Critical Infrastructure at Risk
Sea Level Rise Planning Guidance for California's Coastal Zone

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California Coastal Commission

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Acknowledgements

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Photos on the cover: (left) End of Sunset Street in Newport Beach, Orange County by the California King Tides Project; (top right) Jackson Ranch Road over Liscom Slough in Humbolt County by Humbolt BayKeeper; (bottom right) Rail tracks near Rincon Beach in Santa Barbara County by David Powdrell.

California Coastal Commission Mission Statement

Protecting and Enhancing California's Coast

The Commission is committed to protecting and enhancing California's coast and ocean for present and future generations. It does so through careful planning and regulation of environmentally-sustainable development, rigorous use of science, strong public participation, education, and effective intergovernmental coordination.

How to Use this Document

Use this document as interpretive guidelines, not regulations.

This Guidance is advisory. It provides the Commission's recommendations for how local governments can address sea level rise issues in Local Coastal Programs (LCPs) consistent with the Coastal Act. The Guidance is 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 LCPs, and other applicable laws and regulations as applied in the context of the evidence in the record for that action.

Use this document as examples to modify, not a substitute for consulation with CCC staff.

This Guidance contains model policies that may need to be customized to address local contexts before they can be incorporated into individual LCPs. In addition, not all policies are applicable in every jurisdiction. Commission staff can assist local governments with using the Guidance to develop policies that help prepare for sea level rise impacts in their communities.

Use this document as policy options for consideration, not a checklist.

Not all of the content will be applicable to all jurisdictions. Jurisdictions should consider the policy options that are relevant to their specific situation, rather than view the options as a checklist of requirements. In addition, looking at a single policy does not indicate how the entire LCP achieves compliance with the Coastal Act. Similarly, in this Policy Guidance, many of the model policies work together. Therefore, users of the model policies should consult all sections of this Guidance for assistance in understanding how the policies work together.

CONTENTS

EXECUTIVE SUMMARY

Underpinning and supporting the California coast is a system without which communities could not function – infrastructure. Infrastructure is the foundation on which California's thriving coastal economy is built. Transportation networks carry visitors and residents to and from the coast, workers to coastal jobs, and goods and services to and from coastal and inland areas. Water networks provide clean water for communities, agriculture, and industry, carry and treat wastewater, and direct and address stormwater. Infrastructure sustains California's $44 billion ocean-based economy, which supports over 500,000 jobs and more than $19 billion in wages and salaries (Kildow *et al*., 2016). Coastal infrastructure also supports the nearly 70% of California residents who live in coastal counties and allows millions of visitors to access California's treasured coast each year. However, much of the existing infrastructure that allows people to access, recreate, live, and work in coastal communities was not designed to be resilient to the threats of climate change and sea level rise, which present unprecedented challenges and must be met with proactive adaptation.

The goal of this Guidance is to promote resilient coastal infrastructure and protection of coastal resources by providing local governments, asset managers, and other stakeholders with policy and planning information to help inform sea level rise adaptation decisions that are consistent with the California Coastal Act. The Guidance addresses two main types of critical infrastructure: transportation and water. While other infrastructure types, including power plants, gas pipelines, and desalination facilities, are not explicitly addressed, many described adaptation approaches could broadly apply to these types of infrastructure as well.

The Guidance presents five key considerations for successful infrastructure adaptation planning and makes a series of recommendations for each. In addition, it provides details on the expected impacts of sea level rise on transportation and water infrastructure, describes the regulatory framework that applies to adaptation planning for infrastructure, provides model policies that can be used by local governments as a tool for updating Local Coastal Programs (LCPs), and gives direction to asset managers on how to develop infrastructure adaptation projects that can help to ensure resilience while protecting resources consistent with the Coastal Act. Detailed information is available in the Appendices relating to the laws, reports, data, and authorities cited throughout the report.

To provide flexibility for readers with different levels of interest or focus, this document is written so that it can either be read as a whole or individual chapters can be read alone. Thus, there is some repetition between chapters by design.

SEA LEVEL RISE RISKS

Sea level rise poses a significant threat to the state's infrastructure located within and near the coast. Based on the current best available science, the Ocean Protection Council's *State of California Sea-Level Rise Guidance* and the *California Coastal Commission Sea Level Rise Policy Guidance* recommend evaluating the expected impacts to critical infrastructure that would be caused by approximately 10 feet of sea level rise by 2100 (using what is known as the extreme risk or "H++" scenario) along with other sea level rise scenarios. In addition, in May 2020, the Commission adopted *Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action* (State SLR Principles) which calls for addressing a minimum of 3.5 feet of sea level rise in the next 30 years.

One study that analyzed just 4.6 feet of sea level rise found that hundreds of miles of highways and railways, and thousands of roadway miles, statewide would be threatened or damaged by 100-year flood events under such a scenario (Heberger *et al*., 2009). Under the same scenario, flooding and rising groundwater would threaten at least 28 wastewater treatment plants, as well as wastewater collection, water supply distribution, and wastewater management infrastructure. In addition, flooding would increasingly threaten stormwater systems throughout coastal communities, and seawater intrusion would threaten freshwater supplies in vulnerable areas. With sea level rise beyond 4.6 feet, these impacts would become far more significant.

In many cases, California's aging infrastructure is reaching the end of its useful life and will need major maintenance, upgrades, or replacement over the coming decades. These changes represent significant investments in the future and future infrastructure capacity. The time at which these projects are contemplated provides important opportunities to adapt at-risk infrastructure to coastal hazards and other climate change-related risks now rather than waiting until later. Proactive, collaborative, and thoughtful adaptation planning will be the key to successfully addressing the State's coastal infrastructure needs and protecting coastal resources, now and in the future.

ADAPTATION AND CONSEQUENCES OF DEFERRED PLANNING

Infrastructure adaptation strategies, when planned and implemented in a timely manner, provide a path to avoiding devastating damage and loss of service. Existing infrastructure can be floodproofed, elevated and relocated, and new infrastructure can be sited in areas safe from hazards, or replaced by newer systems, allowing coastal resources to thrive in the changing environment. Failing to protect infrastructure could mean loss of transportation capacity for the movement of people and goods, including public access to the coast and emergency evacuation routes, as well as impacts to basic utilities, wastewater treatment, stormwater flood control, and water supply resources.

However, if California does not adapt the right way, and at the right time, the coastline could face irreparable harm. For example, oftentimes a solution embraced by coastal communities is to armor the shoreline to protect infrastructure. While this may be a reasonable alternative to be considered in the short- and mid-term, it is often less clearly understood that such armoring can have significant adverse impacts on the beach and the shoreline where the armoring is installed. In fact, reliance on shoreline armoring as a long-term solution will eventually lead to the loss of many beaches and wetlands – eliminating precious recreational opportunities and whole ecosystems, as well as their related benefits, such as biodiversity, fish nurseries, flood protection, and water quality enhancement. As detailed earlier, these are the elements of our coast that provide a social fabric and identify and drive local communities and economies. Their protection must also be an important part of the infrastructure adaptation discussion.

Coronado Bridge in San Diego. Photo by Blake Weyland.

KEY CONSIDERATIONS FOR ADAPTATION PLANNING

Taken together, the important role that critical infrastructure plays in daily life, the costs associated with potential damage to infrastructure, and the significant amount of risk posed to a vast amount of critical infrastructure throughout vulnerable areas, all illustrate that proactive adaptation planning is critical for ensuring the health and safety of communities, the state's economy, and the environment. Further, sea level rise impacts will change over time and rates of sea level rise will accelerate in the future depending on emissions trajectories as described in the *State of California Sea-Level Rise Guidance*. A strategy that ensures resilience and protects resources in the near-term may not be successful in the mid- to long-term, and vice versa. Moreover, the physical land on which infrastructure is currently located will in some cases be submerged under water in the future, fundamentally changing the landscape and limiting potential adaptation strategies. Finally, planning infrastructure adaptation can take decades, multiplying the complexity of the planning process and magnifying the uncertainty. In the face of these challenges, this Guidance presents a series of key considerations and recommendations to support successful adaptation for critical infrastructure.

Coordinated Planning

Given the significant challenges posed by infrastructure adaptation planning, planning must be well coordinated within and across jurisdictions. This Guidance recommends coordinating with neighboring jurisdictions, including through regional climate collaboratives; utilizing Local Coastal Program (LCP) planning, Public Works Plans (PWP), and other vulnerability and planning efforts to plan infrastructure improvements at a regional scale; and pursuing funding to support regional adaptation and regional governance mechanisms, such as joint powers authorities and special districts, which can work across jurisdictions.

Environmental Justice

Due to discriminatory land use policies and systemic racism, environmental justice communities often experience disproportionate environmental burdens and are more vulnerable to adverse impacts from a project. Further, environmental justice communities often lack access to the decision-making process and experience procedural barriers to becoming involved in that process. Sea level rise adaptation planning for critical infrastructure may cause or exacerbate these social inequities. This Guidance recommends considering the equitable distribution of burdens and benefits to environmental justice communities at all stages of adaptation planning. This includes early outreach and consistent engagement, maximizing public participation opportunities, identifying direct and indirect adverse impacts, and avoiding and mitigating impacts to those communities.

