal context and circumstances of LCP updates and individual development decisions in context and on a case-by-case basis. For example, although the Coastal Act does not explicitly define what qualifies as an "existing structure" for the purposes of Section 30235, how this term is interpreted in specific cases and through LCPs may be critical to the success of an adaptation strategy over the long-run.

The Commission has relatively infrequently evaluated whether structures built after 1976 should be treated as "existing" and thus entitled to shoreline protection pursuant to Section 30235. When it has, the shoreline protection being proposed to protect the structure has often also been identified as necessary to protect adjacent pre-Coastal Act structures.[47] In a few instances, however, the Commission has treated structures built after 1976 as existing structures entitled to shoreline protection even if no adjacent pre-Coastal Act structure also needed protection. Nonetheless, going forward, the Commission recommends the rebuttable presumption that structures built after 1976 pursuant to a coastal development permit are not "existing" as that term was originally intended relative to applications for shoreline protective devices, and that the details of any prior coastal development approvals should be fully understood before concluding that a development is entitled to shoreline protection under Section 30235.

As mentioned, in order to find new development consistent with Section 30253 or related LCP requirements and to limit the potential proliferation of armoring to protect newly approved structures, the Commission has long used setbacks, assumption of risk conditions and, over the last 15-20 years, generally required that applicants proposing new development in hazardous shoreline locations waive any rights under Section 30235 (or related LCP policies) to build shoreline protection for the proposed new development. Notably, no appellate decision addresses whether the term "existing structures" in this context includes only structures built prior to the Coastal Act or instead includes structures in existence at the time the Commission acts on an application for shoreline protection, or otherwise addresses the interplay between 30235 and 30253.

LCP updates are an opportunity to clarify how the distinction between existing and new development will be applied in specific areas, and some LCP's have already done so. For example, local governments have sometimes specified a date by which a structure must have been constructed in order to qualify as an "existing structure" for the purpose of evaluating whether it may be eligible for shoreline protection. In Marin County, the Local Coastal Program

[47] For example, CDP A-3-CAP-99-023-A1, *Swan and Green Valley Corporation Seawall*. In this situation, repairs to maintain a seawall fronting the pre-coastal Swan Residence could only be undertaken by encroachment onto the adjacent property, Green Valley Corporation; however, the Green Valley Corporation development had been approved with a condition to prohibit any future shore protection.

policy that implements Section 30235 specifies that existing structures are those that existed on the date the LCP was originally adopted (May 13, 1982). LCPs can also codify the prohibition on shoreline protective devices for new development, such as the following provision from the San Luis Obispo County North Coast Area Plan standard:

> ***Seawall Prohibition***. *Shoreline and bluff protection structures shall not be permitted to protect new development. All permits for development on blufftop or shoreline lots that do not have a legally established shoreline protection structure shall be conditioned to require that prior to issuance of any grading or construction permits, the property owner record a deed restriction against the property that ensures that no shoreline protection structure shall be proposed or constructed to protect the development, and which expressly waives any future right to construct such devices that may exist pursuant to Public Resources Code Section 30235 and the San Luis Obispo County certified LCP.*[48]

The distinction between existing and new development inherent in the Coastal Act is often directly raised by proposals for redevelopment as well. This Guidance thus deals directly with potential approaches for managing shoreline hazards and protecting coastal resources as shorelines are redeveloped (see Chapter 7, Strategy A.13). Most recently, the Commission approved a Land Use Plan for the City of Solana Beach that includes many policies designed to address the existing residential development pattern along the high, eroding bluffs of the City. Although further elaboration is yet to come through the City's work on the Implementation Plan, the Solana Beach LUP is a good example of an effort to pragmatically address the need to mitigate the risks to residential development, provide for some redevelopment potential while moving the line of new development inland, avoid and minimize new bluff protection and seawalls, and perhaps remove protective devices in the future to minimize impacts to natural landforms and to protect the beach for long-term public use.

Local governments and other shoreline managers should also take into account that although a public agency may not deny a Coastal Development Permit for a shoreline protective device that meets all of the tests under Section 30235 and equivalent LCP policies, this does not limit the authority of public agencies to refuse to allow construction of shoreline protective devices pursuant to some authority other than the Coastal Act. For example, if a private property owner requests permission from a public agency to build a structure on that agency's property (such as a local or State park or public beach) to protect adjacent private property, the public agency would generally have the authority as the landowner not to agree to the encroachment. Similarly, agencies that are trustees of public trust lands (such as the State Lands Commission and Port Districts) have the authority to prohibit structures that are not consistent with public trust uses and prioritized public trust needs, values, and principles. Public trust uses include maritime commerce, navigation, fishing, boating, water-oriented recreation, and environmental preservation and restoration, but do not typically include non-water dependent uses such as residential or general commercial and office uses. Thus, trustee agencies have the authority to refuse to allow, or to require removal of, shoreline armoring located on public trust lands, including if that armoring unreasonably interferes with public trust uses.

[48] Community-wide standard 15C.

Approval of a Coastal Development Permit for shoreline armoring under Section 30235 may be unavoidable in certain circumstances. Nonetheless, the construction of shoreline armoring will often cause impacts inconsistent with other Coastal Act requirements, including Section 30235's requirement that a shoreline protective device be the least-environmentally damaging, feasible alternative for addressing shoreline hazards. For example, as discussed above, Section 30253(b) prohibits *new development* from in any way requiring the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs. Shoreline protective devices can also adversely affect a wide range of other coastal resources and uses that the Coastal Act protects. They often impede or degrade public access and recreation along the shoreline by occupying beach area or tidelands, by reducing shoreline sand supply, and by fixing the back of the beach, ultimately leading to the loss of the beach. Shoreline protection structures thus raise serious concerns regarding consistency with the public access and recreation policies of the Coastal Act. Such structures can fill coastal waters or tidelands and harm marine resources and biological productivity in conflict with Sections 30230, 30231, and 30233. They often degrade the scenic qualities of coastal areas and alter natural landforms in conflict with Section 30251. Finally, by halting shoreline erosion, they can prevent the inland migration of intertidal habitat, salt marshes, beaches, and other low-lying habitats that rising sea levels will inundate.

Even when an agency approves a Coastal Development Permit for shoreline armoring, the agency has the authority to impose conditions to mitigate impacts on shoreline sand supply and to minimize adverse impacts on other coastal resources. (See *Ocean Harbor House Homeowners Assn. v. California Coastal Comm.* (2008) 163 Cal.App.4th 215, 242; Public Resources Code, §30607.)[49] Any approved shoreline structure, therefore, must avoid or mitigate impacts that are inconsistent with Coastal Act policies.

Because of the wide range of adverse effects that shoreline protective devices typically have on coastal resources, this Guidance recommends avoidance of hard shoreline armoring whenever possible. This can entail denying development in hazardous locations, allowing only development that is easily removable as the shoreline erodes, or requiring new development to be set back far enough from wave runup zones or eroding bluff edges so that the development will not need shoreline armoring during its anticipated lifetime. The Commission's practice when reviewing proposed development in shoreline locations that are potentially vulnerable to shoreline erosion, wave runup, or inundation has been to require applicants to waive rights to shoreline protective devices in the future, and, more recently, to require relocation and/or removal should such development become endangered in the future. See Chapter 7: Adaptation Strategies for further details regarding alternatives to the use of hard armoring structures.

PUBLIC TRUST BOUNDARY

The State of California acquired sovereign ownership of all tidelands and submerged lands and beds of navigable waterways upon its admission to the United States in 1850. The State holds and manages these lands for the benefit of all people of the State for statewide purposes consistent with the common law Public Trust Doctrine ("public trust"). The public trust ensures that title to sovereign land is held by the State in trust for the people of the State. Public trust

[49] Indeed, as noted above, 30235 itself clarifies that even when approvable, such structures should be designed to eliminate or mitigate any adverse impacts on local shoreline sand supply.

uses include maritime commerce, navigation, fishing, boating, water-oriented recreation, visitor-serving facilities and environmental preservation and restoration. Non-water dependent uses such as residential and general office or commercial uses are generally inconsistent with public trust protections and do not qualify as public trust uses.

In coastal areas, the landward location and extent of the State's sovereign fee ownership of these public trust lands are generally defined by reference to the ordinary high water mark (Civil Code §670), as measured by the mean high tide line (*Borax Consolidated v. City of Los Angeles* (1935) 210 U.S. 10); these boundaries remain ambulatory, except where there has been fill or artificial accretion. More specifically, in areas unaffected by fill or artificial accretion, the ordinary high water mark and the mean high tide line will generally be the same. In areas where there has been fill or artificial accretion, the ordinary high water mark (and the state's public trust ownership) is generally defined as the location of the mean high tide line just prior to the fill or artificial influence. It is important to note that such boundaries may not be readily apparent from present day site inspections (*Carpenter v. City of Santa Monica* (1944) 63 C. A. 2nd 772, 787).

The mean high tide line is the intersection of the shoreline with the elevation of the average of all high tides calculated over an 18.6-year tidal epoch. This property line is referred to as "ambulatory" for two reasons: first, gradual changes to the shoreline due to factors such as variations in the height and width of sandy beaches, shoreline erosion or accretion, and uplift or subsidence of land can change the location of where the mean high tide line meets the shoreline. Second, the elevation of the mean high tide line itself changes over time and is likely to increase at an accelerating rate in the future due to sea level rise. Over time, sea level rise will continue to gradually cause the public trust boundary to move inland. Boundaries between publicly-owned waterways and adjoining private properties (referred to as *littoral* along lakes and seas and *riparian* along rivers and streams) have always been subject to the forces of nature and property boundary law reflects these realities.

Accelerating sea level rise will likely lead to more disputes regarding the location of property boundaries along the shoreline, since lands that were previously landward of the mean high tide line have become subject to the State's ownership and protections of the public trust. These disputes, in turn, will affect determinations regarding what kinds of structures and uses may be allowed or maintained in areas that, because of sea level rise, either are already seaward of the mean high tide line, are likely to become seaward of the mean high tide line in the future, or would be seaward of the mean high tide line if it were not for artificial alterations to the shoreline.

California case law does not explicitly address how shoreline structures such as seawalls that artificially fix the shoreline temporarily and prevent inland movement of the mean high tide line affect property boundaries, if at all. The Ninth Circuit Court of Appeals, however, has interpreted federal common law as allowing the owner of tidelands to bring a trespass action against a neighboring upland property owner who built a revetment that prevented the natural inland movement of the mean high tide line. The court ruled that the actual property boundary was where the mean high tide line would have been if the revetment were not there and that the owner of the tidelands could require the upland owners to remove the portions of the revetment that were no longer located on the upland owners' properties. (*United States v. Milner* (9th Cir. 2009) 583 F.3d 1174, 1189-1190.)

Potential Private Property Takings Issues

The United States and California constitutions prohibit public agencies from taking private property for public use without just compensation. Section 30010 of the Coastal Act similarly prohibits public agencies implementing the Coastal Act from granting or denying a permit in a manner that takes or damages private property for public use without payment of just compensation. The classic "takings" scenario arises when a public agency acquires title to private property in order to build a public facility or otherwise devote the property to public use. In 1922, however, the United States Supreme Court ruled that regulation of private property can constitute a taking even if the regulation does not involve acquisition of title to the property. As Justice Oliver Wendell Holmes stated, "while property may be regulated to a certain extent, if regulation goes too far it will be recognized as a taking," (*Pennsylvania Coal Co. v. Mahon* (1922) 260 U.S. 393, 415.)

Courts have struggled in the 90 years since then to give agencies and property owners a more definite sense of exactly when a regulation "goes too far." The Supreme Court has identified three basic categories of takings that can occur in the context of land use regulation. Different legal standards apply depending on what kind of taking is at issue. (See, generally, *Lingle v. Chevron USA, Inc.* (2005) 544 U.S. 528).

The most straightforward test applies to what is variously called a categorical, total, *per se,* or *"Lucas"* takings, which occurs when a regulation deprives an owner of all economically beneficial use of the property. (See *Lucas v. South Carolina Coastal Council* (1992) 505 U.S. 1003). An agency that completely deprives a property owner of all economically beneficial use of the property will likely be found liable for a taking unless background principles of nuisance or property law independently restrict the owner's intended use of the property. Courts have generally been very strict about when they apply this test. If any economically beneficial use remains after application of the regulation, even if the value of that use is a very small percentage of the value of the property absent the regulatory restriction, a *Lucas* taking has not occurred.

Where a regulation significantly reduces the value of private property but does not completely deprive the owner of all economically beneficial use, the multi-factor "*Penn-Central"* test applies (*Penn Central Transportation Co. v. City of New York* (1978) 438 U.S. 104). This test has no set formula, but the primary factors include the economic impact of the regulation, the extent to which the regulation interferes with distinct, reasonable investment-backed expectations, and the character of the governmental action. When evaluating the character of the governmental action, courts consider whether the regulation amounts to a physical invasion or instead more generally affects property interests through a program that adjusts the burdens and benefits of economic life for the common good. Whether a regulation was in effect at the time an owner acquired title is also a relevant factor, but is not by itself dispositive. (See *Palazzolo v. Rhode Island* (2001) 533 U.S. 606, 632-633 (O'Connor, J., concurring)). Because this test takes such a wide range of factors into account, caselaw does not provide clear guidance about the situations in which a regulation is likely to qualify as a "*Penn-Central"* taking. A *Penn-Central* claim is unlikely to succeed, however, unless the plaintiff can establish that the regulation very substantially reduces the value of the property.

The third category of takings claims applies to "exactions," that is, government permitting decisions that require a property owner either to convey a property interest or to pay a mitigation fee as a condition of approval. (See *Nollan v. California Coastal Comm.* (1987) 483 U.S. 825; *Dolan v. City of Tigard* (1994) 512 U.S. 374; *Koontz v. St. Johns River Water Management Dist.* (2013) 133 S.Ct. 2586). Under the *Nollan/Dolan* line of cases, the agency must establish a "nexus" between the condition requiring a property interest or payment and the effects of the project that that property interest or payment is mitigating. That property interest or payment must also be roughly proportional to the impact that it is intended to mitigate. In California, the *Ocean Harbor House* case is a good example of a shoreline structure impact mitigation requirement that was found by the courts to meet the relevant standards of nexus and proportionality.

Various recommendations of this Guidance may potentially give rise to takings concerns. Because the determination of whether a particular regulation may in some circumstances be applied in a way that constitutes a taking is so fact-intensive and context-specific, this Guidance cannot provide a simple set of parameters for when agencies should either allow exceptions to a land use regulation or consider purchasing a property interest. That said, land use restrictions that prevent all economically beneficial use of the entirety of a property[50] are vulnerable to *Lucas* takings claims unless those uses would qualify as a nuisance or are prohibited by property law principles such as the public trust doctrine. Agencies can minimize the risk of these claims by allowing economically beneficial uses on some of the property and by exploring whether legal doctrines regarding nuisance, changing shoreline property lines, or the public trust independently allow for significant limitations on the use of the property. Establishing a transferrable development rights program for properties that are subject to significant development restrictions may also minimize potential exposure to takings claims.

Where a proposed development would be safe from hazards related to sea level rise in the near future, but cannot be sited so as to avoid those risks for the expected life of the structure, agencies may consider allowing the structure, but requiring removal once it is threatened. Property owners may argue that they have a right to protect threatened structures even if they have waived rights to shoreline protection under the Coastal Act, but a recent federal court of appeal ruling casts significant doubt on the existence of any common law right to attempt to fix an ambulatory shoreline boundary through artificial structures such as seawalls (see *United States v. Milner* (9th Cir. 2009) 583 F.3d 1174, 1189-1190).

If an agency is contemplating requiring property owners to dedicate open space easements or other property interests or requiring the payment of fees to mitigate project impacts, the agency should be careful to adopt findings explaining how requiring the property interest or payment is

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50 What qualifies as the entirety of a property can also be the subject of dispute. The property will normally include all legal lots on which the proposed development would be located, but can also include other lots that are in common ownership and adjacent to, or in close proximity with, the lots that would be developed. (See *Norman v. United States* (Fed. Cir. 2005) 429 F.3d 1081, 1091; *District Intown Properties Limited Partnership v. District of Columbia* (D.C. Cir. 1999) 198 F.3d 874, 880.).

both logically related to mitigating an adverse impact of the project and roughly proportional to that impact. Legislatively adopting rules that establish the exact criteria for determining when to require these exactions and, if so, their magnitude, may also reduce an agency's exposure to takings claims.[51] With respect to mitigation fees, California cities and counties should also comply with applicable requirements of the Mitigation Fee Act (Government Code, §66000 *et seq.*).

[51] The California Supreme Court has ruled that courts should be more deferential towards agencies when reviewing fees imposed pursuant to legislatively enacted rules of general applicability than when reviewing fees imposed on an ad hoc basis. (*Ehrlich v. City of Culver City* (1996) 12 Cal.4th 854, 881.) The rationale is that fees imposed pursuant to rules of general applicability that involve little discretion are less likely to impose disproportionate burdens on property owners than fees determined on an ad hoc basis.

Chapter 9

Next Steps

CURRENT AND FUTURE COASTAL COMMISSION EFFORTS:

The Commission has a Strategic Plan for 2013-2018 (2013a) that identifies many action items that the Commission or partner organizations plan to take to address the challenges of sea level rise and climate change. The first priority in the Strategic Plan is for the Commission to adopt Sea Level Rise Policy Guidance for use in Local Coastal Program (LCP) planning and project design (Action 3.1.1), and this Guidance reflects significant progress toward accomplishing this task. The objectives and action items from the Strategic Plan related to sea level rise and climate change are presented within the following pages.

The Commission is also involved in a number of other efforts that meet the climate change planning goals laid out in its Strategic Plan. These include efforts related to the Commission's normal operating business, such as ongoing coordination with local government partners and other agencies, as well as specially funded projects designed to meet specific needs. Several of these efforts that are currently underway or that staff identified as next steps during the completion of this Guidance document are listed below. The Commission anticipates that these items will be completed over the next two to five years, in coordination with other relevant partners and research institutions, as staff capacity and funding allows.

1. **Continue an active program of public outreach on sea level rise.** The Commission will strive to provide public information about sea level rise issues through public workshops, the Commission's website, meetings, outreach, and our public education program. The Commission will work to enhance efforts to coordinate with low-income and underserved populations and communities.

2. **Develop methods for quantifying impacts to coastal resources from shoreline armoring projects.** The Coastal Commission staff has initiated a Project of Special Merit (funded by NOAA) to build upon the Commission's existing efforts to mitigate for the adverse impacts of shoreline development projects to public access and recreation by working with beach ecologists and a valuation economist to develop a method to quantify impacts to biological resources and beach ecology. The final product is anticipated to be a set of guidelines to use in assessing the impacts of proposed shoreline armoring projects and a method(s) for calculating the full value of recreational and ecological loss resulting from installation of shoreline armoring projects (where they may be approved as consistent with the Coastal Act).

3. **Adopt policy guidance and model ordinance language for resilient shoreline residential development in hazardous areas affected by sea level rise.** Under another NOAA-funded Project of Special Merit, the Coastal Commission will conduct a statewide survey to characterize physical shoreline conditions for residential areas along the coast. Informed by this assessment, staff will identify and analyze policy and legal issues for development and redevelopment in hazardous areas, factoring in sea level rise projections that will change shoreline conditions over time. Working collaboratively with local governments, staff will use the policy and legal analysis to develop policy guidance and model ordinance language. The project will build upon this Guidance and is consistent with the Coastal Commission's Strategic Plan goals.

4. **Enhance coordination and planning efforts related to developing adaptation strategies for critical infrastructure.** Addressing sea level rise impacts to critical infrastructure is particularly complex and will require greater amounts of planning time, stakeholder input, and funding. The Commission will support planning efforts in a number of ways including, for example:
    a. Providing guidance or participating in working groups that examine managed retreat of critical infrastructure, including when to consider managed retreat rather than continue with repairs and maintenance in light of sea level rise.
    b. Coordinating closely with Caltrans to address transportation issues. Planning efforts may include integrating LCP planning and regional transportation planning processes; coordinating and supporting phased approaches for realignment projects; and identifying priorities for adaption response.
    c. Coordinating with port and harbor authorities and other relevant stakeholders to address vulnerabilities specific to ports, harbors, fisheries, and navigation, and to develop and enhance adaptation strategies that are particularly applicable for coastal-dependent infrastructure and other port needs.
    d. Coordinating with the State and Regional Water Quality Control Boards to consider vulnerability issues related to water supply and wastewater capacity infrastructure in California.

5. **Consider producing additional guidance documents, including**:
    a. Broader climate change guidance addressing other climate change impacts to the coastal zone.
    b. One-page fact sheets on some adaptation measures such as green infrastructure and conservation easements.
    c. Guidance on the use of 'living shorelines', dune management, beach nourishment, and so on for California, including an assessment of areas or coastal situations where these strategies could be effective, what they need to succeed, monitoring requirements, and maintenance.
    d. Guidance for how to address impacts to critical infrastructure, assets and resources that cross jurisdictional boundaries, and ports, harbors and other coastal-dependent resources.

6. **Implement the Coastal Commission's responsibilities under other state efforts and legislation.**
    a. Governor Brown's April 2015 Executive Order B-30-15 states that state agencies shall take climate change into account in their planning and investment decisions, and employ full life-cycle cost accounting to evaluate and compare infrastructure investments and alternatives. The order requires agencies to ensure that priority is given to actions that build climate preparedness and reduce greenhouse gas emissions, provide flexible and adaptive approaches, protect the state's most vulnerable

populations, and promote natural infrastructure solutions. The Coastal Commission will continue to integrate these principles into its planning and regulatory work.

b. AB2516, authored by Assemblymember Gordon and approved in September 2014, established a *Planning for Sea Level Rise Database* that is anticipated to be available online in early 2016. The database will provide the public with an educational tool from which to learn about the actions taken by cities, counties, regions, and various public and private entities to address sea level rise. The Coastal Commission will contribute data to this effort, including information about grant-funded LCP updates.

c. The Coastal Commission will also participate in the implementation of the 2014 *Safeguarding California* plan, along with the Ocean Protection Council's 2014 Resolution on the Implementation of the Safeguarding California Plan. Key principles are and will continue to be incorporated into Coastal Commission work, including protection of California's most vulnerable populations the integration of risk reduction with emissions reductions, and the development of metrics and indicators of progress on efforts to reduce climate risk.

Coastal Commission Strategic Plan 2013-2018 Excerpts
Actions Related to Sea Level Rise and Climate Change

GOAL 1: Maximize Public Access and Recreation

Objective 1.1 – Enhance Public Access through Updated Beach Access Assessment and Constraints Analysis

Actions:

1.1.5 Identify locations where access may be limited or eliminated in the future due to sea level rise and increased storm events and begin planning for other options such as new vertical accessways to maintain maximum beach access (see also Action 3.2.1).

Objective 1.4 – Expand the California Coastal Trail System through Enhanced Planning and Implementation

Actions:

1.4.4 Identify locations of the CCT that might be at risk from rising sea level and increased storm events and begin planning for trail relocations or other alternatives to insure continued functionality of the CCT (see also Action 3.2.1).

GOAL 3: Address Climate Change through LCP Planning, Coastal Permitting, Inter-Agency Collaboration, and Public Education

Objective 3.1 – Develop Planning and Permitting Policy Guidance for Addressing the Effects of Climate Change on Coastal Resources

Actions:

3.1.1 Adopt general sea level rise (SLR) policy guidance for use in coastal permitting and LCP planning, and amendments based on best available science, including the final report from the National Research Council of the National Academy of Science entitled *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (June 2012).

3.1.2 Based on the general SLR policy guidance, identify and develop specific regulatory guidance for addressing coastal hazards, including recommendations for analytic methods for accounting for SLR and increased storm events in project analysis, standards for redevelopment and development in hazard zones (*e.g.*, bluff top and flood zones), buffers for coastal wetlands, and policies for shoreline structure design and impact mitigation.

3.1.3 Develop a work program to produce policy guidance for coastal permitting and LCPs, to account for other climate change related impacts and adaptation planning including wetland, marine and terrestrial habitat protection, habitat migration, risk of wildfires, water supply and groundwater protection.

3.1.4 Provide public information and guidance through workshops, presentations to local government, *etc.* Assist local governments with interpretation of scientific or other technical information related to climate change and sea level rise that could be of use in adaptation planning.

3.1.5 Contribute to relevant state-wide efforts on climate change and adaptation as a member of the State's Climate Action Team – Coast and Ocean Working Group.

3.1.6 Coordinate with Natural Resources Agency, Office of Planning and Research, California Governor's Office of Emergency Services (Cal OES) and others to provide consistent guidance on climate change in updating general plans, hazard mitigation plans and other planning documents used by local governments.

3.1.7 Coordinate with the State Lands Commission to address sea level rise and shoreline change and implications for the management of public trust resources.

Objective 3.2 – Assess Coastal Resource Vulnerabilities to Guide Development of Priority Coastal Adaptation Planning Strategies

Actions:

3.2.1 Conduct a broad vulnerability assessment of urban and rural areas to identify priority areas for adaptation planning, such as community development, public infrastructure, public accessways, open space or public beaches at risk from sea level rise. Identify and participate in on-going vulnerability assessments and adaptation planning efforts as feasible.

3.2.2 Work with CalTrans and other public agency partners to assess and address roadway, rail, and other transportation infrastructure vulnerabilities, particularly along Highway One and other coastal roads and highways.

3.2.3 Work with the Department of Water Resources, State Water Resources Control Board, and local agencies to assess and address water and wastewater treatment plant vulnerabilities along the coast.

3.2.4 Work with the Conservancy, California Department of Fish and Game *[sic]*, US Fish and Wildlife, and other partners to assess the vulnerability of wetlands and other sensitive habitat areas. Identify habitats that are particularly vulnerable climate change and/or habitats that may be important for future habitat migration (*e.g.*, wetland transitional areas).