Phased Adaptation

Phased adaptation is the incremental implementation of adaptation and resilience strategies over time as sea level rises. Given the changes that are anticipated to the coastline over the near-, middle-, and long-term, the accelerating pace of sea level rise, and the decades of preparation often required to plan for significant infrastructure adaptation, phased adaptation will be a key strategy for success. In fact, phased adaptation is already being used. One method, which has been used in several important cases in California, is to allow temporary armoring to protect threatened structures for a short period of time until relocation of the structures can be completed, after which the temporary armoring is removed to restore coastal processes and habitats along the shore. This strategy ensures infrastructure is maintained and protects coastal resources over the long-term, and can help address the H++ sea level rise scenario recommended for critical infrastructure. Phased adaptation pathways should be periodically revisited and updated if necessary, based on changed conditions and updates to the best available science. The Guidance recommends local governments and asset managers consider phasing adaptation strategies to reduce upfront costs and allow for the planning time needed for development of longer-term adaptation strategies.

Cost and Funding

While there is no comprehensive analysis of the costs associated with addressing vulnerable critical infrastructure in the state, estimates of the costs are in the billions, if not trillions of dollars, over time. Further, studies already show that planning and implementation of adaptation strategies can save $4 to $10 for every $1 spent (Moser et al., 2014), making it more cost effective in the long run. Conversely, responding to crisis is the least cost-effective strategy (see Appendix G). This Guidance explains that proactive and protective land-use planning can significantly reduce costs, and that, over the long-term, relocation will often be the most cost-effective solution for infrastructure vulnerability. However, these efforts will need significant funding, even before structures are threatened, to be successful. The Guidance recommends evaluating the costs and benefits of adaptation strategies over the entire life cycle of the infrastructure, assessing both market and non-market values, and pursuing additional federal and state funding for infrastructure adaptation.

Nature-Based Adaptation Strategies

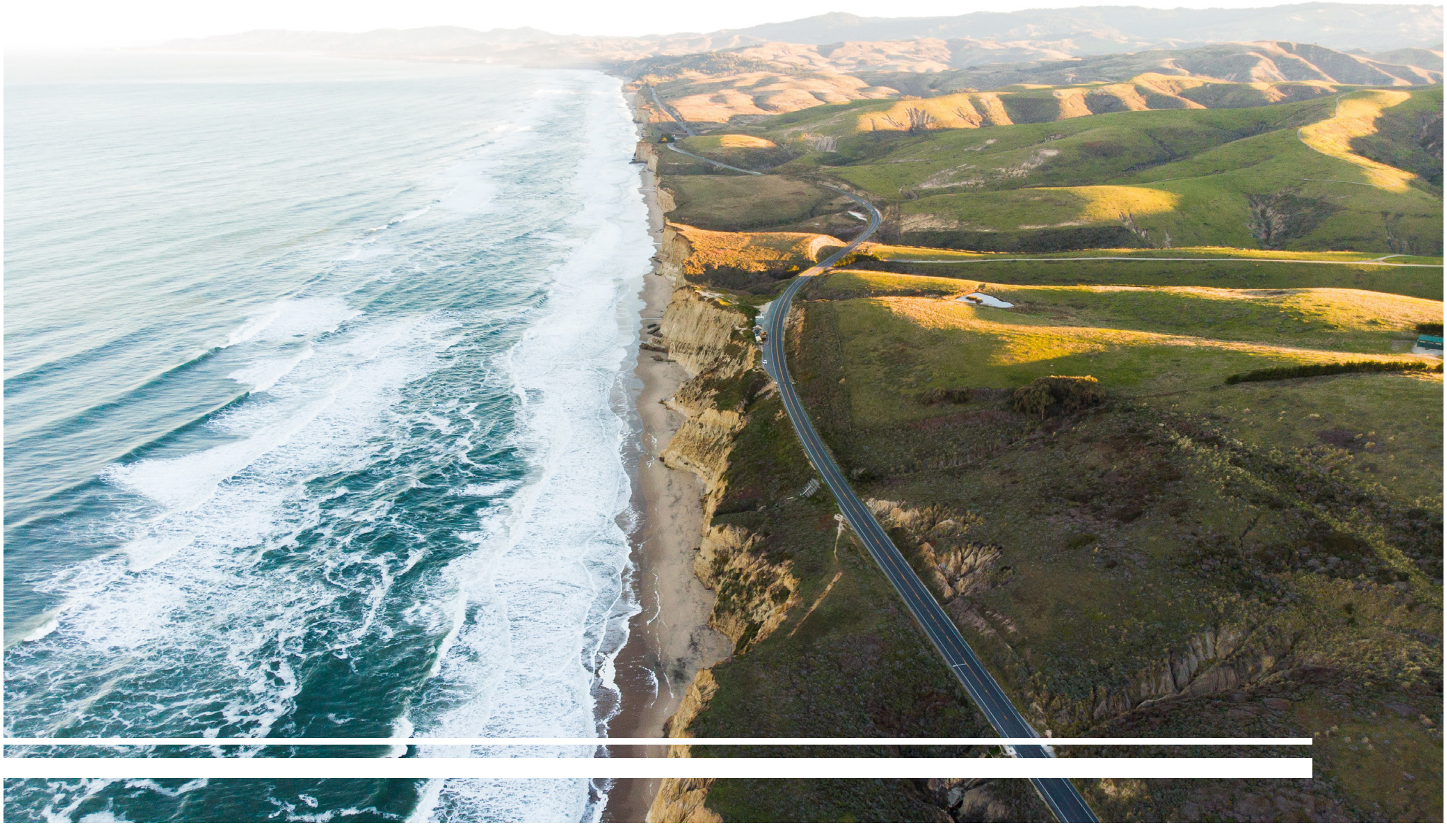
Nature-based adaptation strategies rely on ecological and physical processes to offer protection to the built, inland, or backshore environment. They have the benefit of improving ecological systems while reducing the impacts of coastal flooding and erosion. These strategies also include hybrid armoring approaches, in which natural systems are restored or enhanced in combination with constructed features such as marsh sills, buried revetments, and cobble berms. The Guidance recommends local governments and asset managers prioritize nature-based adaptation strategies in all new sea level rise adaptation planning efforts. The Guidance also recommends that state agencies work together to strengthen and accelerate opportunities for using nature-based adaptation strategies.

MODEL POLICIES

LCPs are the standard of review for nearly all new development in the coastal zone, and as such, they are critically important tools for addressing sea level rise. Since many LCPs were last updated many years or even decades ago, there is a general need to update them to address new coastal resource challenges and changing community needs. In addition, the anticipated acceleration of sea level rise hazards presents the need to implement proactive adaptation measures through LCPs. Without LCP updates, local governments can be poorly situated to properly address sea level rise and adaptation when faced with coastal permit decisions affecting infrastructure.

The Guidance provides example model policies that local governments may choose to work from to help promote critical infrastructure adaptation (see Appendix B). They are meant to serve as ideas or starting points from which to develop policies appropriate for local conditions. They are not a checklist of items the Coastal Commission would expect to see in an LCP. The model policies could be rewritten in any number of ways to account for local conditions and priorities, provided that they are still consistent with the Coastal Act. The model policies provide example language to help ensure Coastal Act consistency and to assist local governments.

San Gregorio in San Mateo County. Photo by Ethan Dow.



LCPs should include sea level rise planning strategies that protect public access and other coastal resources while minimizing hazards, consistent with the Coastal Act. The model policies are provided as a tool to assist local governments in developing their own LCP policies that support sea level rise adaptation for transportation and water infrastructure in their jurisdictions while also meeting Coastal Act requirements. Using the model policies, where relevant, can help ensure Coastal Act consistency, but jurisdictions remain free to modify the policies and/or develop different and complementary policies to best address the local context, so long as they remain consistent with the Coastal Act. The appropriate model policies and adaptation pathways for a particular location will depend on the unique community context, priorities, goals, public input, geography, and other factors. Not all of the model policies will be applicable in all situations.

In addition to the LCP context, the model policies may be useful to managers of water and transportation assets and other utilities as they develop infrastructure adaptation projects that promote resilience while protecting coastal resources, consistent with the Coastal Act.

The model policies cover a spectrum of potential adaptation strategies. However, all communities and asset managers should consider the following principles in infrastructure planning:

- Use the best available science and higher sea level rise projections (scenarios associated with medium-high and extreme risk aversion) to evaluate critical infrastructure in vulnerability assessments.
- Whenever possible, approach sea level rise adaptation planning for infrastructure through collaborative regional planning processes that bring together all relevant jurisdictions, agencies, and stakeholders.
- Maximize public participation.
- Consider planning tools such as Public Works Plans (PWPs) to coordinate cross-jurisdictional projects necessary to implement a sea level rise adaptation plan.
- Address disproportionate burdens and benefits to environmental justice communities and incorporate meaningful engagement practices and equitable public participation processes throughout the entire planning process.
- Consider phased, trigger-based solutions and adaptation pathways.
- Conduct long-term vulnerability assessments and adaptation planning to assess potential impacts of coastal hazards; the social, environmental, and economic costs and benefits of adaptation strategy alternatives over time; and triggers for phased adaptation.
- Initiate adaptation planning efforts before impacts from coastal hazards begin to occur.
- Site infrastructure to avoid hazards. Where hazard avoidance is not feasible, prioritize nature-based adaptation strategies over hard shoreline armoring. When armoring is used, mitigate adverse coastal resource impacts and require planning to identify a long-term solution that is most protective of coastal resources.
- Pursue potential funding and investment opportunities at federal, state, regional, and local levels.

Sustaining the infrastructure that supports the coast and ocean economy and coastal communities will depend on adequate planning for future coastal hazards, protection of coastal resources, meaningful engagement with environmental justice communities, and strategic investments in critical infrastructure. This Guidance aims to support local governments and asset managers in planning and implementing infrastructure adaptation that meets present needs while protecting precious coastal resources for future generations.

APPENDICES

The Guidance includes additional resources that local governments and others might find useful as they review the Critical Infrastructure Guidance. Specifically, Appendix A presents relevant Coastal Act policies in more detail than in the body of the Guidance and Appendix B includes the model policies detailed above. Appendix C summarizes steps for sea level rise adaptation planning that have also been presented in the Commission's updated *Sea Level Rise Policy Guidance*. Appendix D presents information on California's infrastructure vulnerability, including a list of vulnerable wastewater facilities. Appendix E provides detailed case studies that reflect successful approaches to critical infrastructure adaptation in the coastal zone. Appendix F is a summary of nature-based adaptation strategy information that might be useful for people interested in that adaptation approach. Appendix G details the types of cost savings that can result from adaptation and hazard avoidance. Lastly, Appendix H contains descriptions of additional Caltrans planning efforts. The intent of providing these additional resources is to complement the Guidance and offer more stand-alone material to support planning and implementation of infrastructure adaptation.

Big Sur, Monterey County. Photo by James Donovan.

MAIN REPORT

CHAPTER 1

Introduction and Purpose

The following chapter introduces the purpose of this Guidance and describes the types of critical infrastructure that are addressed.

INTRODUCTION

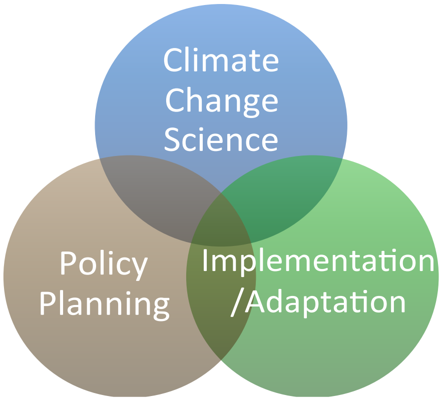
Infrastructure is the foundation on which California's thriving coastal economy is built. The California Coastal Act lays out a framework of strong policies that the Coastal Commission and local coastal governments must use to address risks to infrastructure while protecting our economy and coastal resources. The Coastal Act is implemented in partnership with local governments through Coastal Commission certification of Local Coastal Programs (LCPs), which provide policies and zoning requirements consistent with the Coastal Act and specific to each local jurisdiction in the coastal zone. To address the local impacts of sea level rise effectively, LCPs must be updated to include clear policies and implementing regulations (e.g., zoning ordinances) to help provide for and guide infrastructure adaptation through the coastal permit process. Every local jurisdiction has unique characteristics and circumstances that will influence its path forward on adapting to sea level rise, and therefore each LCP will be unique. However, by law, all LCPs must be consistent with the statewide policies of the Coastal Act. Of the 76 local jurisdictions, about three-quarters have certified LCPs, though many have not been updated for years or even decades. Moving forward, it will be extremely important to update LCPs to include land use policies and ordinances that implement sea level rise adaptation measures to protect vulnerable coastal resources and development, including critical infrastructure.

Given the complexity of sea level rise adaptation planning and the uniqueness of each local jurisdiction, local governments can benefit from clear policy direction to adapt to changing conditions while protecting infrastructure and coastal resources consistent with the Coastal Act. Addressing impacts to infrastructure is particularly complex and will require considerable planning, stakeholder input, and funding because of the significant time and investment needed to build and maintain these systems. Given the Coastal Commission's existing work with local governments in certifying and updating LCPs to address sea level rise, the Commission recognizes the need to offer guidance to local governments on addressing the unique and monumental challenge of adapting infrastructure that is at risk along California's coast. This Guidance is a tool to support planning and promote interagency coordination to advance these efforts.

PURPOSE OF THIS GUIDANCE

This Guidance document builds on the *California Coastal Commission's Sea Level Rise Policy Guidance* (updated 2018). In fact, this Guidance is identified as a "Next Step" in the Sea Level Rise Policy Guidance and supports achievement of a number of the Coastal Commission's Strategic Plan goals. The overall goal of this document is to promote resilient critical infrastructure by providing local governments, asset managers, and other stakeholders with relevant policy and planning information to help inform adaptation decisions. The scope of this Guidance is limited to coastal hazards associated with sea level rise and does not cover other climate change impacts (see *Hazards Associated with Sea Level Rise* in Chapter 2).

This Guidance addresses two main types of critical infrastructure: transportation and water. For the purposes of this document, *critical transportation infrastructure* includes coastal roads, highways and railroad facilities (see Chapter 5), and *critical water infrastructure* includes wastewater treatment, stormwater, and water supply facilities (see Chapter 6). This document combines the latest climate change science with the requirements of the Coastal Act and other relevant laws to present an array of potential adaptation strategies for critical infrastructure. Recognizing that there is no single, correct way to plan for critical infrastructure adaptation, this document provides potential planning and policy strategies as a menu of options which local governments may choose to include in LCPs or permits. The document provides example model policies that local governments may choose to work from to help promote critical infrastructure adaptation (see Appendix B). They are meant to serve as ideas or starting points from which to develop policies appropriate for local conditions. The model policies could be rewritten in any number of ways to account for local conditions and priorities, provided that they are still consistent with the Coastal Act. This format responds to requests by local coastal jurisdictions to provide adaptation policy options depending on various conditions, vulnerabilities, and funding availability.



INFRASTRUCTURE SYSTEMS

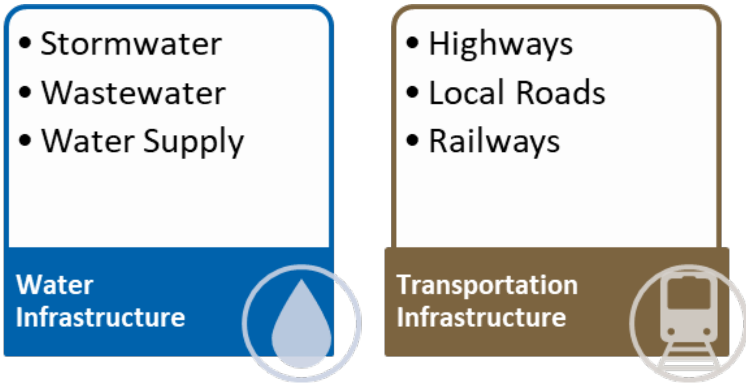
Infrastructure typically refers to assets that support societal functions and protect public health, safety, and welfare. The State of California defines critical infrastructure broadly, with examples including roads, bridges, ports, airports, and railways; water, wastewater, drainage, and sewers; schools, jails, hospitals, and health care facilities; government facilities and commercial buildings; power plants; terrestrial, satellite, and wireless transmission systems; telecommunications; and data information systems (California Governor's Office of Planning and Research, 2018). More broadly, the *National Infrastructure Protection Plan* identifies lifeline functions – which include communications, energy, transportation, and water – as critical infrastructure, and points out that addressing risks from cross-sector dependencies and interdependencies is essential to enhancing critical infrastructure security and resilience (Department of Homeland Security, 2013).

Infrastructure sectors and systems are interconnected, and the loss of one component or service can impact other sectors. For example, water pumps cannot work without power systems, and emergency response cannot work without communication systems. Such interconnectivity means that the problem must be understood across all of these sectors for effective solutions to be implemented. For example, floods can cause an acute loss of municipal utility services during or immediately after a flood event, and, in some cases, may result in ongoing issues that can prevent facilities from operating for weeks after an event (FEMA, 2013).

Coastal communities have unique characteristics that make their resilience planning different from those of inland locations. Specifically, past development patterns have concentrated a large amount of community infrastructure near the coast in areas highly susceptible to coastal hazards. These infrastructure systems include power, wastewater, stormwater, and transportation. Some types of infrastructure, such as ports, harbors, and wastewater outfall lines, specifically require locations near water, and they too are susceptible to the effects of coastal hazards.

CRITICAL INFRASTRUCTURE COVERED IN THIS GUIDANCE

This Guidance focuses on adaptation of transportation infrastructure (Chapter 5) and water infrastructure (Chapter 6), including highways, roads, railroads, wastewater, stormwater, and water supply infrastructure. Often, electrical, gas, and communication infrastructure is collocated with transportation infrastructure, and so those types of infrastructure may be indirectly addressed by the Guidance. Similarly, the California Coastal Trail and other recreational assets are frequently collocated with transportation infrastructure, and planning for those assets is often integrally related to planning for transportation infrastructure. Water and transportation sectors were selected as the focus of this Guidance to limit the scope to projects that are most frequently addressed in Coastal Commission and local government permitting and planning, and those that have planning features in common with other sectors. Other critical infrastructure facilities, such as ports, harbors, airports, power plants, desalination facilities, and hospitals are outside this scope, and thus not specifically addressed in this document.



Natural shoreline features, such as beaches, wetlands, and dunes, can be considered forms of natural infrastructure, and they are critically important to coastal communities. However, because this Guidance is focused on transportation and water infrastructure, it will discuss these systems as resources that can be used to help protect critical water and transportation infrastructure from sea level rise, and that must be protected in those endeavors, rather than as a separate infrastructure sector. In addition, since many natural systems can complement, support, or protect the functions of built infrastructure services, and because such systems can be significantly affected by adaptation decisions, it is vital to consider these natural components in the planning and design of infrastructure development.

Because of the interconnected nature of critical infrastructure, the high cost and long lifespan of such facilities, and the oftentimes lengthy planning and permitting process needed for building or modifying such facilities, it is imperative that local governments begin planning now for sea level rise adaptation for their critical infrastructure investments.

CHAPTER 2

Sea Level Rise Planning and Background

The following chapter provides background on coastal hazards and presents the State's planning and regulatory framework for sea level rise adaptation.