3.2.5 Work with the Coastal Observing Systems, researchers, and others to identify and develop baseline monitoring elements to better understand and monitor changes in coastal conditions related to sea level rise and other climate change impacts.

3.2.6 With the Conservancy and OPC, develop and implement a competitive grant program to provide funding to selected local governments to conduct vulnerability assessments and/or technical studies that can be used to assess a community's risks from climate change and inform updates to LCPs.

ADDITIONAL RESEARCH NEEDS

Additional research is needed to more fully understand and prepare for sea level rise. The research needs are directed toward research institutions at academic, state, federal, and local levels. The Commission will strive to collaborate with and support research related to sea level rise science and adaptation, including with the efforts and ongoing work of the California Climate Change Research Plan.

1. **Modeling.** Sea level rise science is an evolving field, and new science is expected to change and refine our understanding of the dynamics of sea level rise and its associated impacts to both natural and built environments. As such, there is a continual need for models to be developed, updated, and refined to ensure that we continue to have the best understanding of sea level rise-related impacts as possible. In some cases, the modelling capabilities already exist, but there is a need for such modelling to be applied to local areas to understand specific localized impacts. Several topics in particular that are in need of better or more refined modeling include:
    a. Fluvial dynamics as they relate to and interact with rising sea levels
    b. Habitat evolution models (*e.g.*, SLAMM) that project future locations of wetlands and other coastal habitats
    c. The interaction of other climate change-related impacts with the impacts of sea level rise (*e.g.*, changing precipitation patterns, increased frequency and/or intensity of storms)

2. **Improved estimates of local vertical land motion.** Several independent processes – glacial isostatic rebound, groundwater withdrawals, plate movements and seismic activity – influence vertical land motion. Current guidance on sea level projections adjusts for large-scale vertical land motion north and south of Cape Mendocino. These adjustments do not properly address locations that are moving differently from the region, such as Humboldt Bay. A peer-reviewed methodology is needed to determine:
    a. Instances when it will be important to modify the regional sea level rise projections for local vertical land motion
    b. Types of existing information on land motion (*e.g.*, tide gauge records, satellite data, land-based GPS stations) that provide the best estimates of local land trends

c. A procedure for adjusting state or regional sea level rise projections for sub-regional or local conditions

d. Additional data that are needed to implement this procedure

3. **Baseline data and monitoring systems**. Baseline monitoring data are needed for coastal and nearshore waters, beaches, bluffs, dune systems, nearshore reefs, tide pools, wetlands, and other habitat areas to better understand these systems, monitor trends, and detect significant deviations from historic conditions that may be related to sea level rise and other aspects of climate change. Better storm event monitoring data are also needed to support refinements and calibration of models used to project and analyze impacts.

   A system for monitoring and tracking the cumulative impacts of projects in the coastal zone, including both new development and any adaptation strategies, is needed to better understand the impacts of development in the face of sea level rise and the efficacy of various adaptation methods. Monitoring systems may be needed at a variety of scales, including at the local, regional, and state level.

4. **Methods for estimating change in erosion rates and shoreline change due to future sea level rise.** There is a need for a peer-reviewed methodology for estimating change in erosion rates due to sea level rise for bluffs, beaches, and other shorelines exposed to erosion. An improved understanding of future erosion rates is necessary to better evaluate projects affected by such erosion, including in terms of calculating an appropriate setback distance.

5. **Analysis of sea level rise impacts to coastal access and recreation.** To improve public access planning efforts, more information is needed about how sea level rise could affect public access areas and recreation throughout the state, including changes to waves and surfing, and the potential economic costs of these impacts. Additional information about how these changes will affect lower-income populations and underserved communities is particularly important.

   Many currently accessible beach areas have the potential to become inaccessible due to impacts from sea level rise. Shoreline armoring and emerging headlands could isolate connected beaches with sea level rise, which will block lateral access. Rising sea level will also tend to constrict beaches that are prevented from migrating landward by shoreline armoring and development. Some blufftop trails will become inaccessible as segments of trail are lost to erosion. In addition, changes in beach conditions and sediment dynamics due to sea level rise could affect waves and surfing, as can the rise itself by potentially 'drowning out' surf spots combined with the lack of space available for these spots to move (*e.g.*, where new 'tripping' elements can be encountered in the right depth of water to create surfable waves). Research on the specifics of these impacts will help the Commission and others understand the details of the potential impacts to coastal access and recreation.

6. **Methods to evaluate impacts to coastal resources from shoreline protection.** Research is needed to develop and improve methods to evaluate and mitigate for the adverse impacts to recreation, public access and beach ecology from shoreline armoring projects. This information will be used to determine a set of mitigation options that may be considered for use when evaluating individual permit applications to offset anticipated losses to beach

ecology and resources caused by shoreline armoring projects. The Coastal Commission staff is currently working on developing resource valuation guidelines as part of a Project of Special Merit (see Coastal Commission Effort #2).

7. **Analysis of sea level rise impacts to wetlands and strategies for preserving wetlands throughout the state.** Additional research is needed to assess the vulnerability of wetlands and other sensitive habitat areas to climate change, and to identify adjacent areas that may be important for future habitat migration (*e.g.*, wetland transitional areas). Further work is also needed to develop management strategies that are adaptable to local wetland conditions and sea level rise impacts, such as the following:
    a. Methodologies for establishing natural resource area buffer widths in light of sea level rise
    b. Approaches for identifying and protecting migration corridors
    c. Guidance for increasing wetland sediment supply and retention
    d. Techniques for developing an adaptive wetland restoration plan
    e. Monitoring criteria

8. **Assessment of coastal habitat functions in light of sea level rise and other climate change impacts.** It is necessary to develop a better understanding of the value and benefits that intact natural habitats provide, especially as they relate to increasing coastal resiliency to sea level rise. In addition, further research is needed to identify the coastal habitats that are most likely to experience adverse impacts from sea level rise and extreme storms, and what the associated loss of ecosystem services will mean for coastal populations. Research is also needed to identify strategies to ameliorate the vulnerabilities.

9. **Potential effects of sea level rise on groundwater and coastal aquifers.** Additional research is needed to quantify the potential effect of sea level rise on freshwater aquifers located along the California coast, and the degree to which sea level rise could lead to new incidences of intrusion. Research should include: (a) an evaluation of the potential incidence and severity of saltwater intrusion at the scale of individual aquifers, under various sea level rise scenarios, (b) criteria to use when deciding if saltwater intrusion requires mitigation or response and (c) identification of strategies to address the impacts rising groundwater and saltwater intrusion have on agriculture.

10. **Analysis of non-environmental factors that influence sea level rise adaptation.** As suggested in a number of places throughout this Guidance, there are factors beyond just environmental concerns that will influence sea level rise planning. Such factors include environmental justice/social equity, economic, and legal considerations, among others. Understanding how these social concerns interact with environmental vulnerabilities will be important when assessing adaptation planning opportunities and challenges.

Glossary

The following terms were collected from the 2009 *California Climate Change Adaptation Strategy*[52], the Intergovernmental Panel on Climate Change Third Assessment Report[53] , the Coastal Commission's Beach Erosion and Response (BEAR) document,[54] and the California Coastal Act, unless otherwise noted. Some of these definitions are not used in the text of the report, but are included as a resource on coastal-related adaptation issues.

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.

Adaptive capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[55]

Adaptive management: Involves monitoring the results of a management decision, and updating actions as needed and as based on new information and results from the monitoring.

Ambulatory (*as used in public trust boundaries*): Moveable, subject to change, or capable of alteration.[56]

Aquifer: An underground layer of porous rock, sand, or other earth material containing water, into which wells may be sunk.

Armor: To fortify a topographical feature to protect it from erosion (*e.g.*, constructing a wall to armor the base of a sea cliff), or to construct a feature (*e.g.*, a seawall, dike, or levee) to protect other resources (*e.g.*, development or agricultural land) from flooding, erosion, or other hazards.

Atmosphere-Ocean General Circulation Models (or Atmosphere-Ocean General Climate Models; ACGOM): Three-dimensional global models that dynamically link ocean density, circulation, and sea level using wind stress, heat transfer between air and sea, and freshwater fluxes as critical variables. (See also *General Circulation Models*)

Baseline (or Reference): Any datum against which change is measured. It might be a "current baseline," in which case it represents observable, present-day conditions. It might also be a "future baseline", which is a projected future set of conditions excluding the driving factor of interest (*e.g.*, how would a sector evolve without climate warming). It is critical to be aware of what change is measured against which baseline to ensure proper interpretation. Alternative interpretations of the reference conditions can give rise to multiple baselines.[57]

[52] CNRA 2009

[53] IPCC 2001

[54] Many of these definitions were extracted from: USACE 1984, Griggs and Savoy 1985 and Flick 1994.

[55] Willows and Connell 2003

[56] *West's Encyclopedia of American Law* 2008

[57] Moser 2008

Beach: The expanse of sand, gravel, cobble or other loose material that extends landward from the low water line to the place where there is distinguishable change in physiographic form, or to the line of permanent vegetation. The seaward limit of a beach (unless specified otherwise) is the mean low water line.

Beach nourishment: Placement of sand and/or sediment (*e.g.,* beneficial re-use of dredged sediment) on a beach to provide protection from storms and erosion, to create or maintain a wide(r) beach, and/or to aid shoreline dynamics throughout the littoral cell. The project may include dunes and/or hard structures as part of the design.

Bluff (or Cliff): A scarp or steep face of rock, weathered rock, sediment and/or soil resulting from erosion, faulting, folding or excavation of the land mass. The cliff or bluff may be a simple planar or curved surface or it may be step-like in section. For purposes of (the Statewide Interpretive Guidelines), "cliff" or "bluff" is limited to those features having vertical relief of ten feet or more and "seacliff" is a cliff whose toe is or may be subject to marine erosion.

Bluff top retreat (or Cliff top retreat): The landward migration of the bluff or cliff edge, caused by marine erosion of the bluff or cliff toe and subaerial erosion of the bluff or cliff face.

Caisson: A supporting piling constructed by drilling a casing hole into a geologic formation and filling it with reinforcing bar and concrete; used for foundations. (See also *Piling*)

Climate change: Any long-term change in average climate conditions in a place or region, whether due to natural causes or as a result of human activity.

Climate variability: Variations in the mean state of the climate and other statistics (*e.g.*, standard deviations, the occurrence of extremes) on all temporal and spatial scales beyond that of individual weather events.

Coastal-dependent development or use: Any development or use which requires a site on, or adjacent to, the sea to be able to function at all.[58]

Coastal-related development: Any use that is dependent on a coastal-dependent development or use.[59]

Coastal resources: A general term used throughout the Guidance to refer to those resources addressed in Chapter 3 of the California Coastal Act, including beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities.

Development: On land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or

[58] Public Resources Code § 30101

[59] Public Resources Code § 30101.3

thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice of 1973 (commencing with Section 4511).[60]

Ecosystem-Based Management (EBM): An integrated approach to resource management that considers the entire ecosystem, including humans, and the elements that are integral to ecosystem functions.[61]

Ecosystem services: Benefits that nature provides to humans. For example, plants, animals, fungi and micro-organisms produce services or goods like food, wood and other raw materials, as well as provide essential regulating services such as pollination of crops, prevention of soil erosion and water purification, and a vast array of cultural services, like recreation and a sense of place.[62]

Emissions scenarios: Scenarios representing alternative rates of global greenhouse gas emissions growth, which are dependent on rates of economic growth, the success of emission reduction strategies, and rates of clean technology development and diffusion, among other factors.[63]

Environmentally Sensitive [Habitat] Area (ESHA): Any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.[64]

Erosion: The wearing away of land by natural forces; on a beach, the carrying away of beach material by wave action, currents, or the wind. Development and other non-natural forces (*e.g.,* water leaking from pipes or scour caused by wave action against a seawall) may create or worse erosion problems.

Eustatic: Refers to worldwide changes in sea level.

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[60] Public Resources Code § 30106

[61] NOC 2011

[62] Hassan *et al.* 2005

[63] Bedsworth and Hanak 2008

[64] Public Resources Code § 30107.5

Feasible (*as used in "least environmentally damaging feasible alternative"*): Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.[65]

Flood (or Flooding): Refers to normally dry land becoming temporarily covered in water, either periodically (*e.g.*, tidal flooding) or episodically (*e.g.*, storm or tsunami flooding).[66]

General Circulation Models (or General Climate Models; GCM): A global, three-dimensional computer model of the climate system which can be used to simulate human-induced climate change. GCMs are highly complex and they represent the effects of such factors as reflective and absorptive properties of atmospheric water vapor, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures and ice boundaries. The most recent GCMs include global representations of the atmosphere, oceans, and land surface.[67] (See also *Atmospheric-Ocean General Circulation Models*)

Green infrastructure: Refers to the use of vegetative planting, dune management, beach nourishment or other methods that mimic natural systems to capitalize on the ability of these systems to provide flood and erosion protection, stormwater management, and other ecosystem services while also contributing to the enhancement or creation of natural habitat areas.

Greenhouse gases (GHGs): Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride.[68]

Hard protection: A broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. (See also *Revetment, Seawall, Shoreline protective devices*)

Impact assessment: The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Inundation: The process of dry land becoming permanently drowned or submerged, such as from dam construction or from sea level rise.[69]

Local Coastal Program (LCP): A local government's (a) land use plans, (b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of, this division at the local level.[70]

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[65] California Coastal Act § 30108

[66] Flick *et al.* 2012

[67] NASA Earth Observatory Glossary

[68] UNFCCC 2004

[69] Flick *et al.* 2012

[70] Public Resources Code § 30108.6

Mean sea level: The average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides. Relative sea level is sea level measured by a tide gauge with respect to the land upon which it is situated. (See also *Sea level change/sea level rise*)

Mitigation (*as used in climate science*): A set of policies and programs designed to reduce emissions of greenhouse gases.[71]

Mitigation (*as used in resource management*): Projects or programs intended to offset impacts to resources.

Monitoring: Systematic collection of physical, biological, chemical, or economic data, or a combination of these data on a project in order to make decisions regarding project operation or to evaluate project performance.

Passive erosion: The process whereby erosion causes the shoreline to retreat and migrate landward of any hardened structures that have fixed the location of the back beach therefore resulting in the gradual loss of beach in front of the hardened structure.

Permit: Any license, certificate, approval, or other entitlement for use granted or denied by any public agency which is subject to the provisions of this division.[72]

Piling (or Pile): A long, heavy timber or section of concrete or metal driven or drilled into the earth or seabed to serve as a support or protection. (See also *Caisson*)

Potential impacts: All impacts that may occur given a projected change in climate, including impacts that may result from adaptation measures.

Public Trust Lands: All lands subject to the Common Law Public Trust for commerce, navigation, fisheries, recreation, and other public purposes. Public Trust Lands include tidelands, submerged lands, the beds of navigable lakes and rivers, and historic tidelands and submerged lands that are presently filled or reclaimed and which were subject to the Public Trust at any time.[73] (See also *Tidelands, Submerged lands*)

Radiative forcing: Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. In [the IPCC] report radiative forcing values are for changes relative to pre-industrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2).[74]

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[71] Luers and Moser 2006

[72] Public Resources Code § 30110

[73] Public Resources Code § 13577

[74] IPCC 2007

Redevelopment: At a minimum, replacement of 50% or more of an existing structure. LCPs may also consider including limits on the extent of replacement of major structural components such as the foundation or exterior walls, or improvements costing more than 50% of the assessed or appraised value of the existing structure**.**

Revetment: A sloped retaining wall; a facing of stone, concrete, blocks, rip-rap, *etc.* built to protect an embankment, bluff, or development against erosion by wave action and currents. (See also *Hard protection, Seawall, Shoreline protective devices*)

Risk: Commonly considered to be the combination of the likelihood of an event and its consequences – *i.e.*, risk equals the probability of climate hazard occurring multiplied the consequences a given system may experience.[75]

Scenario-based analysis: A tool for developing a science-based decision-making framework to address environmental uncertainty. In general, a range of plausible impacts based on multiple time scales, emissions scenarios, or other factors is developed to inform further decision-making regarding the range of impacts and vulnerabilities.[76]

Sea level: The height of the ocean relative to land; tides, wind, atmospheric pressure changes, heating, cooling, and other factors cause sea level changes.

Sea level change/sea level rise: Sea level can change, both globally and locally, due to (a) changes in the shape of the ocean basins, (b) changes in the total mass of water and (c) changes in water density. Factors leading to sea level rise under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes. Relative sea level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence.[77] (See also *Mean sea level*, *Thermal expansion*)

Sea level rise impact: An effect of sea level rise on the structure or function of a system.[78]

Seawall: A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. It is usually a vertical wood or concrete wall as opposed to a sloped revetment. (See also *Hard protection, Revetment, Shoreline protective devices*)

Sediment: Grains of soil, sand, or rock that have been transported from one location and deposited at another.

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[75] Burton *et al.* 2004

[76] NOAA 2010

[77] IPCC 2007

[78] PCGCC 2007

Sediment management: The system-based approach to the management of coastal, nearshore and estuarine sediments through activities that affect the transport, removal and deposition of sediment to achieve balanced and sustainable solutions to sediment related needs.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (*e.g.*, a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (*e.g.*, climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).

Shore protection: Structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.

Shoreline protective devices: A broad term for constructed features such as seawalls, revetments, riprap, earthen berms, cave fills, and bulkheads that block the landward retreat of the shoreline and are used to protect structures or other features from erosion and other hazards. (See also *Hard protection, Revetment, Seawall*)

Still water level: The elevation that the surface of the water would assume if all wave action were absent.

Storm surge: A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in water level due to atmospheric pressure reduction as well as that due to wind stress.

Submerged lands: Lands which lie below the line of mean low tide.[79] (See also *Public Trust Lands*, *Tidelands*)

Subsidence: Sinking or down-warping of a part of the earth's surface; can result from seismic activity, changes in loadings on the earth's surface, fluid extraction, or soil settlement.

Tectonic: Of or relating to the structure of the earth's crust and the large-scale processes that take place within it.

Thermal expansion: An increase in water volume in response to an increase in temperature, through heat transfer.

Tidal prism: The total amount of water that flows into a harbor or estuary and out again with movement of the tide, excluding any freshwater flow.

Tidal range: The vertical difference between consecutive high and low waters. The Great Diurnal Range is the difference between mean higher high water and mean lower low water; the Mean Range of tide is the difference in height between mean high water and mean low water.[80]

[79] Public Resources Code § 13577

[80] NOAA 2013

Tidelands: Lands which are located between the lines of mean high tide and mean low tide.[81] (See also *Public Trust Lands*, *Submerged lands*)

Transfer of Development Rights (TDR): A device by which the development potential of a site is severed from its title and made available for transfer to another location. The owner of a site within a transfer area may retain property ownership, but not approval to develop. The owner of a site within a receiving area may purchase transferable development rights, allowing a receptor site to be developed at a greater density.[82]

Tsunami: A long period wave, or seismic sea wave, caused by an underwater disturbance such as an earthquake, submarine landslide, or subaerial landslide (slope failure from land into a water body). Tsunamis can cause significant flooding in low-lying coastal areas and strong currents in harbors. (Commonly misnamed a *Tidal wave*)

Vulnerability: The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.

Vulnerability assessment: A practice that identifies who and what is exposed and sensitive to change and how able a given system is to cope with extremes and change. It considers the factors that expose and make people or the environment susceptible to harm and access to natural and financial resources available to cope and adapt, including the ability to self-protect, external coping mechanisms, support networks, and so on.[83]

Wave: A ridge, deformation, or undulation of the surface of a liquid. On the ocean, most waves are generated by wind and are often referred to as wind waves.

Wave height: The vertical distance from a wave trough to crest.

Wave length (or Wavelength): The horizontal distance between successive wave crests or between successive troughs of waves.

Wave period: The time for a wave crest to traverse a distance equal to one wavelength, which is the time for two successive wave crests to pass a fixed point.

Wave runup: The distance or extent that water from a breaking wave will extend up the shoreline, including up a beach, bluff, or structure.

[81] Public Resources Code § 13577

[82] Cal OPR 1987

[83] Tompkins *et al.* 2005

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Appendices

Appendices: Table of Contents

Appendix A

Sea Level Rise Science and Projections for Future Change

DRIVERS OF SEA LEVEL RISE

The main mechanisms driving increases in *global* sea level are: 1) expansion of sea water as it gets warmer (thermal expansion) and, 2) increases in the amount of water in the ocean from melting of land-based glaciers and ice sheets as well as human-induced changes in water storage and groundwater pumping (Chao *et al.* 2008; Wada *et al.* 2010; Konikow 2011).[1] The reverse processes can cause global sea level to fall.

Sea level at the *regional and local levels* often differs from the average global sea level.[2] Regional variability in sea level results from large-scale tectonics and ocean and atmospheric circulation patterns. The primary factors influencing local sea level include tides, waves, atmospheric pressure, winds, vertical land motion and short duration changes from seismic events, storms, and tsunamis. Other determinants of local sea level include changes in the ocean floor (Smith and Sandwell 1997), confluence of fresh and saltwater, and proximity to major ice sheets (Clark *et al.* 1978; Perette *et al.* 2013).

Over the long-term, sea level trends in California have generally followed global trends (Cayan *et al.* 2009; Cayan *et al.* 2012). However, global projections do not account for California's regional water levels or land level changes. California's water levels are influenced by large-scale oceanographic phenomena such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), which can increase or decrease coastal water levels for extended periods of time. Figure A-1 shows how El Niño and La Niña events have corresponded to mean sea level in California in the past. California's land levels are also affected by plate tectonics and earthquakes. Changes to water as well as land levels are important factors in regionally down-scaled projections of future sea level. It follows that the sea level rise projections specific to California are more relevant to efforts in the coastal zone of California than projections of global mean sea level.

[1] Large movements of the tectonic plates have been a third major mechanism for changes in global sea level. The time periods for plate movements to significantly influence global sea level are beyond the time horizons used for even the most far-reaching land-use decisions. Plate dynamics will not be included in these discussions of changes to future sea level.

[2] For further discussion of regional sea level variations and regional sea level rise projections, see Yin *et al.* 2010, Slangen *et al.* 2012, and Levermann *et al.* 2013, as examples.

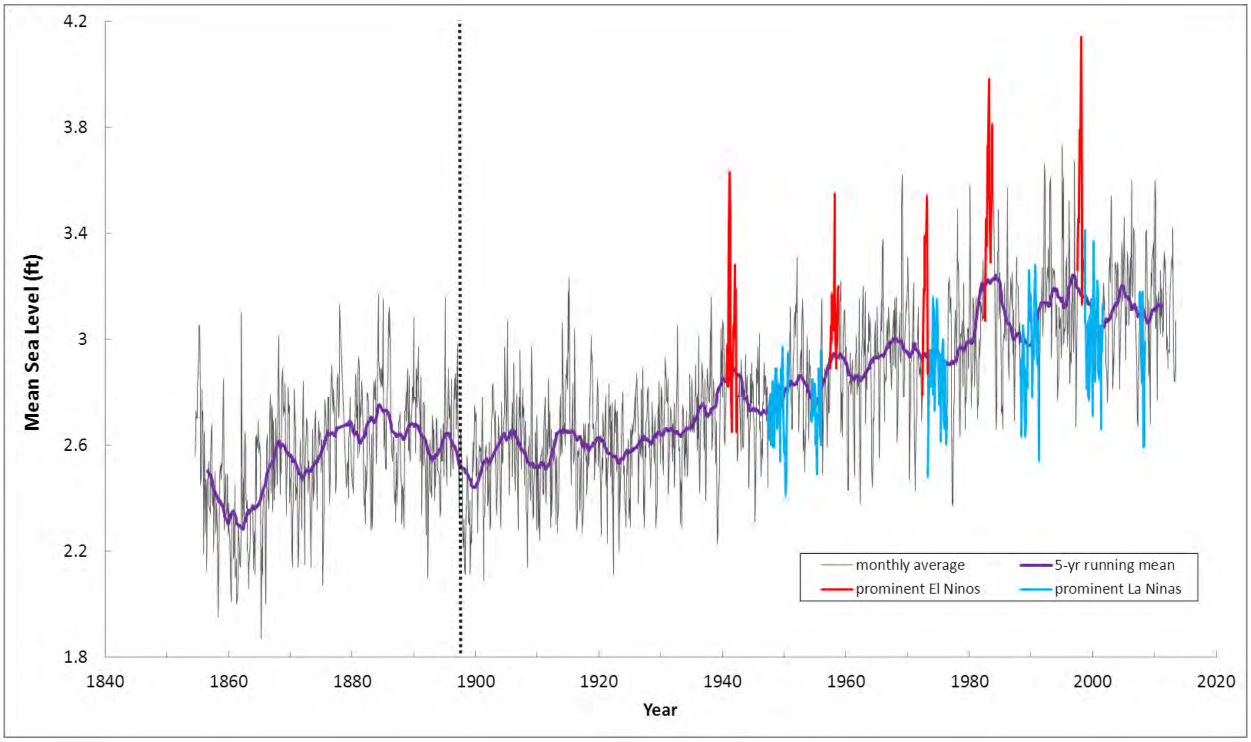

Figure A-1. Variations in monthly mean sea level at Fort Point, San Francisco, 1854 to 2013. Mean sea level heights (in ft) are relative to mean lower low water (MLLW). Purple line represents the 5-year running average. Note that the monthly mean sea level has varied greatly throughout the years and that several of the peaks occurred during strong El Niño events (red highlight). Periods of low sea level often occurred during strong La Niña events (blue highlight). The current "flat" sea level condition can also be seen in the 5-year running average. (*Sources: NOAA CO-OPS data, Station 9414290, http://tidesandcurrents.noaa.gov/ (sea level); NOAA Climate Prediction Center, http://www.elnino.noaa.gov/ (ENSO data)*)

Approaches for Projecting Future Global Sea Level Rise

This section provides an overview of some of the more well-known approaches that have been used to project sea level changes and their relevance to California. Appendix B will cover how these projections can be used to determine water conditions at the local scale.

There is no single, well-accepted technique for projecting future sea level rise. Understanding future sea level rise involves projecting future changes in glaciers, ice sheets, and ice caps, as well as future groundwater and reservoir storage. Two subjects in particular present challenges in sea level rise modeling. First, future changes to glaciers, ice sheets, and ice caps are not well understood and, due to the potential for non-linear responses from climate change, they present many difficulties for climate models (Overpeck 2006; Pfeffer *et al.* 2008; van den Broecke *et al.* 2011; Alley and Joughin 2012; Shepherd *et al.* 2012; Little *et al.* 2013). Second, the actual magnitudes of the two human-induced changes – pumping of groundwater and storage of water in reservoirs – are poorly quantified, but the effects of these activities are understood and can be modeled (Wada *et al.* 2010). Despite these challenges, sea level rise projections are needed for many coastal management efforts and scientists have employed a variety of techniques to model sea level rise, including:

1. Extrapolation of historical trends;
2. Modeling the physical conditions that cause changes in sea level;
3. Empirical or semi-empirical methods; and
4. Expert elicitations

There are strengths and weaknesses to each approach, and users of any sea level rise projections should recognize that there is no perfect approach for anticipating future conditions. This section provides users of the Guidance document with a general understanding of several of the most widely used sea level rise projection methodologies and their respective advantages and disadvantages. Figure A-2 provides a visual summary of several of the more commonly cited projections of future global and regional sea level rise.

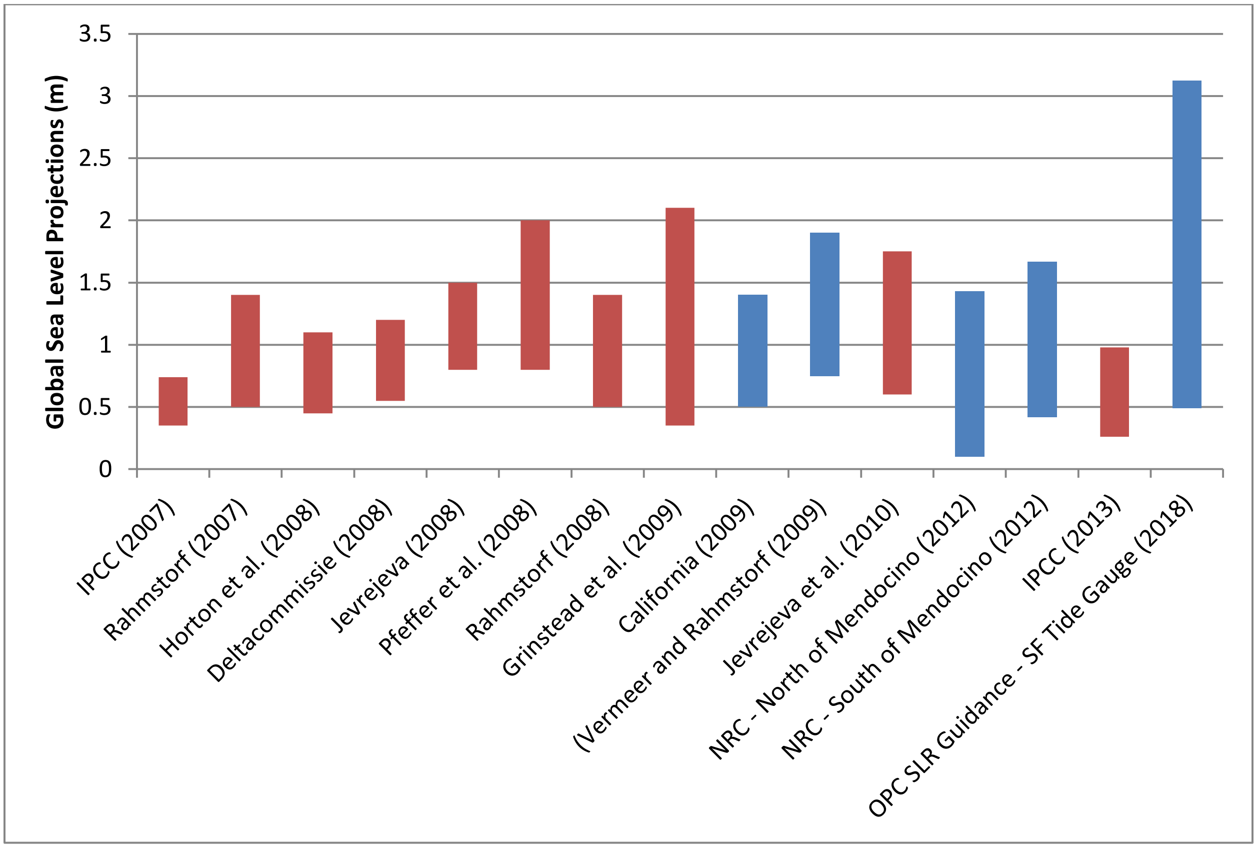

Figure A-2. Sea level rise projections for year 2100 from scientific literature. Graphic summary of the range of average sea level rise (SLR) projections by end of century (2090–2100) from the peer-reviewed literature as compared to the recent National Research Council report for California, Oregon and Washington. The light blue shaded boxes indicate projections for California. Ranges are based on the IPCC scenarios, with the low range represented by the B1 scenario (moderate growth and reliance in the future on technological innovation and low use of fossil fuels) and the high part of the range represented by the A1FI scenario (high growth and reliance in the future on fossil fuels). Details on the methods used and assumptions are provided in the original references.

Extrapolation of Historical Trends

Extrapolation of historical trends in sea level has been used for many years to project future changes in sea level. The approach assumes that there will be no abrupt changes in the processes that drive the long-term trend, and that the driving forces will not change. However, drivers of climate change and sea level rise, such as radiative forcing, are known to be changing, and this method is no longer considered appropriate or viable in climate science.

A recent modification to the historical trend method discussed above has been to estimate rates of sea level rise during the peak of the last interglacial (LIG) period (~125,000 years before present, when some drivers of sea level rise were similar to those today)[3] and use these as proxy records to project sea level rise rates to the 21st Century. For example, Katsman *et al.* (2011) and Vellinga *et al.* (2008) used the reconstructed LIG record of sea level change (from Rohling *et al.* 2008) to reconstruct sea level rise rates during rapid climate warming, and applied these rates to estimate sea level at years 2100 and 2200. Similarly, Kopp *et al.* (2009) used sea level rise rates inferred from the LIG to estimate a range of sea level rise for Year 2100 between 1-3 ft (0.3-1 m). Compared to traditional historical trend extrapolation, this modified approach has the advantage of including the dynamic responses of ice sheets and glaciers to past global climates that were significantly warmer than the present, but is limited by the large uncertainties associated with proxy reconstructions of past sea level.

Physical Models

Physical climate models use mathematical equations that integrate the basic laws of physics, thermodynamics, and fluid dynamics with chemical reactions to represent physical processes such as atmospheric circulation, transfers of heat (thermodynamics), development of precipitation patterns, ocean warming, and other aspects of climate. Some models represent only a few processes, such as the dynamics of ice sheets or cloud cover. Other models represent larger scale atmospheric or oceanic circulation, and some of the more complex General Climate Models (GCMs) include atmospheric and oceanic interactions.

Physical models of sea level changes account for the thermal expansion of the ocean and the transfer of water currently stored on land, particularly from glaciers and ice sheets (Church *et al.* 2011). Currently, coupled Atmosphere-Ocean General Circulation Models (AOGCMs) and ice sheet models are replacing energy-balance climate models as the primary techniques supporting sea level projections (IPCC 2013). Ocean density, circulation and sea level are dynamically connected in AOGCMs as critical components of the models include surface wind stress, heat transfer between air and sea, and freshwater fluxes. AOGCM climate simulations have recently been used as input for glacier models (Marzeion *et al.* 2012) which project land-water contributions to sea level.

The Intergovernmental Panel on Climate Change (IPCC) is one of the main sources of peer-reviewed, consensus-based modeling information on climate change. The IPCC does not undertake climate modeling, but uses the outputs from a group of climate models that project

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[3] During the last interglacial, global mean temperature was 1-2ºC warmer than the pre-industrial era (Levermann *et al.* 2013), while global mean sea level was likely 16.4-29.5 ft (5-9 m) above present mean sea level (Kopp *et al.* 2009; Dutton and Lambeck 2012; Levermann *et al.* 2013).

future temperature, precipitation patterns, and sea level rise, based on specific emission scenarios. Early in the 1990s, the IPCC developed basic model input conditions to ensure comparable outputs from the various models. The IPCC initially developed scenarios of future emissions, based on energy development, population and economic growth, and technological innovation. Four families of scenarios (A1, A2, B1, and B2) and subgroups (A1B, A1FI, A1T) were developed and used for climate and sea level rise projections for early IPCC reports (1990, 1995, 2001, 2007). IPCC used 4 new scenarios for the *5th Assessment Report* (AR5) in 2013, based on Representative Concentration Pathways (RCPs) that are different greenhouse gas concentration trajectories. These trajectories bear similarities to, but are not directly comparable to the earlier emission scenarios. Projections in IPCC AR5 (2013) differ from the earlier IPCC projections due to improvements in climate science, changes due to the new scenarios, and changes in the models to accommodate the new inputs, with improvements in climate science and model capabilities driving the bulk of the changes.

One finding of the earlier 2007 IPCC report called for improved modeling of ice dynamics. Focused research on ice dynamics to improve the ability of climate models to address the scale and dynamics of change to glaciers, ice sheets, and ice caps was subsequently undertaken (*e.g.*, Price *et al.* 2011; Shepherd *et al.* 2012; Winkelman *et al.* 2012; Bassis and Jacobs 2013; Little *et al.* 2013). Recent modeling results presented in the AR5 (IPCC 2013) reflect the scientific community's increased understanding in, as well as advances in modeling of the impacts of glacier melting and ocean thermal expansion on sea level change. AR5 scenarios reflect a greater range of global sea level rise (28-98 cm) based on improved modelling of land-ice contributions.

Semi-Empirical Method

The semi-empirical method for projecting sea level rise is based on developing a relationship between sea level and some factor (a proxy) – often atmospheric temperature or radiative forcing – and using this relationship to project changes to sea level. An important aspect for the proxy is that there is fairly high confidence in models of its future changes; a key assumption that is made by this method is that the historical relationship between sea level and the proxy will continue into the future. One of the first projections of this kind was based on the historical relationship between global temperature changes and sea level changes (Rahmstorf 2007). This semi-empirical approach received widespread recognition for its inclusion of sea level rise projections. These projections looked at the temperature projections for two of the previous IPCC (2007) emission scenarios that span the likely future conditions within the report's framework – B1, an optimistic, low-greenhouse gas emission future, and A1FI, a more "business-as-usual" fossil fuel intensive future.[4] The Rahmstorf 2007 sea level rise projections were used in the California 2009 *Climate Change Scenarios Assessment* (Cayan 2009).

Since the initial semi-empirical projections for future sea level rise (Rahmstorf 2007), other researchers have published different projections based on the IPCC scenarios, using different

[4] When the IPCC began examining climate change, the available models used a broad range of inputs. In an attempt to evaluate the different model outputs based on the different model characteristics rather than the inputs, the IPCC developed a number of standard greenhouse gas emission scenarios. These scenarios are described in *Response Strategies Working Group III* (IPCC 1990). In general, the B1 scenario projects the lowest temperature and sea level increases and the A1FI projects the highest increases.

data sets or best-fit relationships.[5] Notably, Vermeer and Rahmstorf (2009) prepared a more detailed methodology that includes both short-term responses and longer-term responses between sea level rise and temperature. These 2009 projections of sea level rise were used in the *Interim Guidance on Sea Level Rise* (OPC 2010) and the California 2012 *Vulnerability and Assessment Report* (Cayan 2012).

There are also several new semi-empirical sea level rise projections based on scenarios other than those developed by the IPCC. For instance, Katsman *et al.* (2011) use a "hybrid" approach that is based on one of the newer radiative forcing scenarios and empirical relationships between temperature change and sea level. Future projections were then modified to include contributions from the melting of major ice sheets based on expert judgment[6]. This yields what they call "high end" SLR projections for Years 2100 and 2200 under several emissions scenarios.

Zecca and Chiari (2012) produced semi-empirical sea level rise projections based on their own scenarios of when fossil fuel resources would be economically exhausted. Though based on a different set of assumptions about human behavior/choices, in terms of global temperature and radiative forcing, the scenarios do not differ greatly from the IPCC scenarios. The results are identified as being "lower bound" sea level rise projections for high, medium, low fuel use scenarios, and "mitigation" (extreme and immediate action to replace fossil fuel use) scenarios. The report then provides projections for the 2000-2200 time period.

Expert Elicitation

Expert elicitation is one of the newer methods that have been used for projecting or narrowing ranges of future sea level rise. Using expert judgment has been an important aspect of scientific inquiry and the scientific method. The method of expert elicitation is a formalized use of experts in climate science and sea level change to help either narrow uncertainty for sea level projections, or to help with specifying extremes of a range. The elicitation method normally begins with experts refining model output information. One of the first attempts to use expert elicitation for sea level rise was a study by Titus and Narayanan (1996), when it was thought there was only 1% probability that sea level would exceed 3.3 ft (1 m) by Year 2100. In 2011, the Arctic Monitoring and Assessment Programme Report (AMAP 2011) surveyed the climate literature to construct a range of estimates of sea level rise by the year 2100, and then used a panel of experts to decide on a smaller, more plausible range. Not surprisingly, the projections supported by the AMAP experts fell right in the middle of the range shown in Figure A-2. Bamber and Aspinall (2013) used a statistical analysis of a large number of expert estimates to

[5] Semi-empirical projections of sea level rise using relationships between water level and radiative forcing such as those from Grinsted *et al.* (2009), Jevrejeva *et al.* (2010), Katsman *et al.* (2011), Meehl *et al.* (2012), Rahmstorf *et al.* (2012), Schaeffer *et al.* (2012), and Zecca and Chiari (2012) have shown general agreement with the projections by Vermeer and Rahmstorf (2009). The Grinsted *et al.* projections have a wider range than those of Vermeer and Rahmstorf, while the Jevrejeva *et al.* projections are slightly lower. All semi-empirical methods project that sea level in Year 2100 is likely to be much higher than linear projections of historical trends and the projections from the 2007 IPCC.

[6] Expert judgment has long been part of the scientific process. Expert elicitation, which is a formalized process for using expert judgment, has grown in importance and is discussed as a separate approach for projecting future sea level rise.

develop their projected range of future sea level, projecting sea level rise by 2100 ranging from 1–4.3 ft (0.33–1.32 m), under one of the intermediate AR5 scenarios (RCP 4.5).

Horton *et al.* (2014) surveyed experts in sea level science, based upon published papers, to develop a probabilistic assessment of long-term sea level rise (by the years 2100 and 2300), assuming two very different scenarios. Under one scenario, aggressive efforts would limit greenhouse gas concentrations that would cause global temperature to increase slightly until about 2050 when it would slowly drop (AR5's RCP 3 scenario). Under the other scenario, temperatures would continue to increase through to 2300 (AR5's RCP 8.5 scenario). Experts determined that it is likely that sea level rise could remain below 3.3 ft (1 m) for the low emission scenario (RCP 2.6), but that the likely range of future sea level rise for the high emission scenario (RCP 8.5) could be 6.6-9.8 ft (2-3 m).

Kopp *et al.* (2014) have combined detailed process modeling, community assessments and expert elicitation to assign probability distributions of local sea level rise through 2200 for identified communities around the world. Under the high concentration scenario, RCP 8.5, Kopp *et al*. estimate the "maximum physically possible rate of sea level rise" to be 8.2 ft (2.5 m) for the year 2100. This study also finds that sea level rise along the Pacific Coast of the US is close to the global average, and the likely range of sea level is 2-3.3 ft (0.6-1.0 m) by the year 2100 at San Francisco, under the high concentration scenario. In contrast, in areas of high subsidence such as Galveston, Texas, the likely range of sea level in by 2100 ranges from 3.3 to 5 ft (1.0-1.5 m). And, at many of the localities that were examined, including San Francisco, the current 1-in-10 year flooding event is likely to occur every other year by 2100 (five times more frequently) due to sea level rise; the frequency of the 1-in-100 year event is expected to double by the year 2100 with sea level rise.

Coastal communities cannot ignore sea level rise in long-term planning, permitting and project design. The four different approaches to projecting future sea level rise all have varying strengths and weaknesses. As noted earlier in this section, projections, like models, will not be completely accurate, but they are important tools for evaluation nonetheless[7]. The most commonly cited projections provide future sea level as a range, as a way to allow for many of the uncertainties that are part of future climate change. Often, projections of sea level rise rely upon multiple approaches. For example, the 2012 National Research Council (NRC) report was developed through expert judgment that combined information from both physical models and semi-empirical projections.

[7] George E.P. Box, mathematician and statistician is quoted as saying, "Essentially all models are wrong, but some are useful."

BEST AVAILABLE SCIENCE ON SEA LEVEL RISE

Global Projections of Sea Level Rise

The best available science on *global* sea level rise projections is currently the IPCC *Fifth Assessment Report: Climate Change 2013* (AR5) released in September 2013. The new report now projects a more rapid sea level rise than the *Fourth Assessment* (AR4) released in 2007. By Year 2100, the AR5 projects global sea level to be more than 50% higher (26-98 cm) than the old projections (18-59 cm) when comparing similar emission scenarios and time periods. The increase in AR5 sea level projections results from improved modelling of land-ice contributions. Substantial progress in the assessment of extreme weather and climate events has also been made since the AR4 as models now better reproduce phenomena like the El Niño-Southern Oscillation (ENSO; IPCC 2013).

National Projections of Sea Level Rise

The third National Climate Assessment (NCA) was released in May 2014 (Melillo *et al.*), and includes the current best-available science on climate change and sea level rise *at the national scale*. The sea level rise projections in the NCA were informed by the 2012 NOAA report titled *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris *et al.*). This report provides a set of four scenarios of future global sea level rise, as well as a synthesis of the scientific literature on global sea level rise. The NOAA Climate Program Office produced the report in collaboration with twelve contributing authors.[8] The report includes the following description of the four scenarios of sea level rise by the year 2100:

- **Low scenario:** The lowest sea level change scenario (a rise of 8 in (20 cm)) is based on historical rates of observed sea level change.
- **Intermediate-low scenario:** The intermediate-low scenario (a rise of 1.6 ft (0.5 m) is based on projected ocean warming.
- **Intermediate- high scenario:** The intermediate-high scenario (a rise of 3.9 ft (1.2 m)) is based on projected ocean warming and recent ice sheet loss.
- **High scenario:** The highest sea level change scenario (a rise of 6.6 ft (2 m)) reflects ocean warming and the maximum plausible contribution of ice sheet loss and glacial melting.

The Parris *et al*. (2012) report recommends that the highest scenario be considered in situations where there is little tolerance for risk. It also provides steps for planners and local officials to modify these scenarios to account for local conditions. These steps are intended for areas where local sea level rise projections have not been developed. For California, **the 2018 OPC SLR Guidance report (below) provides scenarios that have been refined for use at the local level, and the Coastal Commission recommends using the OPC projections rather than the global or national scenarios**.

[8] Authors include NOAA, NASA, the US Geologic Survey, the Scripps Institution of Oceanography, the US Department of Defense, the US Army Corps of Engineers, Columbia University, the University of Maryland, the University of Florida, and the South Florida Water Management District.

California-Specific Projections of Sea Level Rise and Best Available Science

The State of California has long-supported the development of scientific information on climate change and sea level rise to help guide planning and decision-making. For example, the State helped support the development of the 2012 National Research Council (NRC) report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*, which provided an examination of global and regional sea level rise trends and projections of future sea level. This report was then incorporated into the Ocean Protection Council's 2013 *State Sea-Level Rise Guidance*, and was considered the best available science on sea level rise for California.

More recently, and in response to the release of new scientific studies related to sea level rise, Governor Brown directed the OPC to synthesize recent science on sea level rise and incorporate findings into updates to the State Guidance. In April 2017, a working group of OPC's Science Advisory team (comprised mainly of climate researchers at various academic institutions in California and throughout the country) released a report titled *Rising Seas in California: An Update on Sea-Level Rise Science*. The report highlighted seven key findings:

1. ***Scientific understanding of sea level rise is advancing at a rapid pace*. Sea level rise projections have increased substantially over the last few years, particularly for late in the 21st century and under high emissions scenarios, due to our evolving understanding of the dynamics of ice sheet loss. However, there is still significant uncertainty regarding these processes.**

2. ***The direction of sea level change is clear*. Coastal California is already experiencing the impacts of rising sea levels, and impacts will increase in the future.**

3. ***The rate of ice loss from the Greenland and Antarctic ice sheets is increasing*. Ice sheet loss will soon overtake thermal expansion of seawater as the primary driver of rising sea levels. Due to a variety of ocean circulation dynamics, ice loss from Antarctica, and particularly West Antarctica, has an outsized impact on California compared to the rest of the world (Figure A-3). Continued research on this dynamic is critical for accurately projecting future sea level rise along our coast.**

4. ***New scientific evidence has highlighted the potential for extreme sea level rise*. Recent research (e.g., De Conto and Pollard, 2016; Sweet et al., 2017) has found that, if greenhouse gas emissions are not curtailed, glaciological processes could cross thresholds that lead to rapidly accelerating and effectively irreversible ice loss. The probability of this extreme scenario is currently unknown, but its consideration is important. Significant reductions in greenhouse gas emissions may reduce the likelihood of this extreme scenario, but does not completely eliminate the risk. Importantly, it is difficult to determine if the world is on the track for extreme and irreversible ice loss for some time because the processes that drive extreme ice loss in the later part of the century or beyond are different than those that are driving ice loss now.**

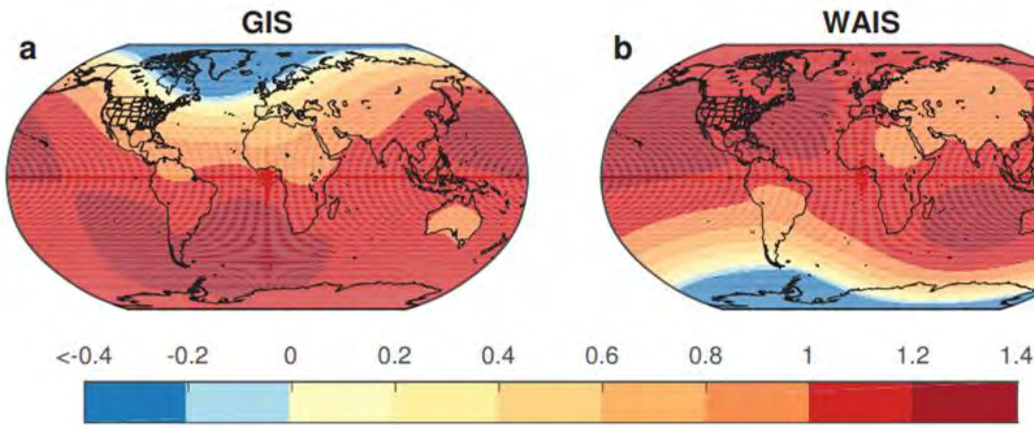

Figure A-3. **Sea level 'fingerprints' resulting from the distribution of ice and water around the Earth and ensuing gravitational and rotational effects. The maps depict the relative response of sea-level to the loss of ice mass from (a) Greenland Ice Sheet (GIS) and (b) West Antarctic Ice Sheet (WAIS). The color bar represents the fractional departure of relative sea level rise from that expected given the ice contribution to global mean sea level. For example, when ice is lost from the Greenland Ice Sheet the relative effect on the US West Coast is 75% of the sea-level rise expected from the water volume added to the ocean. By comparison, when ice is lost from the West Antarctic Ice Sheet the US West Coast experiences 125% of sea-level rise from that expected from the water volume added (*from Griggs et al. 2017*).**

5. ***Probabilities of specific sea-level increases can inform decisions*. A probabilistic approach to sea level rise projections, combined with a clear articulation of the implications of uncertainty and the decision support needs of affected stakeholders, is the most appropriate approach for use in a policy setting.**

   The OPC Scientific Working Group utilized a comprehensive probability approach based on Kopp et al. (2014) that estimates both a comprehensive probability distribution and the likelihood of extreme 'tail' outcomes. It is important to note that probabilistic projections do not provide probabilities of occurrence of sea level rise, but rather probabilities that the ensemble of climate models used to estimate contributions of sea level rise (from thermal expansion, ice sheet loss, oceanographic conditions etc.) will predict a certain amount of sea level rise.

   Note that the probabilistic projections do not consider the H++ extreme ice loss scenario. The extreme ice loss studies were not included in the inputs to the model ensemble, which means the probability distributions may be an underestimate.

6. ***Current greenhouse gas emissions policy decisions are shaping our coastal future*. Before 2050, differences in SLR projections under different emissions scenarios are minor. After 2050, SLR projections increasingly depend on the trajectory of greenhouse gas emissions. If greenhouse gas emissions are not curtailed worldwide, we will see significantly higher rates of sea level rise during the second half of the century.**

7. ***Waiting for scientific certainty is neither a safe nor prudent option*. Taking action today to assess vulnerabilities and identify and implement adaptation strategies will prevent much greater losses than will occur if action is not taken. Taking a precautionary approach that considers high and extreme scenarios is critical for safeguarding the people and resources of coastal California.**

This scientific information was incorporated into OPC's *State Sea-Level Rise Guidance: 2018 Update*. The OPC Guidance includes projection tables for 12 tide gauges along the California coast for each decade from 2030 to 2150. OPC further recommends utilizing three different projection scenarios to guide planning, permitting, investment, and other decisions based on the type of project, its ability to cope with or adapt to sea level rise, and the consequences to the environment and the project associated with sea level rise. The projection table for the San Francisco tide gauge is provided below (Table A-1), and tables for other California tide gauges are presented in Appendix G. The 2018 OPC SLR Guidance (along with the foundational Rising Seas science report) is currently considered best available science on sea level rise for the State of California.