Climate change and extreme weather events associated with drought, extreme heat, storm flooding, tidal flooding (King Tides[1]), wildfire, and mudslides already impact infrastructure in California. This Guidance addresses sea level rise directly because of its associated coastal hazard risks and the potential for them to increase more rapidly with rising global temperatures.

BEST AVAILABLE SCIENCE

The *State of California Sea-Level Rise Guidance (OPC 2018)* (and the related *Rising Seas in California: An Update on Sea-Level Rise Science* report) is currently considered by the Coastal Commission and other agencies and organizations to be the best available science on sea level rise in California. In addition to synthesizing the available research on sea level rise, these documents highlight scientific evidence that indicates the potential for extreme sea level rise due to rapidly accelerating and irreversible ice loss from the Greenland and Antarctic Ice Sheets. They find that there could be upwards of 6-10 feet of sea level

1 NOAA defines a King Tide as a non-scientific term people often use to describe exceptionally high tides.

rise by 2100 (associated with the medium-high and extreme risk aversion scenarios[2]). Further, the *State of California Sea-Level Rise Guidance (OPC 2018)* recommends which sea level rise scenarios to evaluate depending on various planning and project characteristics, and specifically recommends evaluating the extreme risk aversion (also called H++) scenario for critical infrastructure projects. Alongside this best available science, the *Making California's Coast Resilient to Sea-Level Rise: Principles for Aligned State Action* adopted by the Commission (May 2020) call for adaptation plans to address a minimum target of 3.5 feet of sea level rise in the next 30 years to spur statewide action in the near term.

Understanding the Probabilities

The best available science currently offers probabilities of specific sea level projections at tide gauges to be used to inform decisions on the California coast. These probabilities are based on observations, global climate models, and expert opinion. Specifically, the probabilities stem from a set of sea level rise projections derived from global climate models; thus, they are not true probabilities in the traditional sense of the word. Rather, they reflect the probability that a group of climate models will predict a certain amount of SLR, given the range of parameters used in the climate models. While these models constitute the current best available climate science, when they are updated to reflect new research about the global climate, the "probabilities" will shift. Although future changes are expected, by presenting probabilities associated with sea level rise projections, the *State of California Sea-Level Rise Guidance (OPC 2018)* and the *Rising Seas in California* reports offer decision makers useful information to fold into risk assessment and management frameworks.

In addition to the probabilistic projections, the best available science offers a set of extreme sea level rise projections called the "H++ scenario," which are not given an associated probability. This set of scenarios stems from developing research on the mechanisms driving the potential for extreme ice loss. It is important to note that the absence of a probability for the H++ scenario is not because the probability is so low that scientists could not identify it; rather, it is because the climate models used to generate the probabilities had not yet incorporated the mechanisms of extreme ice sheet melt from recent research that gave rise to the H++ scenario. In fact, because of this, the *State of California Sea-Level Rise Guidance (OPC 2018)* and the *Rising Seas in California* reports indicate that the probabilistic projections may underestimate the likelihood of extreme sea level rise under high emissions scenarios. The Ocean Protection Council plans to update the *State Sea-Level Rise Guidance* approximately every five years to incorporate new scientific research, so the next update could present new information about probabilities and the potential for extreme ice melt.

2 The *State of California Sea-Level Rise Guidance (OPC 2018)* includes specific projections for each of 12 tide gauges across California for every 10 years from 2030 to 2150. Further, it includes three scenarios (low, medium-high, and extreme or H++ risk-aversion scenarios) recommended for planning purposes depending on the project type and risk tolerance. This information is integrated into the *Coastal Commission Sea Level Rise Policy Guidance* (see Appendix G for SLR projection tables).

Because of the uncertain timing but very significant consequences of extreme rates of sea level rise, the *State of California Sea-Level Rise Guidance (OPC 2018)* recommends analyzing the H++ scenario for "projects with a design life beyond 2050 that have little to no adaptive capacity, would be irreversibly destroyed or significantly costly to relocate or repair, or would have considerable public health, public safety, or environmental impacts."

Consistent with this direction, the Coastal Commission recommends evaluating the extreme risk aversion (H++) scenario for projects and planning efforts related to critical infrastructure due to the long lifespans and significant consequences associated with this type of development. Importantly, as is discussed in both the *State of California Sea-Level Rise Guidance (OPC 2018)* and the Coastal Commission *Sea Level Rise Policy Guidance* (updated in 2018), the recommendation is to *understand and plan* for the H++ scenario, not necessarily to *site and design* for the H++ scenario. In other words, it may not be appropriate or feasible to site or design a project today such that it will avoid the impacts associated with, for example, ~10 feet of sea level rise (the approximate H++ scenario in 2100 for much of the California coast). However, it is important to analyze this scenario to understand what the associated impacts could be and to begin planning options to adapt to this scenario if and when it occurs, and to ensure that the risks and benefits of economic investments in critical infrastructure are fully understood. More information on how to integrate the H++ scenario into project analyses and adaptation planning and a description of tools available to facilitate this work can be found in Boxes 1 and 2.

As climate science and modeling continue to evolve, the sea level rise projections and their associated probabilities are also likely to change. Thus, considering a range of scenarios and probabilities up to and including the extreme/H++ scenario helps give communities flexibility and options for exploring the potential consequences of hazards to be prepared for as they invest in and maintain their critical infrastructure, especially for timeframes beyond 2050.

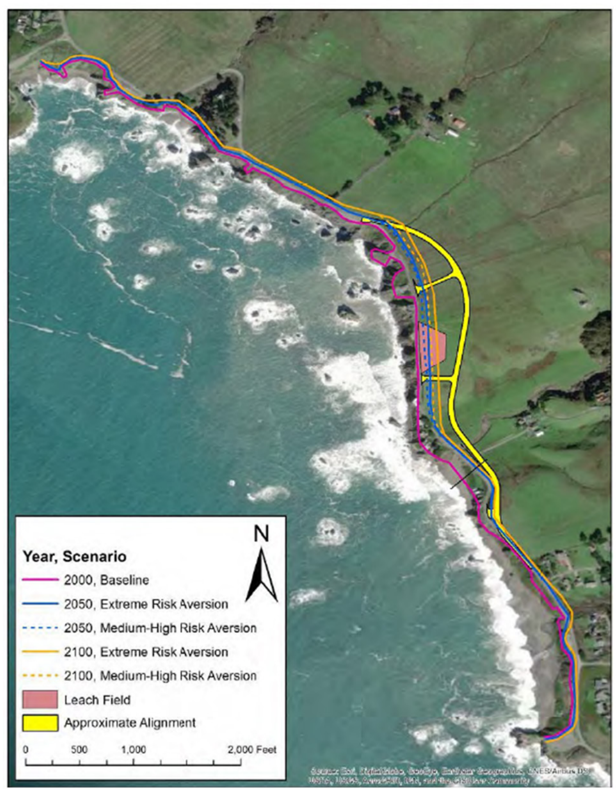
"For high consequence projects with a design life beyond 2050 that have little to no adaptive capacity, would be irreversibly destroyed or significantly costly to relocate/repair, or would have considerable public health, public safety, or environmental impacts should this level of sea-level rise occur, the H++ extreme scenario should be included in planning and adaptation strategies (e.g. coastal power plant)."

- State of California Sea-Level Rise Guidance (OPC 2018)

Box 1. Planning for the H++ Sea Level Rise Scenario

Consistent with statewide guidance, the Coastal Commission recommends evaluating the extreme risk aversion/H++ sea level rise scenario for critical infrastructure projects. In practice, H++ planning will vary depending on a variety of project factors such as current level of impacts, the type of project, and feasibility of alternatives, and the Coastal Commission has allowed for variation in terms of initial analyses and siting and design decisions as well as future required analysis and adaptation planning.

For example, Caltrans incorporated the H++ scenario for 2100 in initial bluff erosion analyses for a major Highway 1 realignment project near Gleason Beach in Sonoma County, and was able to find a feasible location for most of the realigned segment that would avoid this extreme scenario. However, vulnerabilities for the H++ and lower sea level rise scenarios still exist where the new highway alignment ties into the original alignment, so the Commission required Caltrans to monitor erosion in these locations and to initiate additional adaptation planning if reports show that the highway will be vulnerable to hazards within the following 15 years.



Similarly, Caltrans assessed flooding impacts associated with the H++ scenario for the replacement of the Dr. Fine Bridge over the Smith River in Del Norte County. The analysis showed that even extreme storm flooding combined with the H++ scenario for sea level rise would be lower than the originally proposed bridge elevation, and no additional project changes or follow-up adaptation planning was required.

Box 1. Continued

In other cases, the H++ scenario was not thoroughly assessed in initial hazards analyses. For example, a hazards analysis completed for repairs to and replacement of portions of an embankment providing protection for the Capinteria Wastewater Treatment Plant assessed only 5 feet of sea level rise plus a 100-year storm. Additional Commission staff analysis determined that the proposed project would provide safety through approximately 2080 based on the medium-high risk aversion scenario, but that impacts associated with an H++ scenario could occur sooner. Because the embankment replacement and repairs were necessary to provide immediate protection for the wastewater treatment plant, the Commission approved the project on a temporary basis (through 2041, a 20 year approval) and required completion of additional hazards analysis and adaptation planning prior to the expiration of the permit. Specifically, the applicant is required to assess the H++ scenario and determine if the embankment will continue to provide protection (while also minimizing coastal resource impacts) or if alternative adaptation approaches will be necessary at that time or over the longer term. A similar approach of requiring additional hazards analysis and adaptation planning has been used for other critical infrasturtcure projects (*e.g.*, a recent permit for protecting Pacific Coast Highway in Ventura County).