The Coastal Commission recommends that the low, medium-high, and extreme risk aversion scenarios from the OPC 2018 Sea-Level Rise Guidance be considered in all relevant local coastal planning and coastal development permitting decisions.

Table A-1. **Sea Level Rise Projections for the San Francisco Tide Gauge[9] (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.

[9] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

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Appendix B

Developing Local Hazard Conditions Based on Regional or Local Sea Level Rise Using Best Available Science

This Appendix provides technical information regarding how to determine local hazard conditions for sea level rise planning efforts. This process is described more broadly as Steps 1-3 in Chapters 5 and 6 in this document, and includes determining a range of sea level rise projections and analyzing the physical effects and possible resource impacts of sea level rise hazards.

Water level varies locally, so this analysis must be performed on a regional or site specific basis, and applicants and planners should prioritize obtaining data or conducting research at the correct geographical scale. **The 2018 OPC Sea-Level Rise Guidance is considered the best available science on California's regional sea level rise**, and the Commission recommends using it when sea level rise projections are needed. Equivalent resources may be used by local governments and applicants provided that the resource is peer-reviewed, widely accepted within the scientific community, and locally relevant.[93]

Much of the research by the Intergovernmental Panel on Climate Change (IPCC) and others has focused on global and regional changes to mean sea level. However, the coast is formed and changed by local water and land conditions. Local tidal range influences where beaches, wetlands and estuaries will establish; waves and currents are major drivers of shoreline change; and storms and storm waves are often the major factors causing damage to coastal development. It is local conditions that influence beach accretion and erosion, storm damage, bluff retreat, and wetland function.

Local water levels along the coast are affected by local land uplift or subsidence, tides, waves, storm waves, atmospheric forcing, surge, basin-wide oscillations, and tsunamis. Some of these factors, such as tides and waves, are ever-present and result in ever-changing shifts in the local water level. Other drivers, such as storms, tsunamis, or co-seismic uplift or subsidence, are episodic but can have important influences on water level when they occur. The following section discusses these factors in the context of sea level rise and how to incorporate them into planning and project analysis.

In most situations, high water will be the main project or planning concern. For wetlands, the intertidal zone between low and high tides will be of concern, while in some special situations, such as for intake structures, low water might be the main concern. In situations where low water is the concern, current low water is likely to be the low water planning condition and there may be no need to factor future sea level rise into those project or planning situations. In most other situations, hazards analyses will need to account for sea level rise. The following box identifies some of the key situations in which it may be important for coastal managers and applicants to consider sea level rise during project review.

[93] This appendix is written in such a way that it complements the materials from the 2012 NRC Report and the **2018 OPC SLR Guidance**, which is currently considered the best available science on sea level rise in California.
As new reports are issued in the future, Commission staff will assess whether they should be considered the best available science and update the approaches or terminology in this Appendix accordingly.

General situations needing sea level rise analysis include when the project or planning site is:

- Currently in or adjacent to an identified floodplain
- Currently or has been exposed to flooding or erosion from waves or tides
- Currently in a location protected from flooding by constructed dikes, levees, bulkheads, or other flood-control or protective structures
- On or close to a beach, estuary, lagoon, or wetland
- On a coastal bluff with historic evidence of erosion
- Reliant upon shallow wells for water supply

For situations where future sea level conditions will be important for the analyses of hazards or resource impacts, the following sections are provided as guidance for determining local hazards. Figure B-1 shows the general progression for going from global sea level projections to the possible consequences or impacts that can result from local water levels.

The following information provides guidance on using temporally- and regionally-appropriate sea level rise projections to determine future tidal elevations and inundation, future still water, future shoreline change and erosion, potential flooding, wave impacts and wave runup, and flooding from extreme events[94].

Most of these analyses must occur sequentially. Sea level rise is used to determine changes in tidal conditions, and tidal conditions are combined with future surge, El Niño Southern Oscillation (ENSO) events, and Pacific Decadal Oscillations (PDOs) to estimate local still water. Changes in the frequencies of still water levels will in turn affect erosion rates, and the amount of erosion will affect future wave impacts, runup and flooding.

To be consistent with other sections, these different efforts are presented as Steps, with a discussion of how to accomplish each and the expected outcome. Depending upon the planning or project concerns and required analysis, it may not be necessary to proceed step-by-step and readers should use their judgment as to which items are relevant to their concerns. For example, if the concern is about runup on a non-erosive slope due to an increase in the still water level of 5.5 ft (1.7 m), the guidance on wave runup analysis may be all that is necessary.

[94] **Importantly, the 2018 OPC SLR Guidance includes projections tables for 12 tide gauges throughout California, and for every 10 years from 2030 to 2150. As such, adjusting the projections to account for more localized conditions or specific years is likely unnecessary. This is a change from the 2012 NRC report, which included projections for north and south of Cape Mendocino and for only three time periods. Thus, sections within this Appendix that pertained to developing temporally- and spatially-adjusted projections (including mathematic interpolation methods) have largely been removed in the 2018 update**.

Step 1 – Develop temporally- and spatially-appropriate sea level rise projections
Step 2 – Determine tidal range and future inundation
Step 3 – Determine still water level changes from surge, El Niño events and PDOs
Step 4 – Estimate beach, bluff, and dune change from erosion
Step 5 – Determine wave, storm wave, wave runup, and flooding conditions
Step 6 – Examine potential flooding from extreme events

A Note on Hydrodynamic Models versus "Bathtub Fill" Models

It is important to be aware of the differences between a so-called "bathtub fill" model and hydrodynamic models, and the related pros and cons of each for analysis of sea level rise impacts. In general, "bathtub fill" refers to those models that analyze flooding or inundation based solely on elevation. In other words, if sea level is projected to rise 3 ft (1 m), thereby increasing flooding/inundation from a current elevation of +10 ft (3 m) to +13 ft (4 m), these models will, in general, flood everything below the +13 ft (4m) elevation. The modeling does not take into consideration whether the new flood areas are connected to the ocean, nor does it consider how the changes to the water level will change wave propagation or overtopping of flood barriers. This is a significant oversimplification of the processes involved in flooding, but it provides value in allowing individuals to gain a broad view of the general areas that could be impacted by sea level rise without requiring a great deal of technical information.

Conversely, hydrodynamic modeling takes into account the details of local development patterns and the characteristics of waves and storms, and can therefore provide a much better understanding of local sea level rise impacts than is possible from "bathtub fill" models. In particular, hydrodynamic models take into account factors that alter flooding and inundation patterns and impacts. Such factors may include the extent and orientation of development – for example, roadways and linear features that tend to channelize water flows, and buildings or flood barriers that can block and divert flows – as well as the conditions that contribute to flooding and inundation, such as wave conditions, flow velocities, the extent of overtopping, and so on. Although the initial development of the modeling grid that is used to depict the community development patterns can be quite time-consuming to create and the model output will change with differing grid designs (Schubert and Sanders 2012), once the grid is developed, hydrodynamic modeling can be used to better characterize areas of flooding and to distinguish areas of concentrated flooding from those areas that may experience small amounts of flooding only during peak conditions (Gallien *et al.* 2011, 2012).

Significantly, many of the analyses described in this Appendix are the kinds of analyses that go beyond "bathtub fill" modeling to include the hydrodynamic factors that help to specify the more location-specific impacts for which planners should prepare.

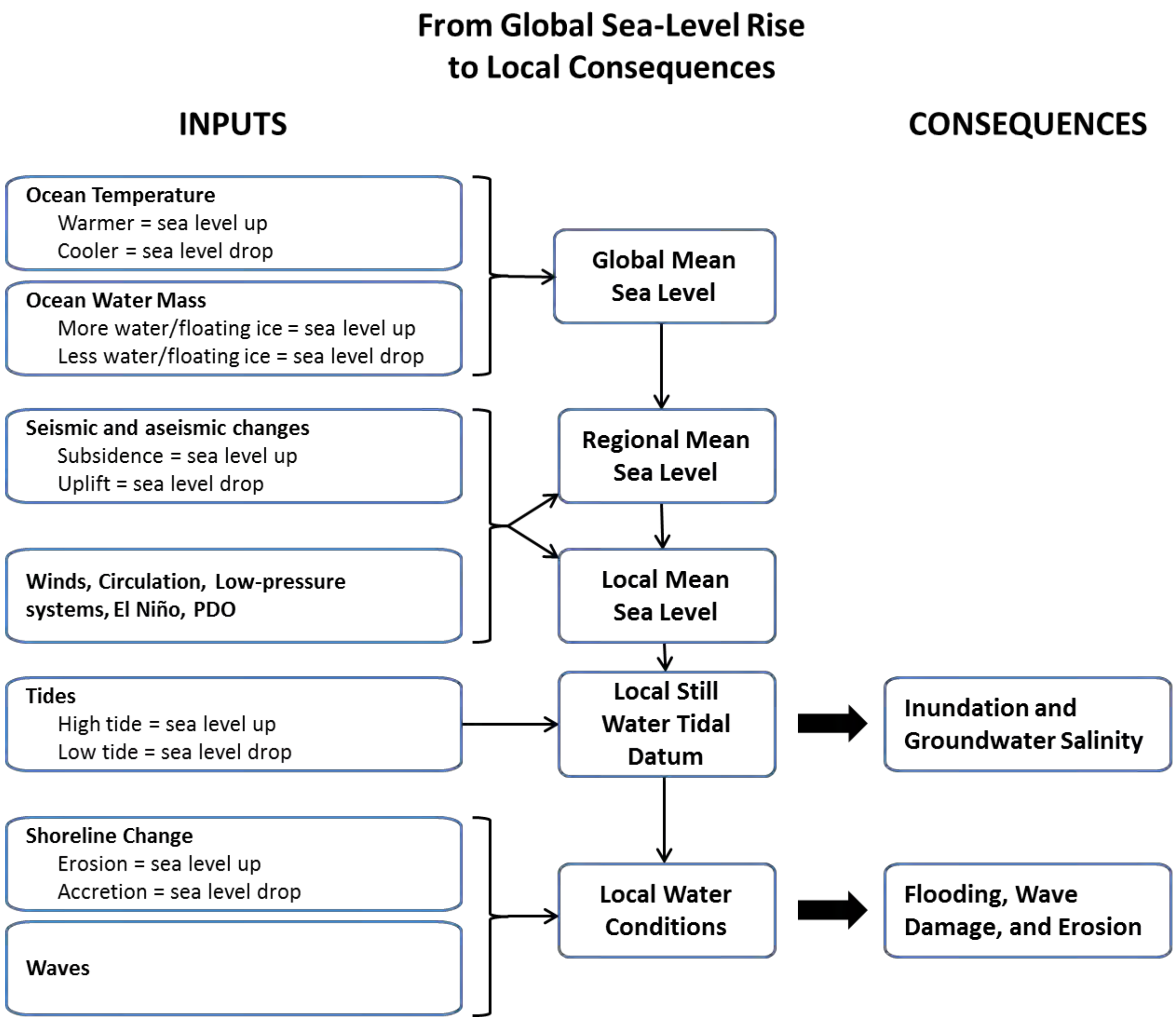

Figure B-1. General process for translating global sea level rise to local consequences

Step 1 – Develop temporally- and spatially-appropriate sea level rise projections

a. Identify the nearest tide gauge

The 2018 OPC Sea-Level Rise Guidance contains projection tables for 12 tide gauges along the California coast in order to account for localized trends in relative sea level rise, related mainly to different rates of vertical land motion. The 12 tide gauges are mapped in Appendix 2 of the OPC Guidance (and copied in Appendix G here). OPC directs users to identify the nearest tide gauge to the project or planning site and to use the associated projection table in planning and permitting. In some cases it may be appropriate to interpolate between two tide gauges (if the project site is equidistant between tide gauges) or to use more locally-specific scientific data, if available. In many cases, though, the differences among projections (either between two tide gauges or from more localized data) are likely to be small, and therefore may be insignificant compared to overall uncertainty in modeling and/or future greenhouse gas emissions scenarios.

b. Determine appropriate planning horizon or expected project life and identify relevant sea level rise projections

The first step in a sea level rise analysis is to determine the appropriate planning horizon based on the expected life of the project. The longer the life of a project or planning horizon, the greater the amount of sea level rise the project or planning area will experience.

Local governments should select their planning horizons to evaluate a broad range of planning concerns. Planning horizons could address the 20-year time period that is typical for *General Plan* updates as well as the long-range planning that is necessary for infrastructure and new development. The 20-year planning horizon may help identify areas within the coastal zone that are now or will soon be vulnerable to sea level rise related hazards as an aid for focusing adaptation planning on the areas of greatest need. Local Coastal Program (LCP) planning will likely use multiple planning horizons and undertake hazards analyses for multiple time periods, multiple sea level rise projections, or both.

At the project level, the LCP may provide insight into the time period that should be considered for the expected project life. At present, LCPs typically provide only a single standard (if any) for the expected life of a structure or development, such as 50, 75, or 100 years. Future LCPs and LCP Amendments (LCPAs) may find it useful to provide greater guidance on expected project life, with differentiations among major development or use classifications. For example, a general range may be chosen based on the type of development such that temporary structures, ancillary development, amenity structures, or moveable or expendable construction should identify a relatively short expected life of 25 years or less. Residential or commercial structures, which will be around longer, should choose a time frame of 75 to 100 years to consider. A longer time frame of 100 years or more should be considered for critical infrastructure like bridges or industrial facilities or for resource protection or enhancement projects that are typically meant to last in perpetuity.

For projects with long lead times, the analysis of impacts from sea level rise should use the projections for the time period when the development will be in use, rather than the current period because the trajectory of future sea level rise is not expected to be linear. For example, a project built today will experience less sea level rise over a 50-year lifetime (**about 1.9 feet under the "medium-high risk aversion" scenario at the San Francisco tide gauge**) than the same project if it were built in the year 2050 (**about 5 feet under the "medium-high risk aversion" scenario at the San Francisco tide gauge**). Thus, it is important to understand the anticipated project life of a structure and the associated planning horizon before starting an analysis for sea level rise concerns.

As explained in Chapters 5 and 6, the point of this step is not to specify exactly how long a project will exist (and be permitted for), but rather to identify a project life timeframe that is typical for the type of development in question so that the hazard analyses performed in subsequent steps will adequately consider the impacts that may occur over the entire life of the development.

Once the appropriate planning/project horizon has been identified, the associated projection for that time period can be identified using the projection tables from the 2018 OPC SLR Guidance. These tables include projections for each decade from 2030 to 2150.

As explained elsewhere in this Guidance, project characteristics (including its ability to withstand or adapt to different sea level rise amounts and the consequences associated with underestimating the amount of sea level rise that occurs) should guide users in choosing which scenario to assess for a particular planning horizon. As general guidance, the Coastal Commission continues to recommend that planners or project applicants take a precautionary approach by evaluating higher sea level rise amounts (for example, the medium-high risk aversion scenario for most development, or the extreme risk aversion scenario for critical infrastructure).

Step 2 – Determine tidal range and future inundation

One of the most basic examinations of changing sea level conditions has been to determine the new intersection of mean sea level or other tidal datums[95] with the shoreline. This is a basic "bathtub" analysis since it looks only at the expansion of areas that will be inundated (*i.e.*, regularly submerged under water) or subject to tidal or wave action. For example, future subtidal levels would be the current subtidal limit plus projected regional mean sea level rise. Future intertidal zones would be bounded by the future higher high tide level (current higher high water plus projected regional sea level rise) and future lower low tide levels (current lower low water plus projected regional sea level rise).[96] For some projects, such as wetland restoration, the identification of future inundation zones may be the only sea level analysis needed for project evaluation. However, if the shoreline is eroding, the location of this elevation would need to also incorporate the rate of erosion. So, if the shoreline is expected to erode due to increased wave attack, not only will the intertidal zone move up in elevation, it will be both higher than and inland of the current zone.

Future Water *Elevation* = Current Tidal Datum + Projected Sea Level Rise

OR

Future Water *Location* = Intersection of Future Water Elevation with Future Shore Location

Future water location will extend to the new inundation elevation on the future shoreline. On beaches with a gradual slope, this can move the inundation location significantly inland, based on the geometric conditions of the beach. (This type of analysis is often called the Bruun Rule). On a stable beach with a slope of 1:X (Vertical:Horizontal), every foot of vertical sea level rise will move the inundation area horizontally X feet inland. For a typical 1:60 beach, every foot of sea level would move the inundation zone inland by 60 ft. If the beach is eroding, the loss due to erosion will add to the loss resulting from inundation.

Figure B-2 shows the influence of tides and sea level rise on low-wave energy beaches. Table B-1 provides some useful resources for inundation studies. Local Tidal Elevations are available from tide gauges maintained by NOAA. Where there are no nearby gauges, NOAA recommends the VDatum software.

95 Tidal datums are based on the latest National Tidal Datum Epoch (NTDE) published by NOAA and are the mean of the observed sea levels over a 19-year period. The latest published epoch is 1983-2001. This tidal epoch can be considered equivalent to the year 2000 baseline for the **OPC** projections.

96 Historical trends of high and low tide have changed differently than mean sea level (Flick *et al.* 2003). Based on historical trends, the changes to various tidal elements are likely to track closely with, but not identically with, changes to mean sea level. The future variability of changes to the tidal components, compared with changes to mean sea level will normally fall within the uncertainty for sea level rise projections and can be disregarded in almost all situations. As this phenomenon of tidal change is better understood and can be modeled, it may be appropriate in the future to include the changes in tidal components into the analysis of inundation and various water level projections.

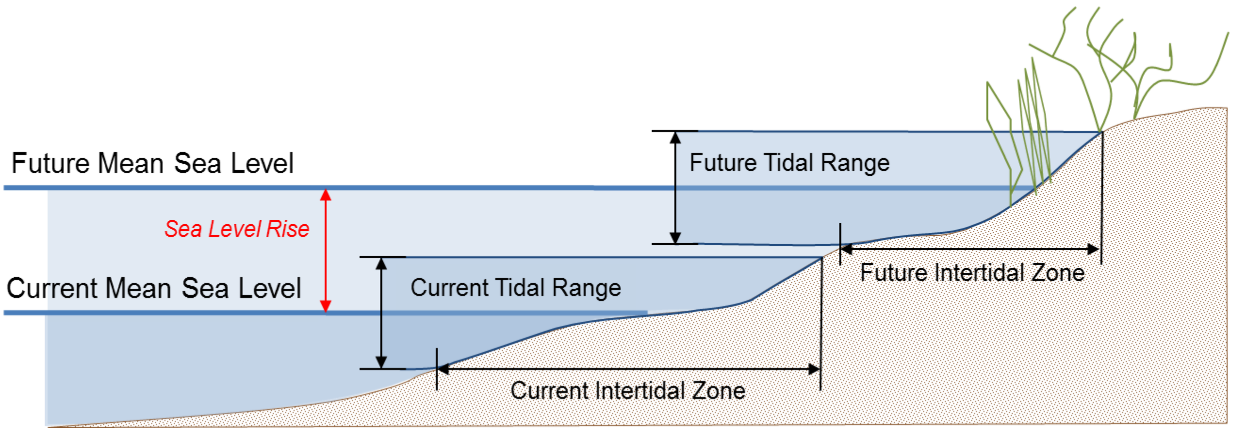

Figure B-2. Sea level rise and changes to tide range and intertidal zone. (*Source: L. Ewing, 2013*).

Table B-1. General Resources for Inundation Studies

Resource	Description	Link
Aerial Photographs	Useful for general information on shoreline trends; ortho-rectified photos can help quantify trends.	California Coastal Records Project, www.californiacoastline.org; Huntington Library; Local Libraries
LIDAR	Fairly detailed topography providing GIS layers for current conditions and comparable with LIDAR data sets for temporal changes.	NOAA Digital Coast, http://coast.noaa.gov/digitalcoast/data/coastallidar
Topographic Maps	Useful for basemaps to overlay site changes; often not at a scale to distinguish small changes in inundation or tidal action.	USGS Map Center, http://www.usgs.gov/pubprod/maps.html
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Useful to show changes in water level location if there are no changes in the land due to erosion.	NOAA Digital Coast, https://coast.noaa.gov/digitalcoast/tools/slr.html
NOAA Tidal Data	Measured and predicted tidal components for locations along the open coast and in bays.	NOAA Center for Operational Oceanographic Products and Services, http://tidesandcurrents.noaa.gov/
NOAA Technical Report NOS 2010-01: *Technical Considerations for use of Geospatial Data in Sea Level Change Mapping and Assessment*	Provides technical guidance to agencies, practitioners, and decision makers seeking to use geospatial data to assist with sea level change assessments.	NOAA National Ocean Service http://www.tidesandcurrents.noaa.gov/publications/tech_rpt_57.pdf

VDatum Software	A Vertical Datum Transformation program that allows users to transform geospatial data among various geoidal, ellipsoidal and tidal vertical datums.	NOAA National Ocean Service, https://vdatum.noaa.gov/
Cal-Adapt – Exploring California's Climate	**Represents inundation location and depth for the San Francisco Bay, the Sacramento-San Joaquin River Delta and California coast resulting from different increments of sea level rise coupled with extreme storm events. Incorporates real, time series water level data from past (near 100 year) storm events to capture the dynamic effect of storm surges in modeling inundation using a three dimensional hydrodynamic model (per Radke et al., 2017).**	http://cal-adapt.org/tools/slr-calflod-3d/
Estimating Sea Level for Project Initiation Documents	Provides guidance on converting tidal datums and predicting future sea levels.	Caltrans Office of Land Surveys, http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Estimating_Sea_Level_v1.pdf

Outcome from Step 2: *Provide information on the projected changes to the tidal range and future zones of inundation. For locations without any influence from erosion, storm surge, or wave energy, the identification of new inundation areas may be sufficient for project analysis and planning efforts. This projected new inundation area may also be useful for anticipating the likely migration of wetlands and low-energy water areas or as input for analysis of changes to groundwater salinity. For most open coast situations, this information will be used to inform further project planning and analysis that examines erosion, surge and storm wave conditions.*

Step 3 – Determine still water changes from surge, El Niño events, and PDOs

Estimates of surge, El Niño, and PDO water elevation changes are developed primarily from historical records. There are no state-wide resources for this information, although it may be included in some Regional Sediment Management Plan studies. General guidance on water level changes that can be expected from surge, El Niño events, and PDOs is provided in Table B-2.

The remaining discussion provides general information on some of these phenomena. It is provided to acquaint readers to the main issues associated with each phenomenon. Readers with a strong background in ocean-atmospheric conditions may want to skim or skip the rest of this section.

The Pacific Ocean is a complex system. Sea level in the Pacific Ocean responds to multiple oceanic and atmospheric forcing phenomena, occurring with different intensities and at different temporal and spatial scales. Some phenomena may reinforce each other, while others may act in opposition, reducing the net effect. Scientists and researchers are attempting to identify the various signals from the multiple phenomena, but these are nascent sciences and there is still much we need to learn.

Regional water levels can be influenced by surge as well as by high and low pressure systems. Surge is a short-term change in water elevation due to high wind, low atmospheric pressure, or both. It is most often associated with East Coast and Gulf Coast hurricanes that can cause up to 15 or 20 ft (4-6 m) or more of short-term water level rise over many miles of the coast. Along the West Coast, storm surge tends to be much smaller, and is rarely a coastal hazard, except in enclosed bays. In southern California, it rarely exceeds 1 ft (0.3 m) and in central California, it rarely exceeds 2 ft (0.6 m). Surge becomes a concern as one of several cumulative factors that cause a temporary rise in sea level. Each rise may be small, but when surge occurs during high tides and/or in combination with storms, it increases the threat of coastal flooding, wave impacts, and erosion.

Two of the more recognized phenomena that affect water temperature in the Pacific are the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). ENSO cycles, which occur on inter-annual timescales (approximately 2-7 years), not only involve ocean-basin-spanning changes in sea surface temperature (SST) and in the depth of the mixed layer in the Equatorial Pacific, but also drive changes in ocean conditions and atmospheric circulation at higher latitudes. El Niño events result in the transfer of warm surface waters into the normally cool eastern equatorial Pacific, resulting in elevated SST and water levels along much of the west coast of the Americas. El Niños also tend to increase the strength and frequency of winter low pressure systems in the North Pacific. These events can persist for months or years at a time, and strongly influence local and regional sea level. For example, the pulse of warm water from the large 1982-83 El Niño caused water levels along California to be elevated by approximately 0.4-0.7 ft (0.12-0.21 m) for many months, with short-term water elevation peaks up to approximately 1 ft (0.3 m; Flick 1998). The opposite phase of ENSO, characterized by unusually cool SSTs and lower water elevations along the eastern Pacific margin, are called La Niña events. Between El Niños and La Niñas are periods of neutral SST and water elevation changes.

The PDO is an ENSO-like pattern of SST and atmospheric variability occurring over multiple decades. In contrast to ENSO, the PDO is more strongly expressed in the North Pacific than in the tropics. The positive or warm phase of the PDO is associated with unusually warm surface water throughout the eastern North Pacific (along the western US coast), while the negative or cool phase PDO is associated with colder than normal waters. As with the ENSO effects, the warm phase PDO has tended to cause elevated sea levels in the eastern Pacific and along the California coast, while the cool phase of the PDO tends to lower sea level in this region.

The PDO has basin-wide influence. Elevated water levels in one part of the Pacific are often accompanied by lowered water levels elsewhere. The cool phase PDO can result in a drop of water level along the eastern Pacific (western US Coast) and a rise in water level along the western Pacific. Recently, sea level along the western Pacific has been rising about three times faster than the global mean sea level rise rate, due in part to the PDO (Bromirski *et al.* 2011; Merrifield 2011). This does not mean the eastern Pacific will experience sea level rise that is three times faster than the global mean sea level rise when there is the next shift in the PDO, but does show that the PDO can have a major influence on basin-wide and regional sea level. The above discussion of El Niño and the PDO may suggest that they are well-understood phenomena, with easily anticipated changes in sea level. However, it is important to note that El Niños have varying strengths and intensities, resulting in different sea changes from one event to the next. Also, changes in regional mean sea level along the eastern Pacific have not always shown a strong connection to the PDO cycles. An apparent jump in regional mean sea level occurred after the mid-1970s shift to the warm phase of the PDO, yet the expected continued rise in sea level along the West Coast seems to have been suppressed by other forces. Tide gauge records for the Washington, Oregon, and California coasts have shown no significant inter-annual rise in sea level from 1983 to 2011 (Cayan *et al.* 2008; Bromirski *et al.* 2011; NOAA 2013). Bromirski *et al.* (2011, 2012) postulate that persistent alongshore winds have caused an extended period of offshore upwelling that has both drawn coastal waters offshore and replaced warm surface waters with cooler deep ocean water. Both of these factors could have caused a drop in sea level, canceling out the sea rise that would otherwise be expected from a warm phase PDO signal.

Water level changes from surge, atmospheric forcing, El Niño events and the PDO can occur in combination. The water elevation changes from each factor may be only about 1 ft (0.3 m) or less, but each can cause changes in the water level over a time period of days, months, or a few years – far more rapidly than sea level rise. In combination, they can potentially cause a significant localized increase in water level.

When high water conditions occur in combination with high tides, and with coastal storms, the threat of coastal flooding, wave impacts and erosion also increases. These conditions can be additive, as shown in Figure B-3. Also, these changes in water level will continue to be important to the overall water level conditions along the California coast and they need to be examined in conjunction with possible changes due to regional sea level rise.

As stated earlier, estimates of surge, El Niño and PDO water elevation changes are developed primarily from historical records. There are no state-wide resources for this information, although it may be included in one of the Regional Sediment Management Plans, available for many coastal areas (see http://www.dbw.ca.gov/csmw/). General guidance on water level changes, surge, and El Niño events is provided in Table B-2.

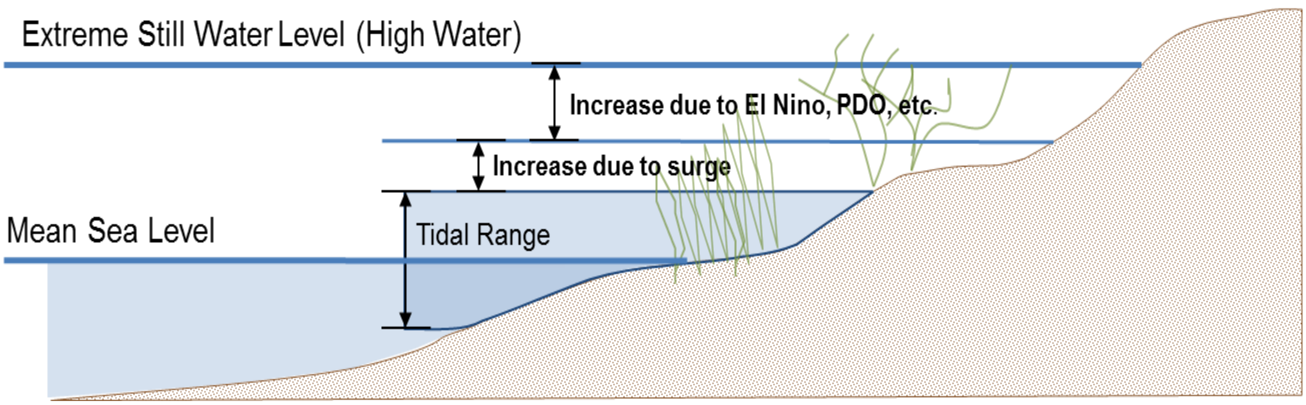

Figure B-3. Changes to extreme still water level due to surge, El Niño events, and PDOs. (*Source: L. Ewing, 2013*).

Table B-2. General Resources for Determining Still Water Elevation, Surge, El Niño events, and PDOs

Resource	Description	Link
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels within wetland areas, and provides visualizations for various amounts of sea level rise. For bays and estuaries, it also provides information on inland areas with the potential to flood if existing barriers to water connectivity are removed or overtopped. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	NOAA Digital Coast, https://coast.noaa.gov/digitalcoast/tools/slr.html
Pacific Institute Sea Level Rise Maps	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report "The Impacts of Sea Level Rise on the California Coast" visit: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/
Cal-Adapt – Exploring California's Climate	**Represents inundation location and depth for the San Francisco Bay, the Sacramento-San Joaquin River Delta and California coast resulting from different increments of sea level rise coupled with extreme storm events. Incorporates real, time series water level data from past (near 100 year) storm events to capture the dynamic effect of**	http://cal-adapt.org/tools/slr-calflod-3d/

	storm surges in modeling inundation using a three dimensional hydrodynamic model (per Radke et al., 2017).	
Regional Sediment Management Plans	Plans for regions of the state to identify how governance, outreach and technical approaches can support beneficial reuse of sediment resources within that region without causing environmental degradation or public nuisance.	http://www.dbw.ca.gov/csmw/

Outcome from Step 3*: Provide estimates of water elevations that can result from surge, El Niño events, and PDOs. When combined with the sea level changes to the tidal range, developed in Step 4, these can provide information on the extreme still water level. For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 4 – Estimate beach, bluff, and dune change from erosion

Predictions of future beach, bluff, and dune erosion are complicated by the uncertainty associated with future waves, storms and sediment supply. As a result, there is no single specific accepted method for predicting future beach erosion. At a minimum, projects should assume that there will be inundation of dry beach and that the beach will continue to experience seasonal and inter-annual changes comparable to historical amounts. When there is a range of erosion rates from historical trends, the high rate should be used to project future erosion with rising sea level conditions (unless future erosion will encounter more resistant materials, in which case lower erosion rates may be used). For beaches that have had a relatively stable long-term width, it would be prudent to also consider the potential for greater variability or even erosion as a future condition. For recent studies that provide some general guidance for including sea level rise in an evaluation of bluff and dune erosion, see, for example, Heberger *et al.* (2009) or Revell *et al.* (2011). Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used. Table B-3, at the end of this section, provides some resources that can be used for projecting future erosion.

The following sections discuss specific concerns associated with beach, bluff and dune erosion and are provided to acquaint readers to the main issues associated with each system. Readers with a strong background in coastal systems may want to skim or skip the rest of this section.

Beach Erosion

Beach erosion and accretion occur on an on-going basis due to regular variability in waves, currents and sand supply. The movement of sand on and off of beaches is an ongoing process. Along the California coast, periods of gradual, on-going beach change will be punctuated by rapid and dramatic changes, often during times of large waves or high streamflow events.

The overall dynamics of beach change have been described many times.[97] Sand moves on and off shore as well as along the shore. Normal sources of sand to a beach are from rivers and streams, bluff erosion or gullies, and offshore sand sources. Sand leaves a beach by being carried downcoast by waves and currents, either into submarine canyons or to locations too far offshore for waves to move it back onto shore. Beaches are part of the larger-scale sediment dynamics of the littoral cell, and in very simple terms, beaches accrete if more sand comes onto the beach than leaves and beaches erode if more sand leaves than is added. Changes in sand supply are a major aspect of beach change.

Beach changes are often classified as being either seasonal or long-term/inter-annual changes. Seasonal changes are the shifts in beach width that tend to occur throughout the year and are usually reversible. During late fall and winter, beaches tend to become narrower as more high energy waves carry sand away from the beach and deposit it in offshore bars. This is later followed by beach widening as gentler waves again bring sand landward, building up a wider dry-sand summer beach. These changes are considered seasonal changes, and if the beach widths return to the same seasonal width each year, then the beach experiences seasonal changes but no long-term or inter-annual changes. If the seasonal beach widths become progressively wider or narrower, these changes become long-term or inter-annual change, and suggest a long-term beach change trend – accretion if the beach is widening and erosion if the beach is narrowing.

If development is at or near beach level, erosion of the beach can expose the development to damage from waves, flooding, and foundation scour. Additionally, waves that hit the coast bring with them vegetation, floating debris, sand, cobbles, and other material which can act like projectiles, adding to the wave forces and flood damage.

At present, approximately 66% of the California beaches have experienced erosion over the last few decades, with the main concentration of eroding beaches occurring in southern California (Hapke *et al.* 2006). This erosion has been due to a combination of diminished sand supplies and increased removal of sand by waves and currents. With rising sea level, beach erosion is likely to increase due to both increased wave energy[98] that can carry sand offshore or away from the beach, and to decreased supply of new sediments to the coast.[99]

There are several factors that will contribute to the effects of sea level rise on seasonal and inter-annual beach change. There will be the changes to the beach due to inundation by rising water levels, as shown in Figure B-4 (see the discussion on inundation earlier in this Appendix for more information on how to determine this change). If the beach cannot migrate inland to accommodate these changes, then the inundation will result in a direct loss or erosion of beach width. This will result in a narrower seasonal beach as well as inter-annual loss of beach.

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[97] See for example, Bascom 1980, Komar 1998, and Griggs *et al.* 2005.

[98] In shallow water, wave energy is proportional to the square of the water depth. As water depths increase with sea level rise, wave energy at the same location will likewise increase.

[99] Many parts of the developed coast are already experiencing drops in sand supplies due to upstream impoundments of water and sediment, more impervious surfaces, and sand mining.

Seasonal and inter-annual beach conditions will also be affected by changes to waves and sediment supply. Since waves are sensitive to bottom bathymetry, changes in sea level may change the diffraction and refraction of waves as they approach the coast, thereby changing the resulting mixture of beach-accreting and beach-eroding waves. However, the influence of climate change (not just rising sea level) on wave conditions, through changes in wave height, wave direction, storm frequency, and storm intensity, will likely be far more significant than the slight changes from bathymetric changes. In addition, changing precipitation patterns will modify the amount and timing of sediment delivery to the beach.

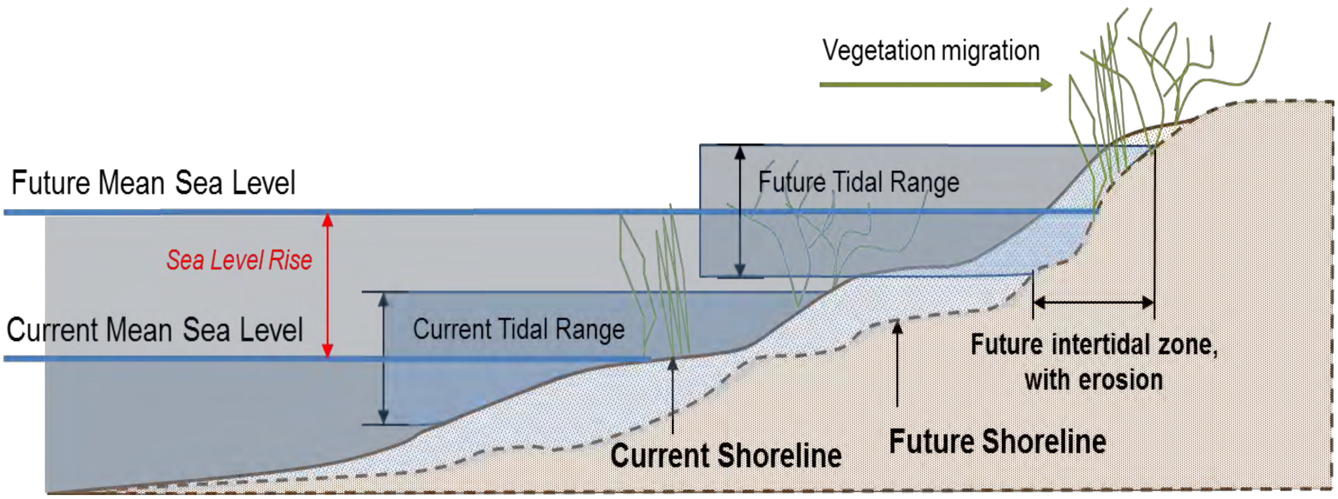

Figure B-4. Changes to the intertidal zone with sea level rise and erosion, without wave impacts. (*Source: L. Ewing, 2013*).

Bluff Erosion

A second type of erosion occurs on coastal bluffs.[100] There is no fully-accepted methodology for estimating future bluff erosion with sea level rise. Guidance for coastal analysts in Hawaii is to assume erosion will increase as a proportion of historical erosion (Hwang 2005). One approach used in the past by the Commission has been to apply one of the higher rates of historical erosion to represent average future trends. A more process-based methodology, used in the Pacific Institute study of erosion due to rising sea level, is to correlate future erosion rates of bluffs with a higher still water level that will allow waves to attack the bluff more frequently (Heberger *et al.* 2009; Revell *et al.* 2011). This approach assumes that all bluff erosion is due to wave impacts and that erosion rates will change over time as the beach or bluff experiences more frequent or more intense wave attack. Such an approach should be considered for examining bluff erosion with rising sea level. Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion can also be used.

[100] Bluffs can be built or expanded during interglacial cycles or following seismic uplift. Many of the marine terraces that are visible along the California coast are remnants of past beach areas that have been uplifted to become bluffs and cliffs. However, natural bluff rebuilding is a millennial or multi-millennial process, and it will not occur during the time periods over which most development projects are evaluated.

Bluff retreat occurs via many different mechanisms. Landslides, slumps, block failures, gullies, and rilling are examples of bluff retreat. At the most basic level, bluff retreat or collapse occurs when the forces leading to collapse of the bluff face are stronger than the forces holding the bluff in place. Forces causing bluff retreat can include earthquakes, wind, burrowing animals, gravity, rain, surface runoff, groundwater, and sheet flow. Coastal bluffs have the added factor of wave attack. Resistance to collapse is mainly a characteristic of the bluff material. For example, granitic bluffs like those along the Big Sur coast retreat at a much slower rate than the soft sandstone and marine terrace bluffs of Pacifica.

Coastal bluff erosion can occur throughout the year, but it often occurs during or after storm periods, when the dry beach will be narrow or non-existent. When coastal bluffs are fronted by wide sand beaches, most waves break on the beach face and the beaches protect the bluffs from direct wave attack. When the beach is narrow, there is less buffering of the wave energy and waves can break directly against the bluffs. A general depiction of bluff retreat with rising sea level is provided in Figure B-5.

Bluff retreat is often episodic – the bluff may be stable for a number of years and then retreat by tens of feet in a few hours or a few days. If the changes to a bluff are examined through endpoint analysis (*i.e.*, looking first at the initial position of the bluff and then at the position of the bluff sometime in the future), researchers can determine the amount of retreat that has occurred during the time from the initial to final positions. This gives information on an average retreat rate that has occurred, but provides no insight about the conditions leading to the retreat, the size of retreat, frequency of retreat events, or the progression of retreat and no retreat. The average retreat rates can give some indication of likely future changes, but they provide little information about when the next retreat episode might occur or how large it might be.

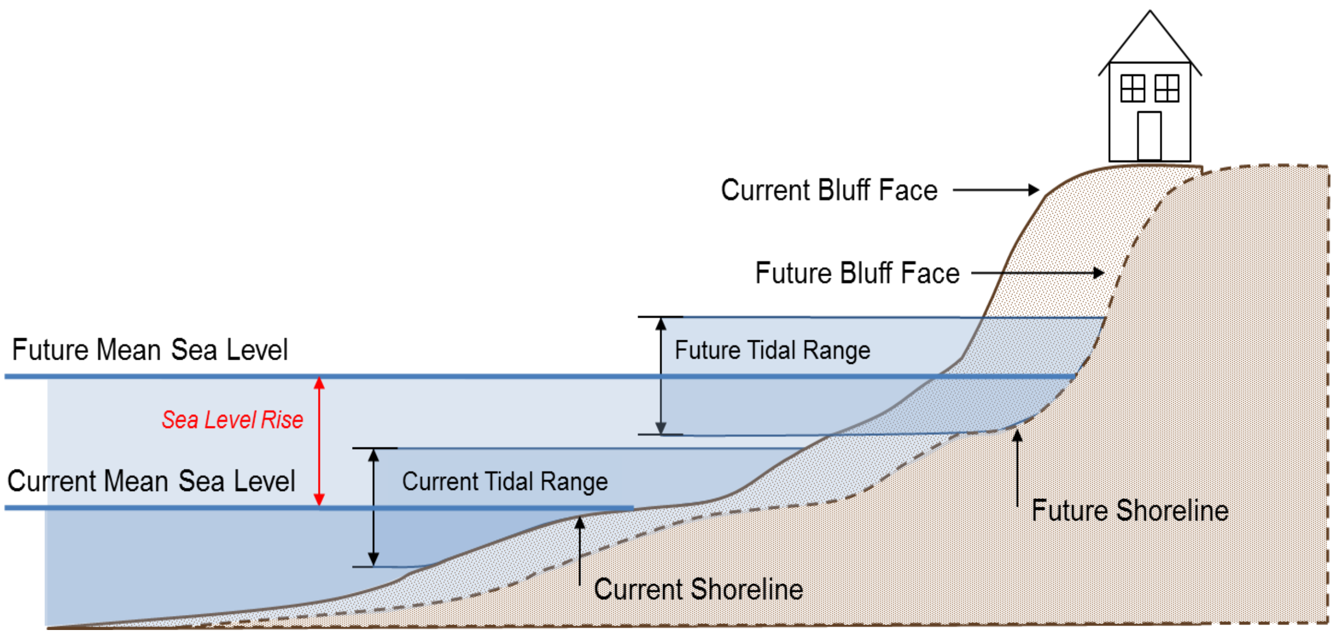

Figure B-5. Bluff erosion with changes in sea level. (*Source: L. Ewing, 2013*).

Dune Erosion

Just as there is no fully-accepted methodology for estimating changes to beach or bluff erosion with sea level rise, there is no fully-accepted methodology for dune erosion. A methodology somewhat similar to that for bluff erosion has been developed for dunes (Heberger *et al.* 2009; Revell *et al.* 2011), and such an approach should be considered for examining dune erosion with rising sea level. Other approaches that recognize the influence of water levels in beach, bluff, or dune erosion may also be used.

Dune erosion occurs when the waves break at or near the dunes, pulling sediment out of the dune. This process deposits sand onto the beach or in the nearshore area, but can result in short-term dune retreat. If sand is not returned to the dunes following these periods of short-term retreat, the sand losses will contribute to long-term dune erosion. Damage will occur to development located on dunes when the dune retreats back to the location of development, either through reversible, short-term retreat or long-term erosion.

For individual cases, determinations of future retreat risk are based on the site-specific conditions and professional analysis and judgment. However, the lack of information about the contributions of all the erosive forces to dunes and the beach-dune interactions makes it challenging to anticipate future changes to coastal dune retreat due to rising sea level and increased wave forces. As with beaches and bluffs for most situations, historical conditions provide a lower limit for future dune *retreat*, or the upper limit of dune *advance* for those sites that are now experiencing accretion or quasi-stability. Projections of future erosion should either: 1) use the high range of historical erosion; 2) develop a sea level rise influenced erosion rate, as done by Heberger *et al.* (2009) or Revell *et al.* (2011); or, 3) develop another approach that considers shoreline changes that are likely to occur under rising sea level conditions.

Table B-3. General Resources for Information on Beach, Bluff and Dune Erosion

Resource	Description	Link
Aerial Photographs	Useful for general information on shoreline trends; ortho-rectified photos can help quantify trends.	California Coastal Records Project, www.californiacoastline.org; Huntington Library; Local Libraries
LIDAR	Fairly detailed topography that can provide GIS layers for current conditions and is comparable with LIDAR data sets for temporal changes.	NOAA's Digital Coast, http://coast.noaa.gov/digitalcoast/data/coastallidar
USGS National Assessment of Shoreline Change with GIS Compilation of Vector Shorelines	Statewide inter-annual beach and bluff erosion; GIS shorelines available for sandy shorelines & cliff edge, showing historical changes for long-term (70 to 100 years) and short-term (25 to 50 years). No projections of future erosion rates available.	Sandy Shorelines – Open File Report 2006-1219, http://pubs.usgs.gov/of/2006/1219, and GIS Data in Open File 2006-1251, http://pubs.usgs.gov/of/2006/1251; Bluff Shorelines – Open File Report 2007-1133, http://pubs.usgs.gov/of/2007/1133, and GIS Data in Open File 2007-1251, http://pubs.usgs.gov/of/2007/1112

Regional Sediment Management Studies	Summaries of seasonal and long-term erosion studies	CSMW Website, http://dbw.ca.gov/csmw/default.aspx; California Beach Erosion Assessment Survey, http://dbw.ca.gov/csmw/library.aspx
US Army Corps of Engineers, Coast of California Studies	Summaries of seasonal and long-term erosion studies	Studies for many regions are available through an internet search (addresses are too numerous to list here)
Beach Profiles and Surveys	Detailed beach or bluff changes with time	NOAA's Digital Coast, https://coast.noaa.gov/digitalcoast/tools/ US Army Corps of Engineers; Regional Beach Studies; University Studies
The Impacts of Sea Level Rise on the California Coast (Pacific Institute Report)	Expected changes to bluff position over time for sea level rise of 4.6 ft (1.4 m) from 2000 to 2100 for California coast from Oregon border through Santa Barbara County.	Pacific Institute Website, http://www.pacinst.org/reports/sea_level_rise/maps/
CoSMoS	**Currently available for Point Arena to the Mexico border, with a statewide expansion anticipated in 2018/2019. The Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that allows detailed predictions of coastal flooding due to both future sea level rise and storms, and integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat)**	https://walrus.wr.usgs.gov/coastal_processes/cosmos/ http://data.pointblue.org/apps/ocof/cms/
TNC Coastal Resilience	**An online mapping tool showing potential impacts from sea level rise and coastal hazards designed to help communities develop and implement solutions that incorporate ecosystem-based adaptation approaches. Available statewide with more detailed modelling for Monterey Bay, Santa Barbara, Ventura, and Santa Monica.**	http://maps.coastalresilience.org/california/

Outcome from Step 4: *Provide projections of future long-term beach, bluff or dune erosion that takes into account sea level rise. For locations without any influence from storm surge, or wave energy, the identification of the extent of beach, bluff or dune erosion may be sufficient for project analysis and planning efforts. This projected new erosion area may also be useful for anticipating the appropriate setback distance for otherwise stable land forms (If slope stability is a concern, refer to Commission guidance on setbacks (*http://www.coastal.ca.gov/W-11.5-2mm3.pdf*)). For most open coast situations, this information will be used to inform further project analysis and planning that examines erosion, surge and storm conditions.*

Step 5 – Determine wave, storm wave, wave runup, and flooding conditions

The main concerns with waves, storm waves, and runup are flooding and damage from wave impacts. Flooding is the temporary wetting of an area by waves, wave runup, surge, atmospheric forcing (such as water elevation during El Niño events) and, at river mouths, the combination of waves and river flows. Wave impacts occur when high-energy waves, often associated with storms, reach backshore areas or development. Coastal flooding and wave impacts are worst when they coincide with high water level events (high tide plus high inundation). As sea level rises, inundation will move inland, and so will flooding and wave impacts. Beach erosion will aggravate these conditions and add to the inland extent of impacts.

Flooding

In most situations, factors that result in high water conditions, such as tides, surge, El Niño events, and PDOs, should be used to determine flood levels and flood areas, as shown below. If the area is exposed to storm waves, these forces should be examined as well.

Future Flooding Level = Higher High Tide + Sea Level Rise + Surge + Forcing + Wave Runup

Flooding Areas = Flooding + Seasonal Eroded Beach + Long-Term Beach Erosion

Waves

Waves, like tides, cause constant changes to the water levels that are observed at the coast. The rhythmic lapping of waves on the beach during summer can be one of the joys of a beach visit. At other times of the year, waves can increase in size and energy and damage or destroy buildings, and cause erosion of bluffs and cliffs. Routine ocean waves are generated by wind blowing across the surface of the water and can travel far from their source, combining with waves generated from other locations to produce the rather erratic and choppy water levels that are seen in most of the ocean. As waves move into shallow water and approach land, they are strongly modified by the offshore bathymetry. They take on a more uniform appearance, aligning somewhat parallel to the shoreline through processes of refraction and diffraction. During most of the year, moderate short-period waves break once they are in water depths of approximately 1.3 times the wave height.

Wave impacts depend greatly upon storm activity – both the intensity and the duration of the storm. Normally projects have used design wave conditions comparable to the 100-year event. For critical infrastructure or development with a long life expectancy, it may be advisable to use a greater design standard, such as a 200-year or 500-year event. It may be suitable for some proposed projects to adjust design waves or the frequency of high energy waves to analyze the consequences of worsening wave impacts.

Waves also vary greatly with bathymetry; offshore reefs and sand bars can cause waves to break far from the coast and greatly reduce the energy of the waves that come onshore. Therefore, changes in offshore water depths can alter the nature of nearshore wave propagation and resultant onshore waves. For areas with complex offshore bathymetry, wave impact changes due to rising sea level may need to be examined in the context of both offshore and nearshore conditions.

Wave impacts to the coast, to coastal bluff erosion and inland development, should be analyzed under the conditions most likely to cause harm. Those conditions normally occur in winter when most of the sand has moved offshore leaving only a reduced dry sand beach to dissipate wave energy (this seasonal change in beach width is often referred to as short-term or seasonal erosion). On beaches that will experience long-term erosion, trends expected to occur over the entire expected life of the development should also be considered. Just as the beach conditions to analyze should be those least likely to protect from damage over the life of the development, the water level conditions considered should also be those most likely to contribute to damage over the life of the development. Waves that cause significant damage during high tide will be less damaging during low tide; all other things being equal, waves will cause more inland flooding and impact damage when water levels are higher. Since water levels will increase over the life of the development due to rising sea level, the development should be examined for the amount of sea level rise (or a scenario of sea level rise conditions) that is likely to occur throughout the expected life of the development. Then, the wave impact analysis should examine the consequences of a 100-year design storm event using the combined water levels that are likely to occur with high water conditions and sea level rise, as well as a long-term and seasonally eroded beach.