While H++ planning will continue to vary based on different project factors, the critical piece is to understand and acknowledge that extreme sea level rise is possible, and it could both increase the potential for impacts to critical infrastructure and result in sea level rise impacts sooner. Analyzing this scenario will help ensure that critical infrastructure will be able to adapt to these impacts if and when they occur by helping to frame future phases of adaptation that can be incorporated into a long-term plan and will help ensure economic investment decisions are fully evaluated. Understanding the full context of these adaptation phases can also help inform the scale of adaptation that makes sense to implement as a first step – for example, it may be cost saving in the long term to alter the design or scope of an initial adaptation strategy when it is considered in the context of a phased, long term plan.

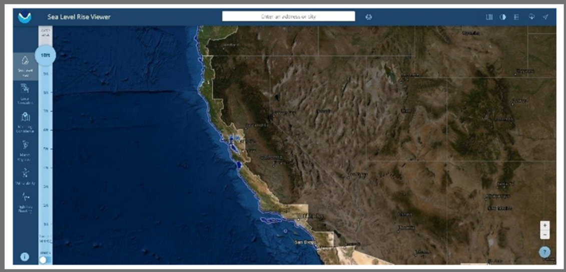
More information on tools to help assess the H++ scenario can be found in Box 2. Further, Chapter 4 of this Guidance provides additional information on phased adaptation, funding mechansims, and other topics that can help stakeholders plan for extreme sea level rise.

Box 2. Tools to Analyze the H++ Sea Level Rise Scenario

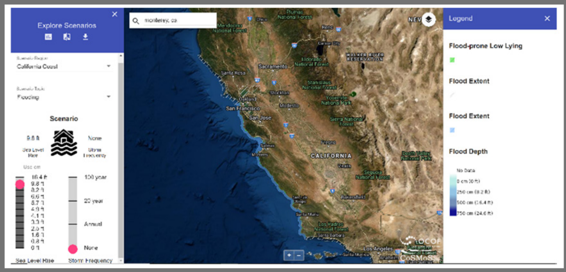
In general, SLR planning processes for critical infrastructure should analyze sea level rise over the appropriate planning horizon for the infrastructure in question, including scenarios up to the H++ scenario for that time horizon. According to the State Sea Level Rise Guidance, under the H++ SLR scenario, 2.7 feet of SLR can be expected by 2050, 6.6 feet by 2080, and 10.2 feet by 2100. Therefore, a critical infrastructure project that will be in place until the year 2100 should analyze SLR scenarios up to and including the 10.2-ft scenario. A project that will be in place until 2080 should analyze SLR scenarios up to and including the 6.6-ft scenario.

There are several tools available that can facilitate analysis of the H++ scenario. Since a 2100 planning horizon can be quite common, stakeholders often look for tools to analyze approximately 10 ft of SLR. The following are publicly available tools that can be used to analyze this 10-ft scenario.

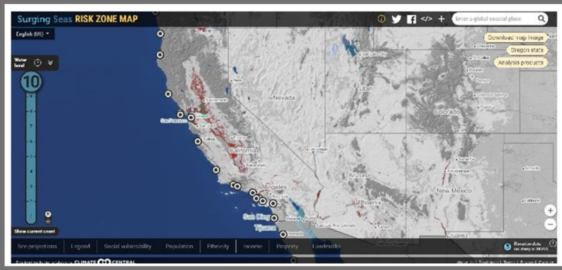
1. **The NOAA Sea Level Rise Viewer** provides SLR scenarios in 1-foot increments up to 10 feet. This SLR model is a bathtub model and does not account for waves, erosion, and storms.



2. **The Our Coast Our Future** tool, which serves the COSMOS data, provides storm flooding, shoreline position, and cliff edge position data for a 9.8-ft scenario for the region from San Francisco to Point Conception. This data layer is expected to be expanded statewide. Additionally, the tool provides groundwater rise data for the 9.8-ft scenario statewide. COSMOS is a hydrodynamic SLR model and users can view SLR scenarios with and without storm conditions.



3. **The Surging Seas** tool by Climate Central provides SLR scenarios in 1-foot increments up to 10 feet. While it does not account for erosion and other coastal processes, it provides information on assets at risk within flood areas.



The SLR scenario closest to 10 ft in whatever SLR model is publicly available for the site in question can also be used. If that scenario falls short of 10 ft, the analysis can still consider the rate of SLR associated with the H++ scenario. For example, if a user of COSMOS in Southern California analyzes the 6.6 ft scenario, they can consider the implications of that amount of SLR occurring by the year 2080 – the year by which 6.6 ft of SLR is expected to occur under the H++ scenario.

HAZARDS ASSOCIATED WITH SEA LEVEL RISE

Sea level rise is expected to increase storm flooding, coastal erosion, tidal inundation, submergence of nearshore lands, groundwater rise, and seawater intrusion. Figure 1 provides examples of how sea level rise can exacerbate these coastal hazards. While each is discussed separately below, when hazards co-occur in space and time, as is often the case along the shoreline, vulnerabilities can increase significantly.

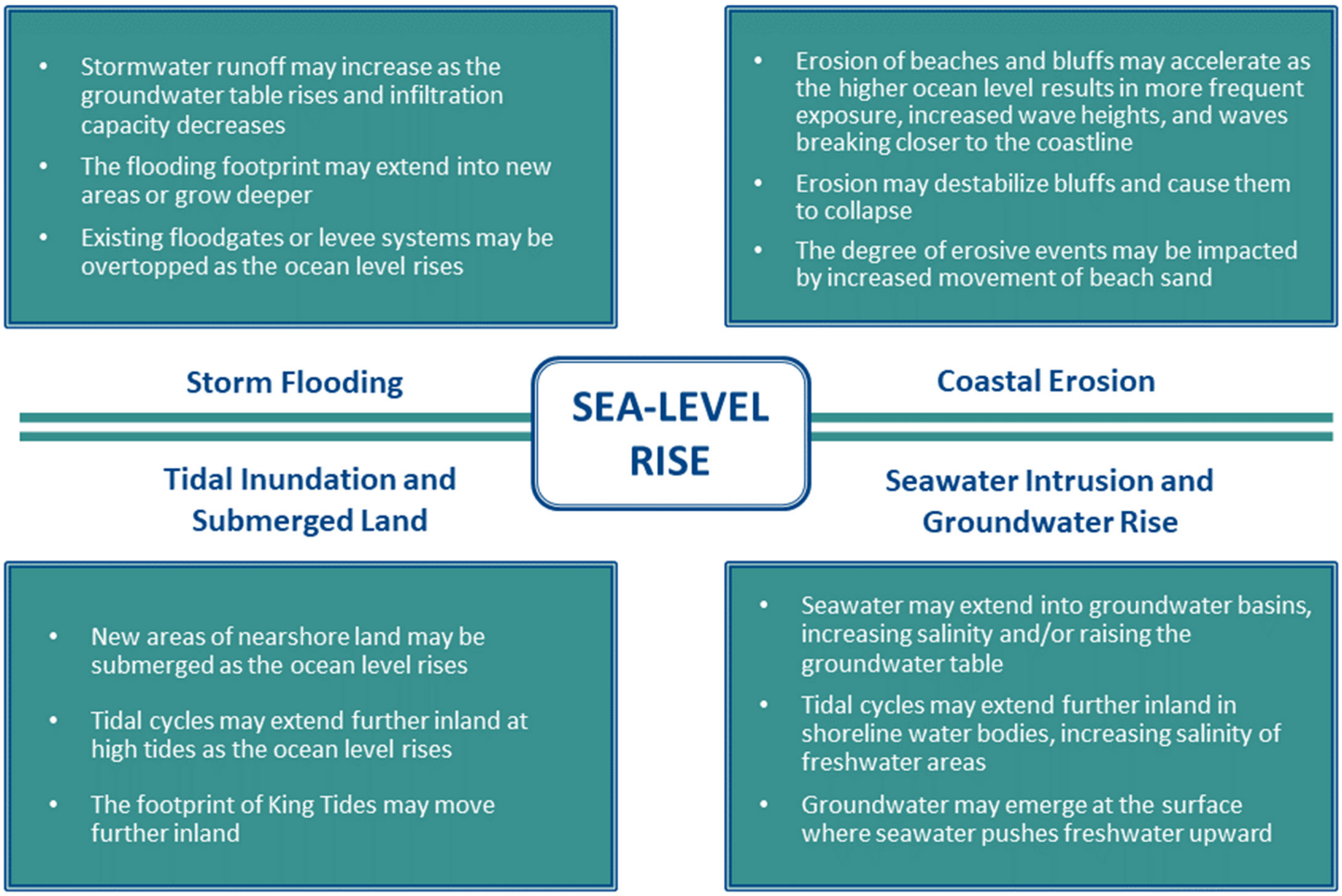


Figure 1. Hazards exacerbated by sea level rise.

Storm Flooding

Sea level rise combined with storms will flood areas not previously prone to flooding. In addition, as riverine and coastal waters come together at river mouths, coastal lagoons, and estuaries, higher water levels at the coast may cause water to back up and increase upstream flooding. Drainage systems that discharge close to sea level are expected to have similar problems, and inland areas may become flooded if outfall pipes back up with saltwater.

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, as will predicted increases in the intensities of rainfall events. Wildfire damage in coastal watersheds can also increase flooding risks to our shorelines.