Eroded Beach Conditions = Seasonal Erosion + Long-Term Erosion*

High Water Conditions = High Tide + Relative Sea Level Rise* + Atmospheric Forcing

Wave Conditions = 100-year Design Storm + High Water + Eroded Beach

* The time period for both long-term erosion and relative sea level rise will be at least as long as the expected life of the development.

The remaining discussion provides general information about waves, the California wave climate, and coastal flooding. It is provided to acquaint readers to the main issues associated with waves and coastal flooding. Readers with a strong background in waves or coastal processes may want to skim or skip the rest of this section.

Storm Waves

During storm conditions, winds can transfer large amounts of energy into waves, increasing wave height, length, and period. Energy transfer to waves depends upon three conditions: the wind energy that is available to be transferred to the water (intensity); the length of time over which the wind blows (duration); and the area over which the wind blows (the fetch). As any of these conditions increases, the energy in the waves will increase, as will the energy that these waves bring to the coastline. Coastal scientists separate waves that are generated far from the coast (swell) from waves that are locally generated (seas). Storms in the mid-Pacific can cause storm-like wave conditions along the coast, even when there are no storms in the area. Likewise, a local storm can cause storm waves along one part of the coast while waves in other sections of the coast may be fairly mild.

Some of the worst storm wave conditions occur when there are intense storms along a large portion of the coast and when this large, distantly generated swell combines with local seas. The 1982/83 El Niño has been cited often as one of the more damaging storm seasons in recent times. In late January 1983, waves from a distant storm combined with locally generated waves and the highest tides of the year. This one storm caused substantial damage along much of the California Coast. The coast was not able to recover before a series of storms in February and March caused additional damage. The full 1982/83 El Niño storm season resulted in damage to approximately 3,000 homes and 900 businesses and destruction of 33 buildings. Damages exceeded $100 million to structures and $35 million to public recreational infrastructure (in 1982 dollars; Flick 1998).

Wave Runup

Wave runup, as depicted in Figure B-6, is the distance or extent to which water from a breaking wave will spread up the shoreline. Much of the wave energy will dissipate during breaking, but wave runup can also be damaging. The runup water moves quickly and can scour or erode the shoreline areas (including the beach), damage structures, and flood inland areas.

Damage from waves and wave runup may increase in the future, due both to rising sea level and to changes in storm intensity and frequency. Waves will break farther landward when water levels are higher. Therefore, increased water levels due to tides, surge, ENSO or PDO variability, or sea level rise will enable more wave energy to reach the beach, back shore, or inland development. The higher water levels do not change the waves. Rather, higher water levels change the point of impact, the extent of runup, and the frequency of wave impact. In locations where high waves now hit the coast, that frequency will increase; in locations where high waves rarely hit the coast, exposure to wave impacts will increase. Increased exposure to wave impacts or wave runup can cause a greater risk of flooding, erosion, bluff failure, and/or damage to development. But, since the focusing of wave energy is strongly influenced by offshore bathymetry, locations of wave exposure may also change with rising sea level and modifications in wave propagation might result from future differences in water depths.

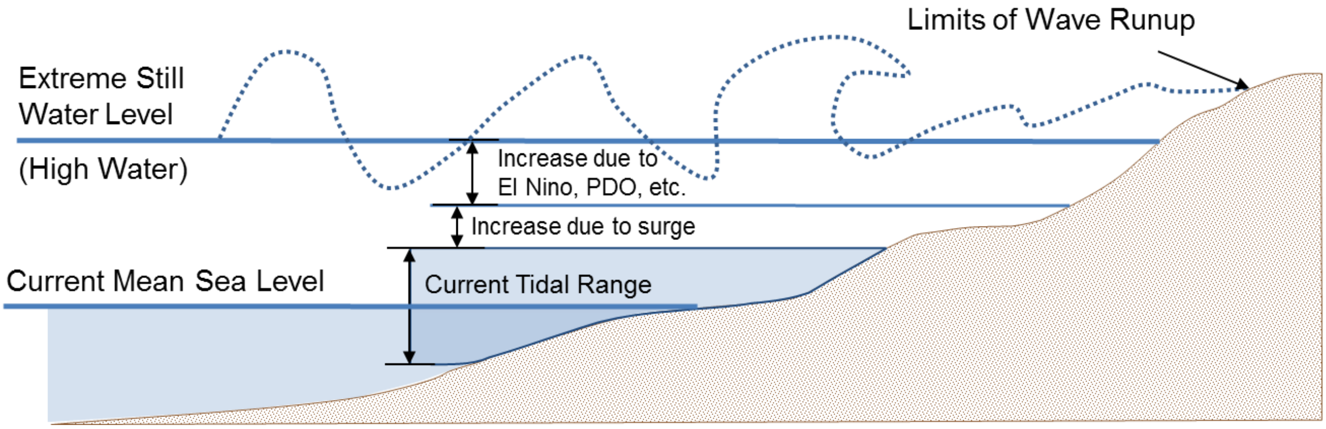

Figure B-6. Wave runup combined with extreme still water (High Water). (*Source: L. Ewing, 2013*).

Summary

Coastal flooding is a significant problem now and it will increase with rising sea level. At present, about 210,000 people in California are living in areas at risk from a 100-year flood event (Heberger *et al.* 2009). A rise in sea level of 55 in (1.4 m) with no change in development patterns or growth along the coast could put 418,000 to 480,000 people at risk from a 100-year flood (Cooley *et al.* 2012). An additional fraction of the California population that relies on critical infrastructure located in potentially hazardous areas is also vulnerable and increases in storm intensity or in the density of development in flood-prone areas will increase the number of people at risk from flooding.

The frequency and intensity of high wave events depends upon the storm conditions that generate the waves. There is less consistency in the output of climate models related to projections of future storm conditions than there has been for temperature projections. A recent report on coastal flooding from years 2000 to 2100 for the California coast has found that "storm activity is not projected to intensify or appreciably change the characteristics of winter nearshore wave activity of the twenty-first century" (Bromirski *et al.* 2012, p. 33). This continuation of current storm conditions is not, however, an indication that storms will not be a problem in the future. Storm damage is expected to continue, and, if sea level rise by the end of the twenty-first century reaches the high projections of about 55 in (1.4 m), "coastal managers can anticipate that coastal flooding events of much greater magnitude than those during the 1982-83 El Niño will occur annually." (Bromirski *et al.* 2012, p. 36)

For most situations, the 100-year storm event should be used as the design storm. This is equivalent to a storm with a 1% annual probability of occurrence. However, most development does outlast one year and this probability of occurrence grows over time such that there is a 22% probability of occurrence during a 25-year period and over 53% probability that this storm will occur at least once during a 75-year period. Even so, the 100-year storm event, like the 100-year flood event, is often used as a design standard for development. However, for structures with a very long projected life or for which storm protection is very critical, a larger, 200-year or 500-year event might be appropriate.

Table B-4 lists many of the resources that are available for finding regional or state-wide information on waves and flooding. Local communities may have records of major erosion episodes or flood events as well.

Table B-4. General Resources for Flooding and Wave Impacts

Resource	Description	Link
CDIP (Coastal Data Information Program)	Current and historical information on wind, waves, and water temperature, wave and swell models and forecasting. As of 2013, there are 19 active stations along the California coast.	http://cdip.ucsd.edu/
Flood Insurance Rate Maps (FIRMs)	FEMA is updating coastal flood maps. Existing FIRMs are based on 1980s topography; flooding includes seasonal beach change but not long-term erosion. Maps do not include sea level rise. Inclusion of a site shows a flood hazard; but exclusion does not necessarily indicate a lack of flood hazard.	FEMA Flood Map Service Center, https://msc.fema.gov/portal
FEMA Flood Hazard Mapping Guidance	*Subsection D.2.8* provides guidance for calculating wave runup and overtopping on barriers. There are special cases for steep slopes and where runup exceeds the barrier or bluff crest.	https://www.fema.gov/media-library/assets/documents/13948
Regional Sediment Management Studies	Some studies show elements of beach flooding and wave impacts.	http://dbw.ca.gov/csmw/default.aspx
Cal-Adapt – Exploring California's Climate	**Represents inundation location and depth for the San Francisco Bay, the Sacramento-San Joaquin River Delta and California coast resulting from different increments of sea level rise coupled with extreme storm events. Incorporates real, time series water level data from past (near 100 year) storm events to capture the dynamic effect of storm surges in modeling inundation using a three dimensional hydrodynamic model (per Radke et al., 2017).**	http://cal-adapt.org/tools/slr-calflod-3d/
US Army Corps of Engineers, Coastal Engineering Manual	Detailed information on all aspects of deep-water wave transformation, shoaling, runup, and overtopping.	https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/
European Overtopping Manual	Descriptions of available methods for assessing overtopping and its consequences. Provides techniques to predict wave overtopping at seawalls, flood embankments, breakwaters and other shoreline structures facing waves. Supported by web-based programs for the calculation of overtopping discharge and design details.	http://www.overtopping-manual.com/

CoSMoS	**Currently available for Point Arena to the Mexico border, with a statewide expansion anticipated in 2018/2019. The Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that allows detailed predictions of coastal flooding due to both future sea level rise and storms, and integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat)**	https://walrus.wr.usgs.gov/coastal_processes/cosmos/ http://data.pointblue.org/apps/ocof/cms/
TNC Coastal Resilience	**An online mapping tool showing potential impacts from sea level rise and coastal hazards designed to help communities develop and implement solutions that incorporate ecosystem-based adaptation approaches. Available statewide with more detailed modelling for Monterey Bay, Santa Barbara, Ventura, and Santa Monica.**	http://maps.coastalresilience.org/california/

Outcome from Step 5: *Provide projections of future flooding and wave impacts resulting from waves, storm waves and runup, taking into account sea level rise.*

Step 6 – Examine potential flooding from extreme events

Extreme events[101], by their very nature, are those beyond the normal events that are considered in most shoreline studies. Examples of extreme events that might occur along the California coast include:

- An individual storm with an intensity at or above the 100-year event
- A series of large, long-duration storms during high tides
- A local storm that coincides with the arrival of distant swell and high tides
- Rapid subsidence, as might happen along the Northern California coast during a Cascadia Subduction Zone earthquake
- Global sea level rise greater than that projected to occur by 2100, when combined with a large storm during normal tides

Planning and project analysis need to consider and anticipate the consequences of these outlier events. In many situations, this assessment might be a qualitative consideration of consequences that could happen if an extreme event does occur. Analysis of the consequences of extreme events presents opportunities to address some of those potential impacts through design and adaptation.

[101] In its report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, the IPCC defines extreme events as "a facet of climate variability under stable or changing climate conditions. They are defined as the occurrence of a value or weather or climate variable above (or below) a threshold value near the upper (or lower) ends ("tails") of the range of observed values of the variable" (IPCC 2012).

In California, there may be some worsening of extreme precipitation and inland flooding from projected changes to atmospheric rivers, narrow bands of concentrated moisture in the atmosphere. In general, however, future extremes are likely to be comparable to the extremes of today, but with the added influence of sea level rise. Extreme storm waves or floods can be addressed with the guidance provided earlier, except that the extreme storm conditions would be used. For tsunamis it is recommended that, for most situations, the appropriate projection of sea level rise be added to the currently projected inundation level from tsunamis. This will provide a close approximation for future inundation from extreme tsunamis. If a detailed analysis of future tsunami impacts is needed, the analysis should be conducted by someone experienced in modeling tsunami waves.

Tsunamis

Tsunamis are large, long-period waves that can be generated by submarine landslides, subaerial landslides (slope failures from land into a water body), large submarine earthquakes, meteors, or volcanic eruptions. They are rare events, but can be extremely destructive when they occur. The extent of tsunami damage will increase as rising water levels allow tsunami waves to extend farther inland. Thus the tsunami inundation zone will expand inland with rising sea level. There has been no research that suggests that climate change will increase the intensity or frequency of seismically-generated tsunamis. However, the number and size of coastal subaerial landslides may increase because of increased coastal erosion due to sea level rise, which in turn may increase the potential for tsunamigenic landslides along the California coast (Highland 2004; Walder *et al.* 2003).

The detailed changes to the inundation zone with rising sea level need to be determined by modeling; however, modeling of long-waves, such as tsunamis, is a specialized area of coastal engineering, and will not be covered in this general Guidance. For most situations, it will be sufficient to get information on possible inundation from the most recent tsunami inundation maps (currently on the Department of Conservation website, http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx). The California Geological Survey and California Governor's Office of Emergency Services are creating new tsunami inundation maps based on probabilistic tsunami hazard analysis (CPTHAWG 2015). As a rough approximation, the change to the tsunami inundation level can be estimated as equal to the change in water elevation due to sea level; a 1-ft rise in sea level could be assumed to result in a 1-ft rise in the inundation elevation. However, in many places, particularly shallow bays, harbors, and estuaries, the change in tsunami inundation zone is likely to scale non-linearly with sea level rise and require careful modeling. California Geological Survey is also working to evaluate the impact of sea level rise with numerical tsunami modeling to verify that an additive approach (tsunami height + SLR) is the appropriate method for integrating SLR and tsunami inundation together. In areas with high tsunami hazards, or where critical resources are at risk, a site-specific analysis of sea level rise impacts on tsunami hazards is crucial, and someone experienced in modeling tsunami waves should be consulted.

Summary

Many different factors affect the actual water levels that occur along the coast and resulting hazards. In California, waves and tides have the largest routine effect on water levels. Tsunamis may have a very large, but infrequent effect on water levels. Sea level rise will affect water levels all along the coast. Until the mid-century, tides and storms are expected to have the biggest effects on local water levels, with sea level rise being a growing concern. After Year 2050, sea level rise is expected to become increasingly influential on water levels and in contributing to damages to inland areas from flooding, erosion and wave impacts. Table B-5 provides a general characterization of all the factors that can affect local water levels, with general estimates of their range and frequency of occurrence.

Outcome from Step 6: *Projections of potential flooding from extreme events including rapid subsidence, extreme precipitation, and tsunamis.*

Table B-5. Factors that Influence Local Water Level Conditions

Factors Affecting Water Level	Typical Range for CA Coast (ft)	Typical Range for CA Coast (m)	Period of Influence	Frequency
Tides	3 – 10	1 – 3	Hours	Twice daily
Low pressure	1.5	0.5	Days	Many times a year
Storm Surge	2 – 3	0.6 – 1.0	Days	Several times a year
Storm Waves	3 – 15	1 – 5	Hours	Several times a year
El Niño events (within the ENSO cycle)	<1.5	< 0.5	Months - Years	2 – 7 years
Tsunami waves	20 – 50 (max) 3 – 10 (typical)	6 – 15 (max) 1 – 3 (typical)	Minutes, Hours, Days	Infrequent but unpredictable
Historical Sea Level, over 100 years	0.7	0.2	Ongoing	Persistent
OPC Sea Level Projections 2000 – 2050 (SF tide gauge; see also App. G)	**1.1 – 2.7**	**0.3 – 0.8**	Ongoing	Persistent
OPC Sea Level Projections 2000 – 2100 (SF tide gauge; see also App. G)	**3.4 – 10.2**	**1.0 – 3.1**	Ongoing	Persistent

Note that all values are approximations. The conversions between feet and meters have been rounded to maintain the general ranges and they are not exact conversions. *Sources*: Flick 1998; **OPC 2018**; Personal communications from Dr. Robert Guza (Scripps Institution of Oceanography), Dr. William O'Reilly (Scripps Institution of Oceanography and University of California, Berkeley), and Rick Wilson, California Geological Survey; and professional judgment of staff.

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Appendix C

Resources for Addressing Sea Level Rise

This section contains lists of sea level rise viewers, guidebooks, guidance documents, and state agency-produced resources, and data clearing houses related to sea level rise. These resources will be particularly relevant for informing Steps 1-6 of the LCP planning process (Chapter 5). Tables include:

- Table C-1 – Sea Level Rise Mapping Tools.
  This may be particularly relevant for Steps 1-3.

- Table C-2 – Sea Level Rise Data and Resource Clearinghouses.
  This may be particularly relevant for Steps 1-4.

- Table C-3 – Adaptation Planning Guidebooks.
  This may be particularly relevant for Steps 1-3.

- Table C-4 – Resources for Assessing Adaptation Measures.
  This may be particularly relevant for Step 4.

- Table C-5 – Examples of Sea Level Rise Vulnerability Assessments in California.
  This may be particularly relevant for Steps 1-3.

- Table C-6 – California Climate Adaptation Plans that Address Sea Level Rise.
  This may be particularly relevant for Steps 1-4.

- Table C-7 – California State Agency Resources

Table C-1. Sea Level Rise Mapping Tools

Tool	Description	Link
Statewide		
NOAA Digital Coast Sea Level Rise and Coastal Flooding Impacts Viewer	Displays potential future sea levels with a slider bar. Communicates spatial uncertainty of mapped sea level rise, overlays social and economic data onto sea level rise maps, and models potential marsh migration due to sea level rise. Maps do not include any influence of beach or dune erosion.	https://coast.noaa.gov/digitalcoast/tools/slr.html
Cal-Adapt – Exploring California's Climate	**Represents inundation location and depth for the San Francisco Bay, the Sacramento-San Joaquin River Delta and California coast resulting from different increments of sea level rise coupled with extreme storm events. Incorporates real, time series water level data from past (near 100 year) storm events to capture the dynamic effect of storm surges in modeling inundation using a three dimensional hydrodynamic model (per Radke et al., 2017).**	http://cal-adapt.org/tools/slr-calflod-3d/
Climate Central Surging Seas	Overlays sea level rise data with socio-economic information and ability to analyze property values, population, socio-economic status, ethnicity, and income or areas at risk. Can compare exposure across the whole state or selected county.	http://sealevel.climatecentral.org/ssrf/california
Pacific Institute Sea Level Rise Maps (Heberger *et al.* 2009)	Downloadable PDF maps showing the coastal flood and erosion hazard zones from the 2009 study. Data are overlaid on aerial photographs and show major roads. Also available are an interactive online map and downloadable maps showing sea level rise and population and property at risk, miles of vulnerable roads and railroads, vulnerable power plants and wastewater treatment plants, and wetland migration potential.	http://www.pacinst.org/reports/sea_level_rise/maps/ For the 2009 report *The Impacts of Sea-Level Rise on the California Coast*, see: http://pacinst.org/publication/the-impacts-of-sea-level-rise-on-the-california-coast/

Sea Level Affecting Marshes Model (SLAMM)	Simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summarized in tabular and graphical form.	http://www.warrenpinnacle.com/prof/SLAMM
Coastal Storm Modeling System (CoSMoS); tool hosted by Our Coast Our Future	**Currently available for Point Arena to the Mexico border, with a statewide expansion anticipated in 2018/2019. The Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that allows detailed predictions of coastal flooding due to both future sea level rise and storms, and integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat)**	https://walrus.wr.usgs.gov/coastal_processes/cosmos/ http://data.pointblue.org/apps/ocof/cms/
TNC Coastal Resilience	**An online mapping tool showing potential impacts from sea level rise and coastal hazards designed to help communities develop and implement solutions that incorporate ecosystem-based adaptation approaches. Available statewide with more detailed modelling for Monterey Bay, Santa Barbara, Ventura, and Santa Monica.**	http://maps.coastalresilience.org/california/
Humboldt Bay Sea Level Rise Adaptation Project	This project is a multi-phased, regional collaboration. Phase I produced the *Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment* which describes current shoreline conditions and vulnerabilities under the current tidal regime. Phase II included hydrodynamic modeling to develop vulnerability maps of areas surrounding Humboldt Bay vulnerable to inundation from existing and future sea levels. Phase II produced the *Humboldt Bay Sea Level Rise Modeling Inundation Mapping Report* and the *Humboldt Bay Sea Level Rise Conceptual Groundwater Model*.	All reports are available at: http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project

Table C-2. Sea Level Rise Data and Resource Clearinghouses

Resource	Description	Link
California State Adaptation Clearinghouse	**Hosted by the OPR Integrated Climate Adaptation and Resiliency Program (ICARP), a centralized source of information that provides the resources necessary to guide decision makers at the state, regional, and local levels when planning for and implementing climate adaptation projects to promote resiliency to climate change in California.**	http://opr.ca.gov/clearinghouse/adaptation/
California Climate Commons	Offers a point of access to climate change data and related resources, information about the science that produced it, and the opportunity to communicate with others about applying climate change science to conservation in California.	http://climate.calcommons.org/
Climate Adaptation Knowledge Exchange (CAKE)	Provides an online library of climate adaptation case studies and resources, plus ways to connect with an online climate adaptation community/ network.	http://www.cakex.org/
Ecosystem Based Management Tools Network Database	Provides a searchable database of tools available for climate adaptation, conservation planning, sea level rise impact assessment, *etc.*	http://www.ebmtools.org/about_ebm_tools.html
Climate.Data.gov	Recently launched federal government data portal that includes a number of data sets on climate change, including sea level rise impacts.	http://www.data.gov/climate/
NOAA Digital Coast	This NOAA-sponsored website is focused on helping communities address coastal issues. The Digital Coast provides coastal data, tools, training, and information from reputable sources.	http://coast.noaa.gov/digitalcoast/

Table C-3. Adaptation Planning Guidebooks

Title	Description	Link
Scanning the Conservation Horizon (National Wildlife Federation 2011)	Designed to assist conservation and resource professionals to better plan, execute, and interpret climate change vulnerability assessments.	https://www.nwf.org/~/media/pdfs/global-warming/climate-smart-conservation/nwfscanningtheconservationhorizonfinal92311.ashx
Adapting to Sea Level Rise: A Guide for California's Coastal Communities (Russell and Griggs 2012)	Intended to assist California's coastal managers and community planners in developing adaptation plans for sea level rise that are suited to their local conditions and communities.	http://seymourcenter.ucsc.edu/OOB/Adapting%20to%20Sea%20Level%20Rise.pdf
California Adaptation Planning Guide (APG) (Cal EMA/CNRA 2012)	Provides guidance to support regional and local communities in proactively addressing the unavoidable consequences of climate change. Includes a step-by-step process for local and regional climate vulnerability assessment and adaptation strategy development.	http://resources.ca.gov/climate/safeguarding/local-action/
Preparing for Climate Change: A Guidebook for Regional and State Governments (Snover *et al.* 2007)	Assists decision makers in a local, regional, or state government prepare for climate change by recommending a detailed, easy-to-understand process for climate change preparedness based on familiar resources and tools.	http://cses.washington.edu/db/pdf/snoveretalgb574.pdf
Adapting to Climate Change: a Planning Guide for State Coastal Managers (NOAA 2010)	Guide offers a framework for state coastal managers to follow as they develop and implement climate change adaptation plans in their own states.	https://coast.noaa.gov/czm/media/adaptationguide.pdf

Using Scenarios to Explore Climate Change: A Handbook for Practitioners (NPS 2013)	Describes the five-step process for developing multivariate climate change scenarios taught by the Global Business Network (GBN). Detailed instructions are provided on how to accomplish each step. Appendices include a hypothetical scenario exercise that demonstrates how to implement the process and some early examples of how national parks are using climate change scenarios to inform planning and decision making.	http://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf
Scenario Planning for Climate Change Adaptation: A Guidance for Resource Managers (Moore *et al.* 2013)	Step-by-step guide to using scenarios to plan for climate change adaptation for natural resource managers, planners, scientists, and other stakeholders working at a local or regional scale to develop resource management approaches that take future climate change impacts and other important uncertainties into account.	http://scc.ca.gov/files/2013/07/Scen-planning_17july2013_FINAL-3.pdf

Table C-4. Resources for Assessing Adaptation Measures

Resource	Description	Link
General		
Georgetown Climate Center's Climate Adaptation Toolkit – Sea Level Rise and Coastal Land Use	Explores 18 different land-use tools that can be used to preemptively respond to the threats posed by sea level rise to both public and private coastal development and infrastructure, and strives to assist governments in determining which tools to employ to meet their unique socio-economic and political contexts.	http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use
What Will Adaptation Cost? (ERGI 2013)	"This report provides a framework that community leaders and planners can use to make more economically informed decisions about adapting to sea level rise and storm flooding. The four-step framework can be used to perform a holistic assessment of costs and benefits of different adaptation approaches across a community, or to focus in on select infrastructure. The report also discusses the expertise needed at each step in the process."	https://coast.noaa.gov/data/digitalcoast/pdf/adaptation-report.pdf
Center for Ocean Solutions: Adaptation in Action: Examples from the Field	Provides case studies of various adaptation strategies including overlay zones, non-conformities, setbacks, buffers, development conditions, shoreline protection devices, managed retreat, capital improvement programs, acquisition programs, conservation easements, rolling easements, tax incentives, transfer development rights, and real estate disclosures.	http://www.centerforoceansolutions.org/sites/default/files/Application%20of%20Land%20Use%20Practices%20and%20Tools%20to%20Prepare.pdf

Combatting Sea Level Rise in Southern California: How Local Government Can Seize Adaptation Opportunities While Minimizing Legal Risk (Herzog and Hecht 2013)	Identifies how local governments can harness legal doctrines to support aggressive, innovative strategies to achieve successful sea level rise adaptation outcomes for Southern California while minimizing legal risk. Broadly outlines likely sea level rise impacts in Southern California, and evaluates the risks and opportunities of potential protection, accommodation, and retreat adaptation strategies that local governments could deploy.	http://www.law.ucla.edu/~/media/Files/UCLA/Law/Pages/Publications/CEN_EMM_PUB%20Combatting%20Sea-Level%20Rise.ashx
Strategies for Erosion-Related Impacts		
Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay	Provides a technical evaluation of various erosion mitigation measures, conducts a cost benefit analysis of some of the more promising measures, and includes recommendations for addressing coastal erosion in Southern Monterey Bay. The report is intended to be relevant for other areas of California as well.	https://montereybay.noaa.gov/research/techreports/tresapwa2012.html
Rolling Easements		
Rolling Easements-A Primer (Titus 2011)	Examines more than a dozen different legal approaches to rolling easements. It differentiates opportunities for legislatures, regulators, land trusts, developers, and individual landowners. Considers different shoreline environments (*e.g.*, wetlands, barrier islands) and different objectives (*e.g.*, public access, wetland migration)	http://papers.risingsea.net/rolling-easements.html
No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast (Caldwell and Segall 2007)	Provides a description of sea level rise impacts to ecosystems and public access, strategies to address these impacts, and case study examples of rolling easement strategies for the California coast.	http://scholarship.law.berkeley.edu/cgi/viewcontent.cgi?article=1833&context=elq

Natural Resources		
PRBO Climate Smart Conservation	Lists science-based, climate-smart conservation planning and management tools and methods, including restoration projects designed for climate change and extremes.	http://www.pointblue.org/priorities/climate-smart-conservation/
US Forest Service System for Assessing Vulnerability of Species- Climate Change Tool	Quantifies the relative impact of expected climate change effects for terrestrial vertebrate species.	http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/savs-climate-change-tool/
The Nature Conservancy: Reducing Climate Risk with Natural Infrastructure report	Presents a series of nine case studies in which natural, “green” infrastructure was successfully used to mitigate climate impacts. The economic costs and benefits of the green infrastructure are compared with traditional “gray” approaches.	http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/ca-green-vs-gray-report-2.pdf
CDFW Essential Habitat Connectivity Project	“The California Department of Fish and Wildlife and the California Department of Transportation (Caltrans) commissioned a team of consultants to produce a statewide assessment of essential habitat connectivity by February of 2010, using the best available science, datasets, spatial analyses, and modeling techniques. The goal was to identify large remaining blocks of intact habitat or natural landscape and model linkages between them that need to be maintained, particularly as corridors for wildlife.”	https://www.wildlife.ca.gov/Conservation/Planning/Connectivity
CDFW Areas of Conservation Emphasis tool	Provides a mapping tool and reports on the best available statewide, spatial information on California's biological richness, including species diversity, rarity, and sensitive habitats, as well as recreational needs and opportunities throughout the state, including fishing, hunting and wildlife-viewing.	http://www.dfg.ca.gov/biogeodata/ace/

Table C-5. Examples of Sea Level Rise Vulnerability Assessments in California

Title	Description	Link
Humboldt Bay Sea Level Rise Adaptation Planning Project	Multiphase project to assess vulnerability of Humboldt Bay shoreline and adjacent areas to sea level rise and coastal hazards.	http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project
Marin Ocean Coast Sea Level Rise Vulnerability Assessment (2018)	Assesses vulnerability of Marin County's ocean coastal areas to sea level rise, specifically evaluating 5 SLR and storm scenarios through approximately 2100. Findings are organized both by asset type and community.	https://www.marincounty.org/depts/cd/divisions/planning/csmart-sea-level-rise/csmart-publications-csmart-infospot
San Francisco Sea Level Rise Existing Data and Analyses Technical Memorandum (2016)	Summarizes existing data and analyses of SLR vulnerability within the Coastal Zone and lays the foundation for San Francisco's proposed LCP amendment.	http://default.sfplanning.org/plans-and-programs/local_coastal_prgm/20160506.SFLCP_SLR_Tech_Memo.FINAL.pdf
Plan Half Moon Bay Sea Level Rise Vulnerability Assessment (2016)	Identifies the primary vulnerabilities within Half Moon Bay and sets forth next steps that the City and other involved agencies may take to further assess and address these vulnerabilities.	http://nebula.wsimg.com/0849a308eececc2c58ce202e2851bade?AccessKeyId=06ACEAA5216D33A5C3B0&disposition=0&alloworigin=1
City of Monterey Final Sea Level Rise and Vulnerability Analyses, Existing Conditions and Issues Report (2016)	Provides a science-based assessment of climate change vulnerabilities that includes extensive field data gathering, and compilation of existing data and information.	https://www.monterey.org/Portals/0/Policies-Procedures/Planning/WorkProgram/LCP/16_0316_FINAL_Monterey_ExistingConditions_wAppendixA_WEB.pdf
City of Pacific Grove Climate Change Vulnerability Assessment (2015)	Provides an evaluation of potential significant impacts of climate change for the city's coastal zone with an emphasis on how anticipated climate change may affect people, resources, and infrastructure along the coast.	http://www.cityofpacificgrove.org/sites/default/files/general-documents/local-coastal-program/pg-lcp-final-vulnerability-assessment-011515.pdf
City of Morro Bay Community Vulnerability and Resilience Assessment (2017)	Provides a best estimate of likely future conditions, based on local demographic projections and the most recently available scientific projections of future climate conditions, given current trends.	http://www.morrobayca.gov/DocumentCenter/View/10676/Final-Draft--Revised-Community-Vulnerability-and-Resilience-Assessment-3-6-17?bidId=

City of Goleta Coastal Hazards Vulnerability Assessment and Fiscal Impact Report (2015)	**Provides a science-based assessment that includes extensive field data gathering, compilation of existing data and information, and the participation of stakeholders such as citizens, business owners, local organizations, and community leaders. Enhances community planning by identifying coastal hazards and associated vulnerabilities that are in balance with fiscal resources.**	https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/GoletaCoastalVulnerability.pdf
City of Oxnard Sea Level Rise Atlas (2016)	**Maps and identifies areas and assets at risk to existing and future conditions, including sea level rise.**	http://nebula.wsimg.com/64b81b1805381307f1e6492bf187b6d9?AccessKeyId=D91312DA8FC16C8BCDB9&disposition=0&alloworigin=1
County of San Diego Climate Change Vulnerability Assessment (2017)	**Identifies the primary threats from a changing climate facing the unincorporated areas of San Diego county, and its vulnerability to these threats.**	https://www.sandiegocounty.gov/content/dam/sdc/pds/advance/cap/publicreviewdocuments/PostBOSDocs/CAP%20Appendix%20D%20-%20Climate%20Change%20Vulnerability%20Assessment.pdf
City of Imperial Beach Sea Level Rise Assessment (2016)	**Identifies vulnerabilities from sea level rise and coastal hazards; a range of adaptation strategies including tradeoffs and economics; and recommends strategies over time that are politically digestible and economically feasible.**	http://www.imperialbeachca.gov/vertical/sites/%7B6283CA4C-E2BD-4DFA-A7F7-8D4ECD543E0F%7D/uploads/100516_IB_Sea_Level_Rise_Assessment_FINAL.pdf
Santa Barbara Sea Level Rise Vulnerability Study (Russell and Griggs 2012)	Assesses the vulnerability of the City of Santa Barbara to future sea level rise and related coastal hazards (by Years 2050 and 2100) based upon past events, shoreline topography, and exposure to sea level rise and wave attack. It also evaluates the likely impacts of coastal hazards to specific areas of the City, analyzes their risks and the City's ability to respond, and recommends potential adaptation responses.	http://www.energy.ca.gov/2012publications/CEC-500-2012-039/CEC-500-2012-039.pdf

City of Santa Cruz Climate Change Vulnerability Assessment (Griggs and Haddad 2011)	Delineates and evaluates the likely impacts of future climate change on the city of Santa Cruz, analyzes the risks that these hazards pose for the city, and then recommends potential adaptation responses to reduce the risk and exposure from these hazards in the future.	http://seymourcenter.ucsc.edu/OOB/SCClimateChangeVulnerabilityAssessment.pdf
Developing Climate Adaptation Strategies for San Luis Obispo County: Preliminary Vulnerability Assessment for Social Systems (Moser 2012)	Describes the likely impacts of climate change on the resources and social systems of San Luis Obispo County, and assesses key areas of vulnerability. Sea level rise is identified as a major source of risk to fishing, coastal tourism, coastal development, and infrastructure.	http://www.energy.ca.gov/2012publications/CEC-500-2012-054/CEC-500-2012-054.pdf
Monterey Bay Sea Level Rise Vulnerability Study (Monterey Bay National Marine Sanctuary and PWA ESA; In progress)	Will assess potential future impacts from sea level rise for the Monterey Bay region. The project will estimate the extent of future coastal erosion in Monterey Bay due to accelerated sea level rise and evaluate areas subjected to coastal flooding by inundation from wave action and/or storm surges. The project will update and refine existing Monterey Bay coastal hazard zones maps (erosion and flooding).	Project scope and grant details: http://scc.ca.gov/webmaster/ftp/pdf/sccbb/2012/1201/20120119Board03D_Monterey_Bay_Sea_Level_Rise.pdf
Sea Level Rise Vulnerability Study for the City of LA (Adapt LA) (USC Sea Grant 2013)	This report provides a summary of the initial research on the potential impacts of sea level rise and associated flooding from storms for coastal communities in the City of L.A. The study concentrates on the City's three coastal regions: Pacific Palisades from Malibu to Santa Monica; Venice and Playa del Rey; and San Pedro, Wilmington and the Port of Los Angeles.	http://dornsife.usc.edu/uscseagrant/la-slr/

See also the Coastal Commission's LCP Grant website for a status chart of sea level rise work completed by grantees (updated on an approximately quarterly basis).

Table C-6. California Climate Adaptation Plans that Address Sea Level Rise

Title	Description	Link
Marin Ocean Coast Sea Level Rise Adaptation Report (2018)	**Presents near-, medium-, and long-term options to accommodate, protect against, or retreat from the threats of SLR and extreme events and is intended to inform Marin County's Local Coastal Program (LCP), coastal permitting, and other county goals related to SLR preparation.**	https://www.marincounty.org/depts/cd/divisions/planning/csmart-sea-level-rise/csmart-publications-csmart-infospot
Morro Bay Sea Level Rise Adaptation Strategy Report (2018)	**Presents adaptation strategies for three sites within the City, selected to represent the general exposure of a type of hazard or asset.**	http://www.morro-bay.ca.us/DocumentCenter/View/11753/Sea-Level-Rise-Adaptation-Report-January-2018
Adapting to Rising Tides (ART) Project	The ART project is a collaborative planning effort led by the San Francisco Bay Conservation and Development Commission to help SF Bay Area communities adapt to rising sea levels. The project has started with a vulnerability assessment for a portion of the Alameda County shoreline.	http://www.adaptingtorisingtides.org/
Santa Cruz Climate Adaptation Plan	An update to the 2007 Hazard Mitigation Plan, the adaptation plan includes strategies and best available science for integrating climate change impacts into City of Santa Cruz operations.	Complete plan is available: http://www.cityofsantacruz.com/home/showdocument?id=23644
San Diego Bay Sea Level Rise Adaptation Strategy	The strategy provides measures to evaluate and manage risks from sea level rise and other climate change impacts, and includes a vulnerability assessment of community assets at risk, and broad recommendations to increase resilience of these assets.	http://icleiusa.org/wp-content/uploads/2015/08/San-Diego-Sea-Level-Rise.pdf

**** See also the Coastal Commission's LCP Grant website for a status chart of sea level rise work completed by grantees (updated on an approximately quarterly basis).***

Table C-7. California State Agency Resources

Agency	Document	Description and Link
California Natural Resources Agency	***Safeguarding California Plan: 2018 Update (2018)***	**An update to the 2014 Safeguarding document:** http://resources.ca.gov/docs/climate/safeguarding/update2018/safeguarding-california-plan-2018-update.pdf
	Safeguarding California from Climate Change (2014)	An update to the 2009 *California Climate Adaptation Strategy*: http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf
	California Climate Adaptation Strategy (2009)	Summarizes climate change impacts and recommends adaptation strategies across seven sectors: Public Health, Biodiversity and Habitat, Oceans and Coastal Resources, Water, Agriculture, Forestry, and Transportation and Energy: http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf
Office of the Governor	*Executive Order S-13-08* (2008)	This 2008 Executive Order required the CA Natural Resources Agency to develop a statewide climate adaptation strategy, and requested that the National Academy of Sciences convene an independent scientific panel to assess sea level rise in California. http://www.climatechange.ca.gov/state/executive_orders.html
	Executive Order B-30-15 (2015)	This 2015 Executive Order established an interim greenhouse gas reduction target of 40 percent below 1990 levels by 2030 to expand upon the targets already included in AB32 and emphasized the need for adaptation in line with the actions identified in the *Safeguarding California* document. http://gov.ca.gov/news.php?id=18938
California Ocean Protection Council (and the Coasts & Oceans Climate Action Team, or CO-CAT)	***State of California Sea-Level Rise Guidance: 2018 Update (2018)***	**Provides guidance for incorporating sea level rise projections into planning and decision making. Updated to include *Rising Seas* science, 2018:** http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/
	Rising Seas in California: An Update on Sea-Level Rise Science	**Provides a synthesis of the state of the science on sea-level rise and forms the scientific foundation for the updated OPC SLR Guidance.** http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

	Resolution on Implementation of the Safeguarding California Plan for Reducing Climate Risks (2014)	Resolves that OPC staff and the State Coastal Leadership Group on SLR will develop an action plan to implement the *Safeguarding California* plan. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20140827/Item5_OPC_Aug2014_Exhibit_1_Safeguarding_Resolution_ADOPTED.pdf
	Resolution on Sea Level Rise (2011)	Recognizes that state agencies should address SLR through various actions such as the consideration of SLR risks in decision making, investment of public funds, stakeholder engagement, state SLR guidance updates, *etc*. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf
	California State Sea-Level Rise Guidance Document (2013)	Provides guidance for incorporating sea level rise projections into planning and decision making for projects in California. Updated to include NRC projections March 2013: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf
California Coastal Conservancy	*Climate Change Policy* (2010)	Includes policies on 1) consideration of climate change in project evaluation, 2) consideration of sea level rise impacts in vulnerability assessments, 3) collaboration to support adaptation strategies, and 4) encouragement of adaptation strategies in project applications mitigation and adaptation: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/
	Project Selection Criteria (2011)	Adds sea level rise vulnerability to project selection criteria: http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/
	Guidance for addressing climate change in CA Coastal Conservancy projects (2012)	Includes the following steps: 1) conduct initial vulnerability assessment, 2) conduct more comprehensive vulnerability assessment, 3) reduce risks and increase adaptive capacity, and 4) identify adaptation options: http://scc.ca.gov/2013/04/24/guidance-for-grantees

San Francisco Bay Conservation and Development Commission (BCDC)	*Climate Change Bay Plan Amendment* (2011)	Amends *Bay Plan* to include policies on climate change and sea level rise. Policies require: 1) a sea level rise risk assessment for shoreline planning and larger shoreline projects, and 2) if risks exist, the project must be designed to cope with flood levels by mid-century, and include a plan to address flood risks at end of century. Assessments are required to "identify all types of potential flooding, degrees of uncertainty, consequences of defense failure, and risks to existing habitat from proposed flood protection devices": http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml
	Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline (2011)	Provides the background staff report identifying vulnerabilities in the Bay Area's economic and environmental systems, as well as the potential impacts of climate change on public health and safety. The report provides the basis for all versions of the proposed findings and policies concerning climate change: http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf
California Department of Transportation (Caltrans)	*Estimating Sea Level for Project Initiation Documents* (2012)	Provides guidance on converting tidal datums and predicting future sea levels. http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Estimating_Sea_Level_v1.pdf
	Guidance on Incorporating Sea Level Rise (2011)	Provides guidance on how to incorporate sea level rise concerns into programming and design of Caltrans projects. Includes screening criteria for determining whether to include SLR and steps for evaluating degree of potential impacts, developing adaptation alternatives, and implementing the adaptation strategies: http://www.dot.ca.gov/ser/downloads/sealevel/guide_incorp_slr.pdf

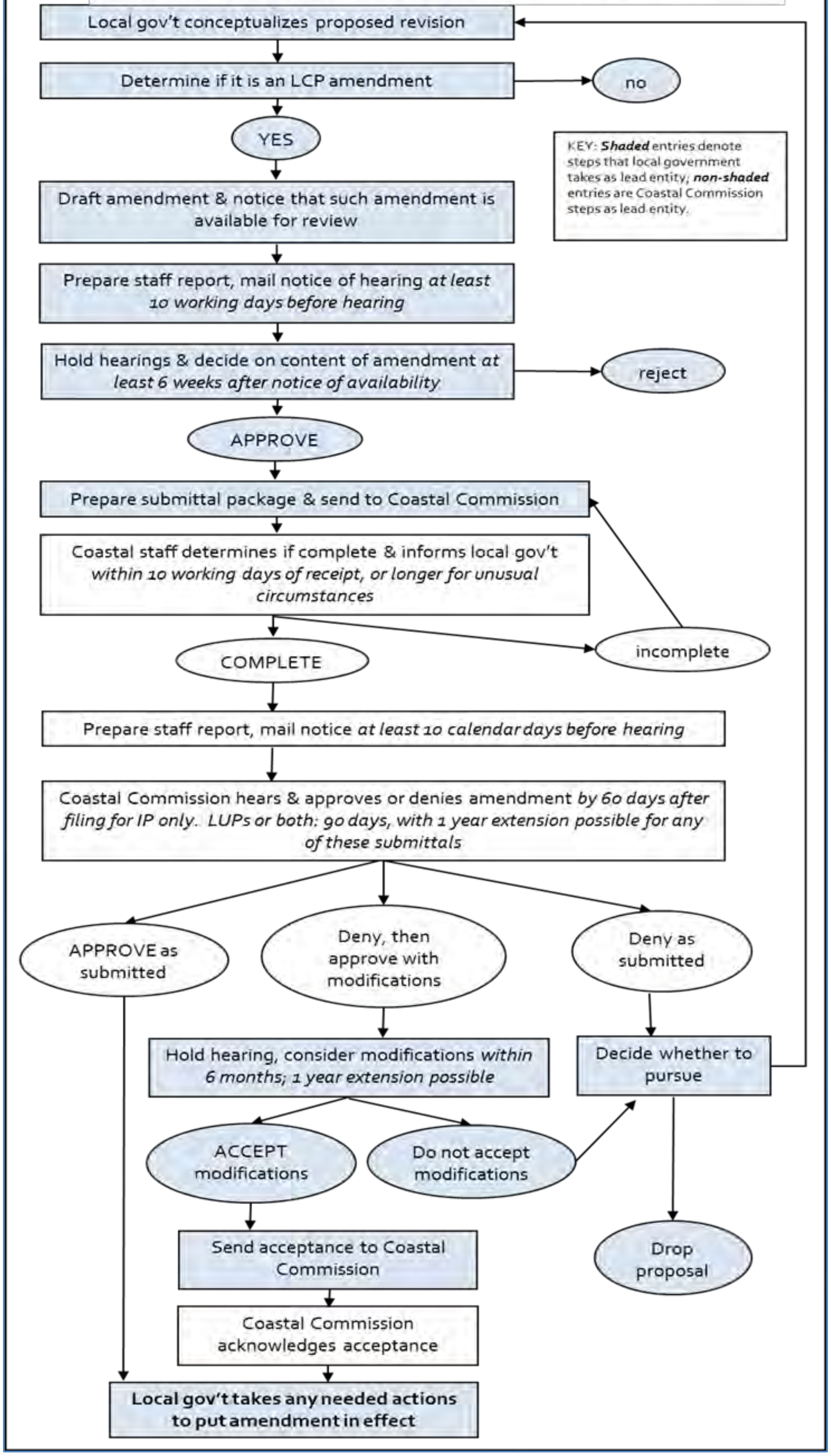
	Addressing Climate Change in Adaptation Regional Transportation Plans: A Guide for MPOs and RTPAs (2013)	Provides a clear methodology for regional agencies to address climate change impacts through adaptation of transportation infrastructure: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf
Cal OES	*California Multi-Hazard Mitigation Plan* (Draft SHMP 2018)	**The California (CA) State Hazard Mitigation Plan (SHMP) represents the state's primary hazard mitigation guidance document - providing an updated analysis of the state's historical and current hazards, hazard mitigation goals and objectives, and hazard mitigation strategies and actions. The plan represents the state's overall commitment to supporting a comprehensive mitigation strategy to reduce or eliminate potential risks and impacts of disasters in order to promote faster recovery after disasters and, overall, a more resilient state**: http://www.caloes.ca.gov/for-individuals-families/hazard-mitigation-planning/state-hazard-mitigation-plan
State Lands Commission	Application for Lease of State Lands	Requires assessment of climate change risks, and preference is given to projects that reduce climate change risks: http://www.slc.ca.gov/Forms/LMDApplication/LeaseApp.pdf
California State Parks	Sea level rise guidance (*in development*)	Will provide guidance to Park staff on how to assess impacts to parklands.
Groups of state agencies	California Climate Change Center's 3rd Assessment	Explores local and statewide vulnerabilities to climate change, highlighting opportunities for taking concrete actions to reduce climate-change impacts: http://climatechange.ca.gov/climate_action_team/reports/third_assessment/
	California Climate Adaptation Planning Guide (APG)	Provides a decision-making framework intended for use by local and regional stakeholders to aid in the interpretation of climate science and to develop a systematic rationale for reducing risks caused, or exacerbated, by climate change (2012): http://resources.ca.gov/climate/safeguarding/local-action/

Appendix D

General LCP Amendment Processing Steps and Best Practices

Sea level rise is one of many topics that should be addressed in a Local Coastal Program (LCP) or LCP amendment. The Coastal Commission offers a *Local Coastal Program (LCP) Update Guide* that outlines the broad process for amending or certifying an LCP, including guidance for both Land Use Plans and Implementation Plans. It addresses major Coastal Act concerns, including public access, recreation and visitor serving facilities, water quality protection, ESHA and natural resources, agricultural resources, new development, archaeological and cultural resources, scenic and visual resources, coastal hazards, shoreline erosion and protective devices, energy and industrial development, and timberlands. Therefore, this *Sea Level Rise Policy Guidance* should be used in conjunction with the LCP Update Guide to perform complete LCP amendments or certifications. The following figure depicts the general LCP amendment process.

Figure I: General LCP Amendment Processing Steps



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Appendix E

Funding Opportunities for LCP Planning and Implementation

Project Implementation Funds

The following table includes a list of grant funding available for implementation of sea level rise adaptation projects and programs. Much of this information was compiled by the Governor's Office of Emergency Services (Cal OES).

Grant Name	Agency	Purpose	Contact
Proposition 1 & Proposition 84 Competitive Grant Programs	**Ocean Protection Council**	**Funding from Prop 1 is intended to fund projects that provide more reliable water supplies, restore important species and habitat, and develop a more resilient and sustainably managed water system (water supply, water quality, flood protection, and environment) that can better withstand inevitable and unforeseen pressures in the coming decades. Proposition 84 funds may be used for a wide range of purposes including scientific research, adaptive management, and conservation of marine resources.**	OPC http://www.opc.ca.gov/category/funding-opportunities/
Proposition 1 Grants **Climate Ready Grants**	**California Coastal Conservancy**	**Proposition 1 Grants for multi-benefit ecosystem and watershed protection and restoration projects.** **Climate Ready Grants are focused on supporting planning, project implementation and multi-agency coordination to advance actions that will increase the resilience of coastal communities and ecosystems**	Coastal Conservancy http://scc.ca.gov/grants/proposition-1-grants/ http://scc.ca.gov/climate-change/climate-ready-program/
SB 1 Adaptation Planning Grants	**Caltrans**	**Support actions at the local and regional level to advance climate change adaptation efforts on the state transportation system**	Caltrans http://www.dot.ca.gov/hq/tpp/grants.html

Hazard Mitigation Grant (HMG) Program	Administered by: Cal OES Funded by: US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	Provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/recovery/disaster-mitigation-technical-support/404-hazard-mitigation-grant-program FEMA https://www.fema.gov/hazard-mitigation-grant-program
Flood Mitigation Assistance (FMA) Program	Administered by: Cal OES Funded by: US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	Provides grants to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the NFIP.	Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation FEMA https://www.fema.gov/flood-mitigation-assistance-program
Public Assistance (PA) Program	US Department of Homeland Security, Federal Emergency Management Agency (FEMA)	To provide supplemental Federal disaster grant assistance for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain Private Non-Profit (PNP) organizations. The PA Program also encourages protection of these damaged facilities from future events by providing assistance for hazard mitigation measures during the recovery process.	FEMA https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit
Community Development Block Grant (CDBG) Program	US Department of Housing and Urban Development	Program works to ensure decent affordable housing, to provide services to the most vulnerable in our communities, and to create jobs through the expansion and retention of businesses.	HUD http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs
Watershed Surveys and Planning	US Department of Agriculture, Natural Resource Conservation Service	To provide planning assistance to Federal, state and local agencies for the development or coordination of water and related land resources and programs in watersheds and river basins.	NRCS http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wsp/

Watershed Protection and Flood Prevention	US Department of Agriculture, Natural Resource Conservation Service	To provide technical and financial assistance in planning and executing works of improvement to protect, develop, and use of land and water resources in small watersheds.	NRCS http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/
Land and Water Conservation Fund Grants	US Department of the Interior, National Park Service	To acquire and develop outdoor recreation areas and facilities for the general public, to meet current and future needs.	NPS http://www.nps.gov/lwcf/index.htm
SBA Disaster Loan Program	US Small Business Administration	SBA provides low-interest disaster loans to businesses of all sizes, private non-profit organizations, homeowners, and renters. SBA disaster loans can be used to repair or replace the following items damaged or destroyed in a declared disaster: real estate, personal property, machinery and equipment, and inventory and business assets.	SBA https://www.sba.gov/content/disaster-loan-program
Clean Water Act Section 319 Grants	US Environmental Protection Agency	To implement state and tribal non-point source pollution management programs, including support for non-structural watershed resource restoration activities.	EPA https://www.epa.gov/nps/319-grant-program-states-and-territories
Flood Control Works/ Emergency Rehabilitation	US Department of Defense, Army Corps of Engineers	To assist in the repairs and restoration of public works damaged by flood, extraordinary wind, wave or water action.	USACE http://www.usace.army.mil/Missions/EmergencyOperations/NationalResponseFramework/FloodControl.aspx
Emergency Streambank and Shoreline Protection	US Department of Defense, Army Corps of Engineers	To prevent erosion damages to public facilities by the emergency construction or repair of streambank and shoreline protection works (33 CFR 263.25)	USACE http://www.mvr.usace.army.mil/BusinessWithUs/OutreachCustomerService/FloodRiskManagement/Section14.aspx
Small Flood Control Projects	US Department of Defense, Army Corps of Engineers	To reduce flood damages through small flood control projects not specifically authorized by Congress.	USACE www.usace.army.mil See also: https://www.cfda.gov/index?s=program&mode=form&tab=core&id=2216ee03c69db437c431036a5585ede6

Appendix F

Primary Coastal Act Policies Related to Sea Level Rise and Coastal Hazards

Legislative Findings Relating to Sea Level Rise

Section 30006.5 of the Coastal Act states (Legislative findings and declarations; technical advice and recommendations) states (emphasis added):

> *The Legislature further finds and declares that sound and timely scientific recommendations are necessary for many coastal planning, conservation, and development decisions and that the commission should, in addition to developing its own expertise in significant applicable fields of science, interact with members of the scientific and academic communities in the social, physical, and natural sciences so that the commission may receive technical advice and recommendations with regard to its decisionmaking, especially with regard to issues such as coastal erosion and geology, marine biodiversity, wetland restoration, the question of sea level rise, desalination plants, and the cumulative impact of coastal zone developments.*

Public Access and Recreation

Section 30210 of the Coastal Act (Access; recreational opportunities; posting) states:

> *In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.*

Section 30211 of the Coastal Act (Development not to interfere with access) states:

> *Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.*

Section 30212 of the Coastal Act (New development projects) states:

> *(a) Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where: (1) it is inconsistent with public safety, military security needs, or the protection of fragile coastal resources, (2) adequate access exists nearby, or (3) agriculture would be adversely affected. Dedicated accessway shall not be required to be opened to public use until a public agency or private association agrees to accept responsibility for maintenance and liability of the accessway.*

Section 30214 of the Coastal Act (Implementation of public access policies; legislative intent) states:

> (*a) The public access policies of this article shall be implemented in a manner that takes into account the need to regulate the time, place, and manner of public access depending on the facts and circumstances in each case including, but not limited to, the following:*
>
> *(1) Topographic and geologic site characteristics.*
>
> *(2) The capacity of the site to sustain use and at what level of intensity.*

(3) The appropriateness of limiting public access to the right to pass and repass depending on such factors as the fragility of the natural resources in the area and the proximity of the access area to adjacent residential uses.