Coastal Erosion

As seas rise, waves and tides will force water further and further inland, particularly during coastal storms, triggering consequences including both episodic and increased shoreline erosion, as well as damage to shoreline development. Erosion rates along coastal bluffs, beaches, and dunes are expected to increase with rising sea levels and are likely to further increase if waves, storms, and coastal flooding increase in size and intensity or become more frequent. Large sections of the California coast consist of coastal bluffs that are often highly susceptible to erosion. Fire damage in coastal locations could also result in significant erosion of exposed slopes that have lost vegetation. As sea level rises, the amount of time that these bluffs are exposed to wave attack and ocean waters will increase, causing further erosion. This, in turn, could trigger landslides and the loss of structural and geologic stability of bluffs. Signs of these effects are already becoming evident along various portions of the shoreline.

Image 1. Stormwater infrastructure in Fort Bragg, Mendecino County.

Tidal Inundation and Submerged Land

In addition to storm flooding and coastal erosion, sea level rise will also impact tidal flooding. As the ocean migrates inland, new lands will become tidally influenced and more areas will become permanently submerged. Bathymetry, built structures, and the natural coastline configuration will influence how rising seas will translate into encroaching tidal footprints.[3]

Seawater Intrusion and Groundwater Rise

Research also indicates that sea level rise is likely to raise groundwater levels and push saltwater into fresh groundwater; however, the degree of impact will vary greatly depending on local conditions. When a low-lying coastal area has shallow groundwater with subsurface connections to the ocean, sea level rise can cause groundwater levels to rise and emerge at the surface, contributing to chronic flooding (Hoover *et al*. 2017; Befus *et al*. 2020).

3 Submerged lands lie below the line of mean low tide; tidelands are located between the lines of mean high tide and mean low tide (California Code of Regulations, §13577).

Additionally, even if groundwater is relatively deep in a low-lying area, existing lower groundwater can rise to shallow elevations, increasing the need for pumping to protect infrastructure from inundation. Sea level rise may also drive seawater intrusion into freshwater aquifers, increasing the salinity of groundwater and leading to potential impacts to infrastructure and water supplies. Generally, the most vulnerable areas will be where groundwater is shallow, where aquifers are unconfined along low-lying coasts, or where aquifers have already experienced overdraft and saltwater intrusion.

SEA LEVEL RISE PLANNING AND REGULATORY FRAMEWORK

With over 1,100 miles of coastline, California has a vested interest in assuring that new and existing development is prepared to handle the various impacts of climate change, including hazards associated with rising seas. State policy requirements call for multiple parties to play a role in helping the state to be ready to address the challenges of climate change.

Roles and Responsibilities

Multiple entities are involved in the planning, permitting, and adaptation of critical infrastructure.

Federal Agencies

Federal agencies are relevant to the planning and implementation of many types of critical infrastructure projects. Federal agencies that support and are otherwise involved in infrastructure projects include the National Oceanic and Atmospheric Administration (NOAA); the U.S. Fish and Wildlife Service: U.S. Army Corps of Engineers; Federal Emergency Management Agency; U.S. Environmental Protection Agency; and Federal Highway Administration and Federal Railroad Administration. The transportation and water chapters (Chapter 4 and Chapter 5) describe federal agency processes relevant to those respective infrastructure types.

California Coastal Commission and Other State Agencies and Tribes

The Coastal Commission plays a central role in supporting the State’s efforts to plan for sea level rise and other climate change impacts. The Commission has primary responsibility in the coastal zone to implement the State’s Coastal Management Program and the Coastal Act, through partnerships with local governments with certified Local Coastal Programs. The Coastal Commission has nearly 50 years of experience addressing coastal hazards, including planning and permitting development in a manner that considers storm flooding, coastal erosion, tidal inundation, groundwater rise, and seawater intrusion. As coastal hazards management has become more complicated due to sea level rise, the Commission has taken on the role of providing policy and technical support to link science to policy and planning, and ultimately to the practical application of developing permit conditions and policies necessary to adapt to hazards. The Commission synthesizes and disseminates sea level rise planning information to local governments, other agencies, and various stakeholders. The Commission also convened and participates in a working group with representatives of the California State Association of Counties and the League of Cities to collaboratively address challenges and opportunities related to sea level rise adaptation. Finally, as of 2020, the Commission has provided over $8 million in funding to local governments for sea level rise vulnerability assessments, adaptation plans, and LCP updates.

Coastal Commission

Carry out the Coastal Act and use expertise to support sea level rise planning in the coastal zone

Federal Other State Agencies

Fulfill mission and use expertise to support sea level rise planning and communication statewide

Local Governments

Integrate sea level rise planning into land use decision-making to manage coastal hazards and land use under the Coastal Act and climate change laws; Undertake community-level vulnerability assessments and adaptation plans

Asset Managers

Use latest information and tools to plan for, maintain, and adapt infrastructure facilities in consideration of future sea level rise impacts; Undertake site-specific vulnerability assessments as necessary

Climate Change Science Advisors

Gather data, disseminate best available information, and provide guidance on the science of climate change and rising seas

Coastal Communities

Given predicted local risks to infrastructure, community members can be drivers of change through expression of priorities, expectations, and financing solutions

Figure 2. Roles and responsibilities related to sea level rise adaptation for critical infrastructure.

Other state agencies also address sea level rise as a part of their respective regulatory, planning, stewardship, policy-setting, or grant-making functions. Given the serious potential impacts of sea level rise and extreme weather events, California has directed all state agencies to consider climate change in planning and investment, including infrastructure investment.[4]

- The California Natural Resources Agency (CNRA) helps coordinate the strategy for state government to address the impacts of climate change, including through development of the State Adaptation Strategy, (previously called Safeguarding California (2018)), which is the State's roadmap of actions that state agencies will carry out to protect communities, infrastructure, services, and the natural environment from climate change impacts.
- The Ocean Protection Council (OPC) coordinates funding and activities of ocean-related state agencies to improve the effectiveness of state efforts to protect ocean resources. OPC also establishes policies to coordinate the collection and sharing of data related to the coast and ocean, and updates the *State of California Sea-Level Rise Guidance* every five years.
- The State Coastal Conservancy uses non-regulatory approaches to purchase, protect, restore, and enhance coastal resources, promote public access, and facilitate coastal climate adaptation.
- The State Lands Commission provides stewardship of sovereign lands and waterways, including coastal tidelands that are affected by potential adaptation actions such as hard armoring and beach nourishment, and through AB 691 (2013) has evaluated sea level rise vulnerability in the state's ports and harbors.
- The California Department of Parks and Recreation (State Parks) manages and protects its public recreational lands and natural and cultural resources, which cover nearly 25 percent of the state's coastline. State Parks also acts as an asset manager that provides facilities and infrastructure that facilitates access to the coast.
- The California Department of Transportation (Caltrans) manages highways and multi-modal transportation infrastructure, and is involved with intercity railways and public airports, many of which are located in the coastal zone and are potentially vulnerable to coastal climate impacts. Caltrans is increasingly considering sea level rise throughout their planning and project development processes, including in early project development phases. Caltrans has also conducted sea level rise vulnerability assessments (including evaluation of cliff retreat and storm surge) along the entire coastline and is actively engaged in adaptation planning priorities throughout the state.
- The San Francisco Bay Conservation and Development Commission (BCDC) protects and enhances San Francisco Bay, and it regulates development in and adjacent to the Bay and coordinates local adaptation planning efforts. BCDC has primary responsibility within San Francisco Bay to implement the State's Coastal Management Program.

4 See, e.g., Executive Order (EO) B-30-15, *Planning and Investing for a Resilient California: A guidebook for state agencies*

- The State and Regional Water Resources Control Boards (Water Boards) manage water resources and drinking water supplies, including resources and infrastructure located in the coastal zone and potentially vulnerable to coastal climate impacts. The Water Boards have begun addressing climate change impacts to water resources, including through the passage of several regional resolutions.
- The California Energy Commission guides state energy policy and planning for power plants, transmission and distribution lines, and other energy infrastructure located in the coastal zone, some of which may be potentially vulnerable to coastal climate change impacts.
- The Office of Planning and Research (OPR), through the Integrated Climate Adaptation and Resiliency Program (ICARP), coordinates resources for local, regional, and statewide climate adaptation planning and decision-making. OPR is responsible for coordinating and maintaining the State Adaptation Clearinghouse which serves as 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 change adaptation projects. In addition, OPR convenes the Technical Advisory Council, which is an appointed body of representatives from state agencies, local and regional governments, and NGOs, community-based organizations, and private sector. The role of the TAC is to facilitate coordination among state, regional, and local agency efforts to adapt to the impacts of climate change by: developing tools and guidance; promoting and coordinating state agency support for local and regional efforts; and informing state-led programs, including state planning processes, grant programs, and guideline development, to better reflect the goals, efforts and challenges faced by local and regional entities pursuing adaptation, preparedness and resilience. ICARP is centrally focused on efforts that advance climate equity and support integrated climate strategies, or those strategies that benefit both greenhouse gas reductions and adaptation.
- The California Strategic Growth Council (SGC) works collaboratively with public agencies, communities, and other stakeholders to coordinate activities and programs that support sustainable communities, emphasizing strong economies, social equity, and environmental stewardship. SGC is tasked with advancing the priorities developed in Safeguarding California, including through administration of grant programs funded through California Climate Investments (the statewide program funded through cap-and-trade dollars).

Tribes

Tribes have governmental planning and regulatory roles (self-governance as sovereign nations) as well as asset manager roles (on lands owned in fee and in trust). Tribes also have oversight over traditional lands and resources throughout the coastal zone and play an important advisory role, especially given their traditional ecological knowledges.

Regional Organizations

A variety of regional organizations such as Regional Adaptation Collaboratives, Metropolitan Planning Organizations, Associations of Governments, Joint Power Authorities, Utility Districts, etc., play roles in sea level rise adaptation depending on the location. Regional organizations can help garner resources and work more effectively across jurisdictional boundaries on climate change impacts, including where no one existing entity is set up to address all of the impacts that a region faces.