(4) The need to provide for the management of access areas so as to protect the privacy of adjacent property owners and to protect the aesthetic values of the area by providing for the collection of litter.

(b) It is the intent of the Legislature that the public access policies of this article be carried out in a reasonable manner that considers the equities and that balances the rights of the individual property owner with the public's constitutional right of access pursuant to Section 4 of Article X of the California Constitution. Nothing in this section or any amendment thereto shall be construed as a limitation on the rights guaranteed to the public under Section 4 of Article X of the California Constitution.

(c) In carrying out the public access policies of this article, the commission and any other responsible public agency shall consider and encourage the utilization of innovative access management techniques, including, but not limited to, agreements with private organizations which would minimize management costs and encourage the use of volunteer programs.

Section 30220 of the Coastal Act (Protection of certain water-oriented activities) states:

Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas shall be protected for such uses.

Section 30221 of the Coastal Act (Oceanfront land; protection for recreational use and development**)** states:

Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.

Section 30223 of the Coastal Act (Upland areas) states:

Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.

Wetlands and Environmentally Sensitive Resources

Section 30231 of the Coastal Act (Biological productivity; water quality) states in part:

The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored…

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:*

Section 30240 of the Coastal Act (Environmentally sensitive habitat areas; adjacent developments) states:

> *(a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.*
>
> *(b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Coastal Act Section 30121 defines "Wetland" as follows:

> *"Wetland" means lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.*

The California Code of Regulations Section 13577(b) of Title 14, Division 5.5, Article 18 defines "Wetland" as follows:

> *(1) Measure 100 feet landward from the upland limit of the wetland. Wetland shall be defined as land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes, and shall also include those types of wetlands where vegetation is lacking and soil is poorly developed or absent as a result of frequent and drastic fluctuations of surface water levels, wave action, water flow, turbidity or high concentrations of salts or other substances in the substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deep-water habitats. For purposes of this section, the upland limit of a wetland shall be defined as:*
>
> > *(A) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover;*
> >
> > *(B) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or*
> >
> > *(C) in the case of wetlands without vegetation or soils, the boundary between land that is flooded or saturated at some time during years of normal precipitation, and land that is not.*
>
> *(2) For the purposes of this section, the term "wetland" shall not include wetland habitat created by the presence of and associated with agricultural ponds and reservoirs where:*

(A) the pond or reservoir was in fact constructed by a farmer or rancher for agricultural purposes; and

(B) there is no evidence (e.g., aerial photographs, historical survey, etc.) showing that wetland habitat pre-dated the existence of the pond or reservoir. Areas with drained hydric soils that are no longer capable of supporting hydrophytes shall not be considered wetlands.

In addition, Coastal Act Section 30107.5 defines "Environmentally sensitive area" as follows:

"Environmentally sensitive area" means any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.

Agricultural and Timber Lands

Section 30241 of the Coastal Act (Prime agricultural land; maintenance in agricultural production) states:

The maximum amount of prime agricultural land shall be maintained in agricultural production to assure the protection of the areas' agricultural economy, and conflicts shall be minimized between agricultural and urban land uses…

Section 30242 of the Coastal Act (Lands suitable for agricultural use; conversion) states:

All other lands suitable for agricultural use shall not be converted to nonagricultural uses unless (1) continued or renewed agriculture use is not feasible, or (2) such conversion would preserve prime agricultural land or concentrate development consistent with Section 30250. Any such permitted conversion shall be compatible with continue agricultural use on surrounding lands.

Section 30243 of the Coastal Act (Productivity of soils and timberlands; conversions) states:

The long-term productivity of soils and timberlands shall be protected, and conversions of coastal commercial timberlands in units of commercial size to other uses or their division into units of noncommercial size shall be limited to providing for necessary timber processing and related facilities.

Archaeological and Paleontological Resources

Section 30244 of the Coastal Act (Archaeological or paleontological resources) states:

Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required.

Marine Resources

Section 30230 of the Coastal Act (Marine resources; maintenance) states:

> *Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.*

Section 30231 of the Coastal Act (Biological productivity; water quality) states:

> *The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface waterflow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.*

Section 30233 of the Coastal Act (Diking, filling or dredging; continued movement of sediment and nutrients) states:

> *(a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects…*
>
> *(d) Erosion control and flood control facilities constructed on watercourses can impede the movement of sediment and nutrients that would otherwise be carried by storm runoff into coastal waters. To facilitate the continued delivery of these sediments to the littoral zone, whenever feasible, the material removed from these facilities may be placed at appropriate points on the shoreline in accordance with other applicable provisions of this division, where feasible mitigation measures have been provided to minimize adverse environmental effects. Aspects that shall be considered before issuing a Coastal Development Permit for these purposes are the method of placement, time of year of placement, and sensitivity of the placement area.*

Section 30234 of the Coastal Act (Commercial fishing and recreational boating facilities**)** states:

> *Facilities serving the commercial fishing and recreational boating industries shall be protected and, where feasible, upgraded. Existing commercial fishing and recreational boating harbor space shall not be reduced unless the demand for those facilities no longer exists or adequate substitute space has been provided. Proposed recreational boating facilities shall, where feasible, be designed and located in such a fashion as not to interfere with the needs of the commercial fishing industry.*

Section 30234.5 of the Coastal Act (Economic, commercial, and recreational importance of fishing) states:

> *The economic, commercial, and recreational importance of fishing activities shall be recognized and protected.*

Coastal Development

Section 30250 of the Coastal Act (Location; existing developed area) states:

> *(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.*
>
> *(b) Where feasible, new hazardous industrial development shall be located away from existing developed areas.*
>
> *(c) Visitor-serving facilities that cannot feasibly be located in existing developed areas shall be located in existing isolated developments or at selected points of attraction for visitors.*

Section 30251 of the Coastal Act (Scenic and visual qualities) states:

> *The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas...*

Section 30253 the Coastal Act (Minimization of adverse impacts) states in part:

> *New development shall do all of the following:*
>
> *(a) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.*
>
> *(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...*

Section 30235 of the Coastal Act (Construction altering natural shoreline) states:

> *Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public*

> *beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible.*

Section 30236 of the Coastal Act (Water supply and flood control) states:

> *Channelizations, dams, or other substantial alterations of rivers and streams shall incorporate the best mitigation measures feasible, and be limited to (l) necessary water supply projects, (2) flood control projects where no other method for protecting existing structures in the flood plain is feasible and where such protection is necessary for public safety or to protect existing development, or (3) developments where the primary function is the improvement of fish and wildlife habitat.*

Ports

Section 30705 of the Coastal Act (Diking, filling or dredging water areas) states:

> *(a) Water areas may be diked, filled, or dredged when consistent with a certified port master plan only for the following: …*
>
> *(b) The design and location of new or expanded facilities shall, to the extent practicable, take advantage of existing water depths, water circulation, siltation patterns, and means available to reduce controllable sedimentation so as to diminish the need for future dredging.*
>
> *(c) Dredging shall be planned, scheduled, and carried out to minimize disruption to fish and bird breeding and migrations, marine habitats, and water circulation. Bottom sediments or sediment elutriate shall be analyzed for toxicants prior to dredging or mining, and where water quality standards are met, dredge spoils may be deposited in open coastal water sites designated to minimize potential adverse impacts on marine organisms, or in confined coastal waters designated as fill sites by the master plan where such spoil can be isolated and contained, or in fill basins on upland sites. Dredge material shall not be transported from coastal waters into estuarine or fresh water areas for disposal.*

Section 30706 of the Coastal Act (Fill) states:

> *In addition to the other provisions of this chapter, the policies contained in this section shall govern filling seaward of the mean high tide line within the jurisdiction of ports:*
>
> > *(a) The water area to be filled shall be the minimum necessary to achieve the purpose of the fill.*
> >
> > *(b) The nature, location, and extent of any fill, including the disposal of dredge spoils within an area designated for fill, shall minimize harmful effects to coastal resources, such as water quality, fish or wildlife resources, recreational resources, or sand transport systems, and shall minimize reductions of the volume, surface area, or circulation of water.*

> *(c) The fill is constructed in accordance with sound safety standards which will afford reasonable protection to persons and property against the hazards of unstable geologic or soil conditions or of flood or storm waters.*
>
> *(d) The fill is consistent with navigational safety.*

Section 30708 of the Coastal Act (Location, design and construction of port related developments) states:

> *All port-related developments shall be located, designed, and constructed so as to:*
>
> *(a) Minimize substantial adverse environmental impacts.*
>
> *(b) Minimize potential traffic conflicts between vessels.*
>
> *(c) Give highest priority to the use of existing land space within harbors for port purposes, including, but not limited to, navigational facilities, shipping industries, and necessary support and access facilities.*
>
> *(d) Provide for other beneficial uses consistent with the public trust, including, but not limited to, recreation and wildlife habitat uses, to the extent feasible.*
>
> *(e) Encourage rail service to port areas and multicompany use of facilities.*

Public Works Facilities

According to Coastal Act Section 30114, public works facilities include:

> *(a) All production, storage, transmission, and recovery facilities for water, sewerage, telephone, and other similar utilities owned or operated by any public agency or by any utility subject to the jurisdiction of the Public Utilities Commission, except for energy facilities.*
>
> *(b) All public transportation facilities, including streets, roads, highways, public parking lots and structures, ports, harbors, airports, railroads, and mass transit facilities and stations, bridges, trolley wires, and other related facilities. For purposes of this division, neither the Ports of Hueneme, Long Beach, Los Angeles, nor San Diego Unified Port District nor any of the developments within these ports shall be considered public works.*
>
> *(c) All publicly financed recreational facilities, all projects of the State Coastal Conservancy, and any development by a special district.*
>
> *(d) All community college facilities.*

Greenhouse Gas Emissions Reduction

Section 30250(a) of the Coastal Act (Location, existing developed areas states) in part:

> *(a) New residential, commercial, or industrial development, except as otherwise provided in this division, shall be located within, contiguous with, or in close proximity to, existing developed areas able to accommodate it or, where such areas are not able to accommodate it, in other areas with adequate public services and where it will not have*

> *significant adverse effects, either individually or cumulatively, on coastal resources. In addition, land divisions, other than leases for agricultural uses, outside existing developed areas shall be permitted only where 50 percent of the usable parcels in the area have been developed and the created parcels would be no smaller than the average size of surrounding parcels.*

Section 30252 of the Coastal Act (Maintenance and enhancement of public access) states:

> *The location and amount of new development should maintain and enhance public access to the coast by (1) facilitating the provision or extension of transit service, (2) providing commercial facilities within or adjoining residential development or in other areas that will minimize the use of coastal access roads, (3) providing nonautomobile circulation within the development, (4) providing adequate parking facilities or providing substitute means of serving the development with public transportation, (5) assuring the potential for public transit for high intensity uses such as high-rise office buildings, and by (6) assuring that the recreational needs of new residents will not overload nearby coastal recreation areas by correlating the amount of development with local park acquisition and development plans with the provision of onsite recreational facilities to serve the new development.*

Section 30253(d) of the Coastal Act (Minimization of adverse impacts) states in part:

> *New Development shall:*
>
> > *(d) Minimize energy consumption and vehicle miles traveled….*

Appendix G

Sea Level Rise Projections for 12 California Tide Gauges

Map of Tide Gauge Locations

Figure G-1. Map of tide gauge locations (from OPC 2018)

Table G-1. **Sea Level Rise Projections for the Crescent City Tide Gauge[102] (OPC 2018)**

Projected Sea Level Rise (in feet): *Crescent City*			
	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	0.3	0.5	0.8
2040	0.4	0.9	1.4
2050	0.7	1.5	2.3
2060	0.9	2.1	3.3
2070	1.2	2.8	4.5
2080	1.6	3.7	5.9
2090	2.0	4.7	7.4
2100	2.5	5.9	9.3
2110*	2.5	6.2	11.0
2120	3.0	7.4	13.1
2130	3.4	8.7	15.3
2140	3.9	10.1	17.8
2150	4.4	11.6	20.6

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.

[102] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-2. **Sea Level Rise Projections for the North Spit Tide Gauge[103] (OPC 2018)**

Projected Sea Level Rise (in feet): *North Spit*			
	Probabilistic Projections (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	0.7	1.0	1.2
2040	1.1	1.6	2.0
2050	1.5	2.3	3.1
2060	1.9	3.1	4.3
2070	2.4	4.0	5.6
2080	2.9	5.1	7.2
2090	3.5	6.2	8.9
2100	4.1	7.6	10.9
2110*	4.3	8.0	12.7
2120	4.9	9.4	15.0
2130	5.5	10.9	17.4
2140	6.2	12.5	20.1
2150	6.8	14.1	23.0

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.

[103] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-3. **Sea Level Rise Projections for the Arena Cove Tide Gauge[104] (OPC 2018)**

Projected Sea Level Rise (in feet): *Arena Cove*			
	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	0.7	1.0
2040	0.7	1.2	1.6
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	2.6	5.4	8.0
2100	3.1	6.7	9.9
2110*	3.2	7.0	11.6
2120	3.8	8.2	13.9
2130	4.3	9.7	16.2
2140	4.8	11.1	18.7
2150	5.4	12.6	21.5

****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.***

[104] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-4. **Sea Level Rise Projections for the Point Reyes Tide Gauge[105] (OPC 2018)**

Projected Sea Level Rise (in feet): *Point Reyes*			
	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	0.6	0.8	1.0
2040	0.8	1.3	1.8
2050	1.1	2.0	2.8
2060	1.5	2.7	3.9
2070	1.9	3.5	5.2
2080	2.4	4.6	6.7
2090	2.9	5.6	8.3
2100	3.5	7.0	10.3
2110*	3.6	7.3	12.0
2120	4.2	8.6	14.3
2130	4.7	10.1	16.6
2140	5.3	11.5	19.2
2150	5.9	13.1	22.0

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.

[105] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-5. **Sea Level Rise Projections for the San Francisco Tide Gauge[106] (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.***

106 **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-6. **Sea Level Rise Projections for the Monterey Tide Gauge[107] (OPC 2018)**

Projected Sea Level Rise (in feet): *Monterey*			
	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	1.2	1.7
2050	1.1	1.9	2.7
2060	1.4	2.6	3.8
2070	1.8	3.4	5.1
2080	2.3	4.4	6.6
2090	2.8	5.5	8.2
2100	3.3	6.9	10.1
2110*	3.4	7.2	11.8
2120	4.0	8.5	14.0
2130	4.5	9.9	16.4
2140	5.1	11.3	18.9
2150	5.7	12.9	21.8

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.

[107] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-7. **Sea Level Rise Projections for the Port San Luis Tide Gauge[108] (OPC 2018)**

Projected Sea Level Rise (in feet): *Port San Luis*			
	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	0.7	1.0
2040	0.7	1.2	1.6
2050	1.0	1.8	2.6
2060	1.3	2.5	3.7
2070	1.7	3.3	5.0
2080	2.1	4.3	6.4
2090	2.6	5.3	8.0
2100	3.1	6.7	9.9
2110*	3.2	7.0	11.6
2120	3.7	8.2	13.8
2130	4.3	9.6	16.2
2140	4.8	11.1	18.7
2150	5.4	12.6	21.5

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.

[108] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-8. **Sea Level Rise Projections for the Santa Barbara Tide Gauge[109] (OPC 2018)**

Projected Sea Level Rise (in feet): *Santa Barbara*			
	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	0.4	0.7	1.0
2040	0.7	1.1	1.6
2050	1.0	1.8	2.5
2060	1.3	2.5	3.6
2070	1.7	3.3	4.9
2080	2.1	4.3	6.3
2090	2.6	5.3	7.9
2100	3.1	6.6	9.8
2110*	3.2	6.9	11.5
2120	3.7	8.2	13.7
2130	4.2	9.5	16.0
2140	4.8	11.0	18.6
2150	5.3	12.6	21.4

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.

[109] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-9. **Sea Level Rise Projections for the Santa Monica Tide Gauge[110] (OPC 2018)**

Projected Sea Level Rise (in feet): *Santa Monica*			
	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	1.2	1.7
2050	1.1	1.9	2.6
2060	1.4	2.6	3.8
2070	1.8	3.4	5.1
2080	2.3	4.4	6.5
2090	2.8	5.5	8.1
2100	3.3	6.8	10.0
2110*	3.5	7.2	11.7
2120	4.0	8.5	14.0
2130	4.5	9.8	16.3
2140	5.1	11.3	18.9
2150	5.7	12.9	21.7

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.

[110] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-10. **Sea Level Rise Projections for the Los Angeles Tide Gauge[111] (OPC 2018)**

Projected Sea Level Rise (in feet): *Los Angeles*			
	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	0.7	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
2140	4.9	11.1	18.7
2150	5.4	12.7	21.5

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.

[111] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-11. **Sea Level Rise Projections for the La Jolla Tide Gauge[112] (OPC 2018)**

Projected Sea Level Rise (in feet): *La Jolla*			
	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	0.6	0.9	1.1
2040	0.9	1.3	1.8
2050	1.2	2.0	2.8
2060	1.6	2.7	3.9
2070	2.0	3.6	5.2
2080	2.5	4.6	6.7
2090	3.0	5.7	8.3
2100	3.6	7.1	10.2
2110*	3.7	7.5	12.0
2120	4.3	8.8	14.3
2130	4.9	10.2	16.6
2140	5.4	11.7	19.2
2150	6.1	13.3	22.0

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.

112 **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Table G-12. **Sea Level Rise Projections for the San Diego Tide Gauge[113] (OPC 2018)**

Projected Sea Level Rise (in feet): *San Diego*			
	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	0.6	0.9	1.1
2040	0.9	1.3	1.8
2050	1.2	2.0	2.8
2060	1.6	2.7	3.9
2070	2.0	3.6	5.2
2080	2.5	4.6	6.7
2090	3.0	5.7	8.3
2100	3.6	7.0	10.2
2110*	3.7	7.5	12.0
2120	4.3	8.8	14.3
2130	4.9	10.2	16.6
2140	5.4	11.7	19.2
2150	6.1	13.3	22.0

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.

[113] **Probabilistic projections for the height of sea level rise and the H++ scenario are presented. The H++ projection is a single scenario and does not have an associated likelihood of occurrence. Projections are with respect to a baseline year of 2000 (or more specifically, the average relative sea level over 1991-2009). Table is adapted from the 2018 OPC SLR Guidance to present only the three scenarios OPC recommends evaluating. Additionally, while the OPC tables include low emissions scenarios, only high emissions scenarios, which represent RCP 8.5, are included here because global greenhouse gas emissions are currently tracking along this trajectory. The Coastal Commission will continue to update best available science as necessary, including if emissions trajectories change.**

Appendix H

Coastal Commission Contact Information

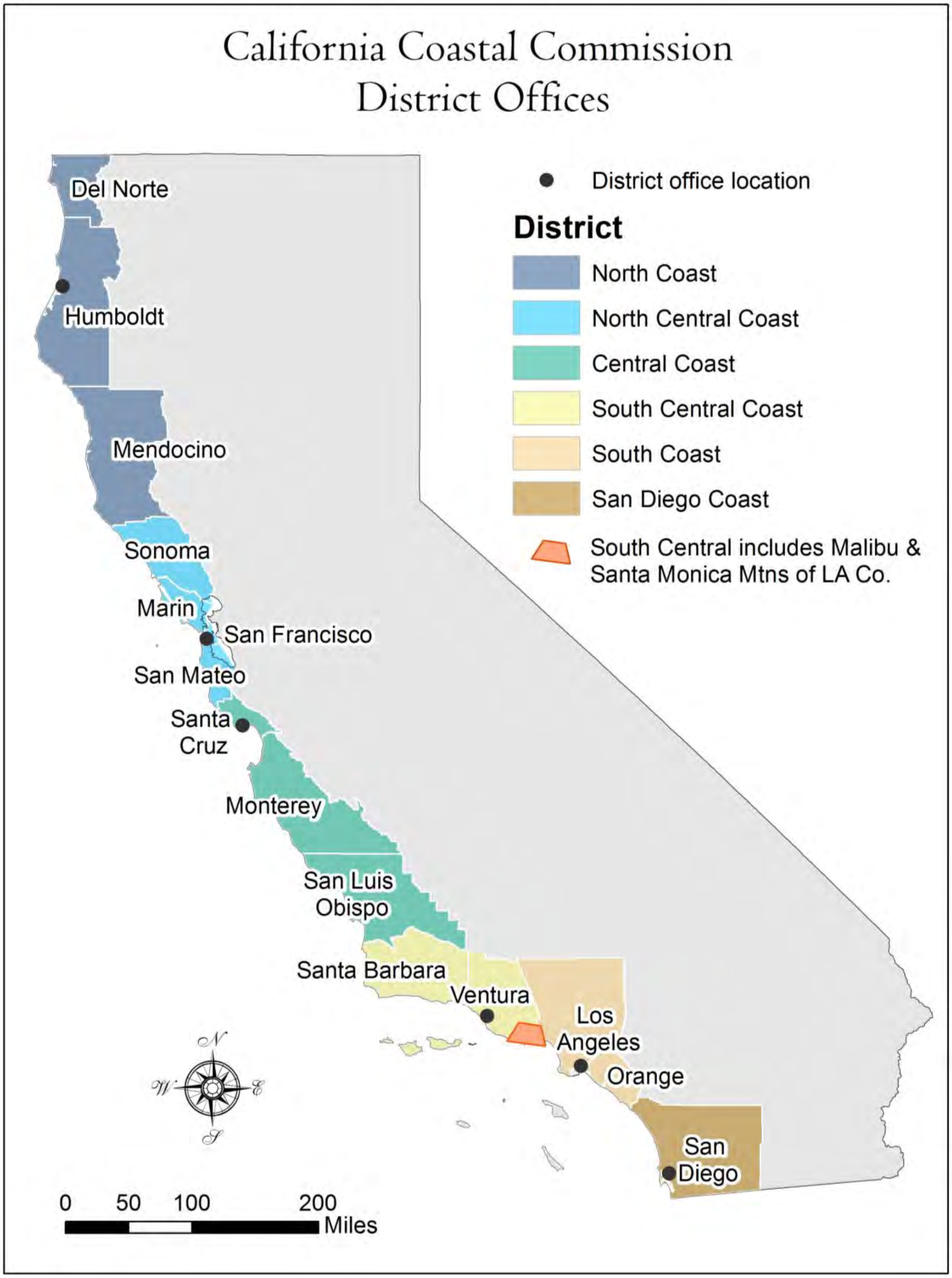

Figure H-1. Location of Coastal Commission Offices

Coastal Commission District Office Contact Information

North Coast (Del Norte, Humboldt, Mendocino Counties)
(707) 826-8950

Headquarters and North Central Coast (Sonoma, Marin, San Francisco, San Mateo Counties)
(415)-904-5200

Central Coast (Santa Cruz, Monterey, San Luis Obispo Counties)
(831) 427-4863

South Central Coast (Santa Barbara and Ventura Counties, and the Malibu portion of Los Angeles County)
(805) 585-1800

South Coast (Los Angeles (except Malibu) and Orange Counties)
(562) 590-5071

San Diego (San Diego County)
(619) 767-2370

Coastal Commission Staff Sea Level Rise Team

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