Local Governments

The 76 local jurisdictions (15 counties and 61 cities) within the coastal zone have a critical and direct role in planning for development and resource protection in relation to coastal hazards. Cities and counties have responsibilities related to their land use planning and regulatory authority (including via LCPs), ownership of critical infrastructure, and provision of essential services. In general, planning and zoning laws require that local jurisdictions provide essential services necessary for orderly buildout of an area's planned development. In the coastal zone, the Coastal Act requires local governments to site and design infrastructure to minimize risk from coastal hazards while protecting coastal resources. Many local governments develop sea level rise vulnerability assessments and adaptation plans that address the issues specific to their jurisdictions, and are also involved in regional sea level rise planning efforts.

State law requires local governments to evaluate how vulnerable local assets are to sea level rise impacts (see also the Regulatory Environment and Guidance section below). In addition, some local cities or counties may be asset managers that are directly responsible for management and upkeep of infrastructure, as discussed below.

Asset Managers

Asset managers are entities with direct responsibility for infrastructure services and facilities. For example, asset managers include, but are not limited to, cities or counties with departments assigned to carry out critical infrastructure services and functions, state agencies like Caltrans and State Parks, private entities like railroad and power companies, and special districts. Asset managers are responsible for planning for and maintaining infrastructure facilities, including obtaining permits and developing long-term plans to ensure adequate services where there are potential future impacts. This often requires detailed coastal hazard reports that build a site-specific profile of the coastal hazard. For example, Caltrans has developed climate change vulnerability assessments for all of its districts and is currently developing adaptation priorities reports for the State Highway System.[5] State Parks developed a “Cool Parks” initiative that identifies environmental resources within their parks that are most vulnerable to climate change, and is working with other organizations to examine and acquire open spaces that will preserve the State’s biodiversity. In addition, numerous wastewater operators have completed site-specific vulnerability assessments for their facilities.

5 Caltrans is developing these reports on a district-by-district basis. They have completed vulnerability assessments for all Districts and currently have Adaptation Strategies Reports in the development process for District 4 and District 12.

Climate Change Science Advisors

To help address the evolving nature of climate change impacts, there are entities that gather data, disseminate best available information, and provide guidance on the science of climate change and rising seas. For example, agencies such as the OPC, the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS) are instrumental in supporting technical needs associated with understanding climate change and its effects, including by updating sea level rise projections.

Coastal Communities

There are a number of ways coastal communities assess and prioritize investment in planning, development, and maintenance of critical infrastructure. Given predicted local risks to infrastructure that serves the public, community members can be drivers of change through expression of priorities, expectations, and financing solutions. Meaningful engagement with low-income communities, communities of color, and other environmental justice communities can inform equitable adaptation planning and outcomes.

Regulatory Environment and Guidance

The Coastal Act is a significant land use and resource protection law in the coastal zone; however, it is not the only law that places requirements on infrastructure planning relative to coastal hazards and resource protection. Key state laws, executive orders, and sea level rise guidance for California are described below.

Image 2. Lover’s Point, Monterey County.

State Law

<u>Land Use Planning in the Coastal Zone</u>

- Coastal Act
- Public Trust Doctrine
- California Planning and Zoning Law

<u>Infrastructure/Sea Level Rise Specific</u>

- SB 379 (2015) Coastal Jurisdictions Must Undertake Vulnerability Assessments & Hazard Mitigation Plan Updates
- AB 1482 (2015) Climate Data & Transportation
- AB 2800 (2016) Climate-Safe Infrastructure Working Group

Executive Order

- B-30-15 (2015) Climate Change Link to the State's 5-Year Infrastructure Plan

Sea Level Rise Guidance

- *State of California Sea-Level Rise Guidance* (OPC 2015, Updated 2018)
- *Coastal Commission Sea Level Rise Policy Guidance* (2018 Update)
- AB 2800 Paying It Forward: *The Path Toward Climate-Safe Infrastructure in California*
- *Safeguarding California* (2018 Update)

Figure 3. Key state laws, executive orders, and sea level rise guidance for California.

Coastal Act Framework

The Coastal Act requires new development to be structurally stable, requires risks from flooding and other hazards to be minimized, and protects coastal resources, including by limiting the use of shoreline armoring. The Act will govern decisions regarding the siting and design of new critical infrastructure; the repair and maintenance of existing critical infrastructure, including replacement or upgrades of individual sections or components of current infrastructure; and the adaptation strategies designed to address current or future vulnerabilities related to coastal hazards and sea level rise. Taken together, the Coastal Act mandates protection and, where feasible, enhancement and restoration of coastal resources including public access, recreation, marine environments, water quality, agricultural land, and environmentally sensitive habitat. Coastal Act policies also require that new development be located in areas with adequate public services, and other policies prioritize certain uses over others. LCP policies related to critical infrastructure and sea level rise adaptation will need to be consistent with these Coastal Act policies. Key Coastal Act policies relevant to critical infrastructure and sea level rise adaptation are provided in Appendix A.

In addition to Commission-issued permits where infrastructure is located within the Commission's retained permitting jurisdiction, the Coastal Act provides for two other processing pathways that allow local governments or other local bodies to undertake land use and public works planning: Local Coastal Programs and Public Works Plans. These are described briefly below and local circumstances will generally dictate which of these pathways provides the best method of planning that can be feasibly implemented.

Local Coastal Programs

The Coastal Act requires each of the 76 coastal jurisdictions in California to prepare a Local Coastal Program (LCP). LCPs contain the ground rules for future development and protection of coastal resources through the local coastal permitting process, and specify appropriate locations, types, and scale of new or changed uses of land and water. Each LCP includes a land use plan and measures to implement the plan (such as zoning ordinances). While each LCP reflects the unique characteristics of individual local coastal communities, regional and statewide interests and concerns must also be addressed in conformity with Coastal Act goals and policies. Following adoption by a city council or county board of supervisors, an LCP is submitted to the Coastal Commission for review for consistency with the Coastal Act. After an LCP has been approved, the Commission's coastal permitting authority over most new development is transferred to the local government, which applies the requirements of the LCP in reviewing such development. The Commission retains permanent coastal permit jurisdiction over development proposed on tidelands, submerged lands, and public trust lands, and the Commission also acts on appeals from certain local government coastal permit decisions. The Commission reviews and approves any amendments to previously certified LCPs. LCPs are key tools for addressing sea level rise, including as it impacts critical infrastructure.

LCP

An LCP is a land use planning document that lays out a framework for development and resource protection in cities and counties within the coastal zone.

Public Works Plans

The Coastal Act also allows for public agencies to develop Public Works Plans (PWPs).[6] Particularly suited for planning for large scale or multi-part infrastructure projects, a PWP is a land use planning tool that describes one or more public works projects[7] across one or more local government jurisdictions. PWPs must be submitted to and certified by the Coastal Commission, and they must be consistent with the certified LCPs of the jurisdictions they are in, or, if the LCPs are not certified, Chapter 3 of the Coastal Act. Once the Coastal Commission approves a PWP, no coastal development permit is required for a project described within it; rather, before a project commences, the public agency notifies the Commission of its intent to undertake a project, and the Commission determines whether it is consistent with the certified PWP or if special conditions are necessary to make it consistent. While they require a great deal of upfront technical analysis and project and mitigation planning, PWPs can be a good alternative to individual project-by-project coastal permit reviews. They can also assist in more regional planning for public works projects that would require multiple coastal development permits in multiple jurisdictions – making them effective and efficient tools for implementing sea level rise adaptation projects in an entire corridor, system, or network of critical infrastructure. Appendix E Case Study 5 provides an example of how a PWP called the North Coast Corridor Public Works Plan/Transportation and Resource Enhancement Program (NCC PWP/TREP) was developed in San Diego County through just such a regional and highly collaborative planning process.

PWP

A PWP is a planning document that plans for and details a public works project or activity that may cross multiple jurisdictional boundaries in the coastal zone.

Public Trust Doctrine

The modern Public Trust Doctrine refers to the principle that the government holds sovereign title to certain lands and must protect them for public use. It is rooted in English common law, under which the sovereign held in trust all navigable waterways and submerged lands for public commerce, navigation, and fishing. The State of California acquired sovereign ownership of all tidelands, submerged lands, and beds of natural, navigable waterways upon its admission to the United States in 1850. While private parties can own coastal upland property, the state continues to own most tidelands, submerged lands, and waters in trust for the public. The Public Trust Doctrine is not static but is continuously evolving to reflect the needs and values of Californians. Presently, uses that may be considered consistent with the Public Trust on these Public Trust lands include maritime commerce, navigation, fishing, boating, water-oriented recreation, public access, and environmental preservation and restoration. On all sovereign land, the Public Trust Doctrine prioritizes public uses and interests over private ones (Center for Ocean Solutions, 2017).

6 See California Public Resources Code, §30605

7 See CA PRC, §30114 for the definition of “public works”

The landward location and extent of the State's Public Trust lands are generally defined by reference to the ordinary high-water mark (California Civil Code §670), which is ambulatory. It is expected that in the majority of locations sea level rise will cause the ordinary high-water mark, and thus the Public Trust boundary, to move inland over time. Therefore, as sea level rises, some critical infrastructure along the shoreline, which is currently located on upland property, may come to be located on Public Trust lands. Adaptation planning for infrastructure needs to account for the legal protections that the Public Trust Doctrine imposes on such Public Trust lands.

The responsibility for protecting the Public Trust on California's outer coast falls upon the California Legislature, California State Lands Commission, California Coastal Commission, other state agencies with relevant jurisdiction or property interests, and local governments. In cases where development is proposed on sovereign land, the applicant will need to obtain a lease or other appropriate authorization from the State Lands Commission or the appropriate legislative grantee in addition to an appropriate coastal development approval from the Coastal Commission, which retains permitting authority for development on tidelands even in areas where there is a certified LCP. In considering these authorizations, the agencies will consider the proposed development's consistency with the Coastal Act and Public Trust Doctrine. Thus, the Public Trust Doctrine provides a framework through which state agencies, local governments, infrastructure owners and managers, and other stakeholders should approach sea level rise adaptation planning for critical infrastructure.

Statewide Framework

In addition to the Coastal Act, there are several relevant laws, Executive Orders, and State guidance documents directed at climate change and sea level rise adaptation planning that inform critical infrastructure planning.

Senate Bill 379

Senate Bill 379 (2015) enacted Government Code §65302(g)(4)(A)-(D), which requires jurisdictions to review and update the safety element of their general plans or their local hazard mitigation plans and to develop "a vulnerability assessment that identifies the risks that climate change poses to the local jurisdiction and the geographic areas at risk from climate change impacts" (CA Government Code, §65302(g)(4)(A)(i)). The law requires that jurisdictions gather information on "(e)xisting and planned development in identified at-risk areas, including structures, roads, utilities, and essential public functions" and develop implementation measures to carry out adaptation goals, policies, and objectives to protect the community (CA Government Code, §65302(g)(2)(A)(x)). As guidance from the Governor's Office of Planning and Research states, "any new infrastructure should be built to withstand the identified risk" (CA Governor's Office of Planning and Research, 2017).

Government Code §65302(a) also requires that a general plan's land use element "identify and annually review those areas covered by the plan that are subject to flooding identified by flood plain mapping prepared by the Federal Emergency Management Agency (FEMA) or the Department of Water Resources." The 2017 *State of California General Plan Guidelines* put out by the Governor's Office of Planning and Research state that:

> "[w]hen fully informed by applicable flood information and assessments of climate change impacts and management practices, careful land use planning can effectively reduce vulnerability to potential flood damage in cities and counties. Such careful planning can include non-structural flood protection measures, low impact development, and improved stormwater management practices. Federal, state, and local agencies may construct and operate flood protection facilities to reduce flood risks, but some amount of risk will remain for those residing in floodplains. Therefore, increasing awareness can help ensure Californians recognize the potential threat and are better prepared to respond to flood emergencies."

Senate Bill 1

Senate Bill 1 (2017) provides funding for transportation infrastructure, including for a Road Maintenance and Rehabilitation Program for deferred maintenance on the state highway system and local street and road system. The law requires climate change impacts be addressed, where feasible, for projects in this program. Specifically, Section 2030(e) states that "to the extent possible and cost effective... departments and cities and counties receiving funds under the program shall include features... to better adapt the asset to withstand the negative effects of climate change and make the asset more resilient to impacts such as fires, floods, and sea level rise."

Assembly Bill 1482

Assembly Bill 1482 (2015) requires all state agencies and departments to prepare for climate change by continuing collection of climate data, considering climate change in state investments, and promoting reliable transportation strategies.

Assembly Bill 2800

Assembly Bill 2800 (2016) requires all state agencies to take into account climate change impacts during planning, design, building, operations, maintenance, and investments in infrastructure. Assembly Bill 2800 also established formation of the Climate-Safe Infrastructure Working Group, which released its final report in 2018, *Paying it Forward: The Path Toward Climate Safe Infrastructure in California*, detailing ways climate change impacts can be incorporated into the planning and design of the state's infrastructure (see below for more information).

Senate Bill 1072

California SB 1072 (2018) establishes a Regional Climate Collaborative Program to build and support existing regional climate collaboratives across the state that will assist under-resourced communities in accessing state funding for climate change mitigation and adaptation projects. The law requires the Strategic Growth Council (SGC) to develop best practices and technical assistance guidelines, and award annual grants to collaboratives for capacity building.

Senate Bill 246

California SB 246 (2015) establishes the Integrated Climate Adaptation and Resiliency Program (ICARP) to be administered by the Office of Planning and Research to coordinate regional and local efforts with state climate adaptation strategies to adapt to the impacts of climate change. It also requires, within one year of an update to the *Safeguarding California Plan*, the Office of Emergency Services, in coordination with the Natural Resources Agency, the Office of Planning and Research, and relevant public and private entities, to review and update the *Adaptation Planning Guide*.

Executive Order B-30-15

Executive Order B-30-15 (2015) requires, among other things, that the State's *Five-Year Infrastructure Plan* take climate change into account when making investment decisions and that state agencies take climate change into account to employ full life cycle cost analysis to evaluate and compare infrastructure investments. The guidebook, *Planning and Investing for a Resilient California: A Guidebook for State Agencies*, provides guidance on how to implement Executive Order B-30-15.

State of California Sea-Level Rise Guidance

The Ocean Protection Council (OPC) coordinates activities of ocean-related state agencies to improve the effectiveness of state efforts to protect ocean resources. The agency funded a science update (*Rising Seas in California: An Update on Sea-Level Rise Science)* and recommended best practices for planning and addressing anticipated impacts in their *State of California Sea-Level Rise Guidance: 2018 Update*. The guidance documents address critical infrastructure and other development with a very long project life (e.g., 100 years or greater) that would be irreversibly destroyed or significantly costly to repair, and/or would have considerable public health, public safety, or environmental impacts.[8] OPC recommends that agencies take a precautionary approach and consider extreme sea level rise scenarios to ensure that investments in new or redeveloped systems remain reliable and safe throughout their expected lifespans. Infrastructure investments that plan for rising seas and associated impacts will be more resilient to current and future coastal hazards. Going forward, updates to the state guidance are expected every five years as updated sea level rise projections become available.

8 The *State of California Sea-Level Rise Guidance (OPC 2018)* provides sea level rise projections for the extreme H++ scenario for 12 gauges along California's coast.

Coastal Commission Sea Level Rise Policy Guidance

Following the issuance of the 2018 OPC *State of California Sea Level Rise Guidance*, the Coastal Commission updated its *Sea Level Rise Policy Guidance* in November 2018 to reference the latest scientific advancements and recommendations of OPC. The Coastal Commission *Sea Level Rise Policy Guidance* focuses specifically on how to apply the Coastal Act to the challenges presented by sea level rise through LCP certifications 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. It includes guiding principles such as: to use best available science; to use a precautionary approach by considering high or extreme sea level rise projections, particularly for high-risk decisions like those for critical infrastructure; to consider local conditions, goals, and priorities when developing adaptation strategies; to account for the social and economic needs of the people of the state, including by considering environmental justice implications; to maximize protection of public access, recreation, and sensitive coastal resources, including public trust and water-dependent uses; to maximize natural shoreline values and processes, including through encouraging nature-based adaptation strategies; to coordinate planning and regulatory decision making with appropriate local, state, and federal partners; and to maximize public participation in planning and regulatory processes.

Coastal Commission Local Government Working Group

A local government working group was established in 2019 with representatives from the California State Association of Counties (CSAC), the League of California Cites, and a Coastal Commission subcommittee. The purpose of the working group is to develop strategies to improve collaboration and communications between local governments and the Commission on sea level rise adaptation planning and LCP updates. In 2020, the Local Government Working Group developed a set of shared principles that provide a foundation for its collective efforts on sea level rise adaptation planning going forward. The full *Joint Statement on Adaptation Planning* outlines guiding principles, opportunities, challenges, and actions associated with proactive and effective sea level rise adaptation for California's coastal communities.

Paying It Forward: The Path Toward Climate-Safe Infrastructure in California

The report completed pursuant to AB2800 (see above), *Paying it Forward: The Path Toward Climate Safe Infrastructure in California*, offers comprehensive statewide guidance on the infrastructure design and implementation process that supports climate change mitigation and adaptation, nature-based adaptation strategies, and social equity measures. Much work remains to integrate climate change and sea level rise science into state infrastructure plans and design, engineering, investment, and construction decisions. Rather than requiring everything be built today for the high-emissions scenario decades from now, the report's Working Group recommends taking an adaptive, phased approach over time.

California Adaptation Strategy

As a result of this recent increase in climate-safe infrastructure planning bills and executive actions, recent state guidance has also begun to address infrastructure-specific issues. For example, the 2018 iteration of the *California State Adaptation Strategy*, called *Safeguarding California*, lists several goals and outcomes related to infrastructure, including:

> O-1.8. Use regulatory authority to reduce risk to existing property impacted by sea level rise and plan to adapt publicly-owned critical infrastructure at risk from sea level rise such as highways, wastewater treatment plants, airports, ports, pipelines, and transmission lines.
>
> O-1.8a. Invest in engineering and cost feasibility studies to move all vulnerable infrastructure that can be relocated to a higher or more protected area.
>
> O-1.8b. Reinforce non-moveable infrastructure at risk of sea level rise and storm surge.
>
> O-1.9. Regularly monitor all at-risk coastal infrastructure.

The next iteration of the *State Adaptation Strategy* is expected in 2021.

Sea Level Rise Principles for Aligned State Action

In early 2020, the Secretaries of the California Natural Resources Agency and CalEPA convened 17 state entities with coastal climate resilience responsibilities, including the Coastal Commission, to develop *Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action*, which was then adopted by the Coastal Commission in May 2020. The principles fall into seven main categories:

- Develop and utilize best available science
- Build coastal resilience partnerships
- Improve coastal resilience communications
- Support local leadership and address local conditions
- Strengthen alignment around coastal resilience
- Implement and learn from coastal resilience projects
- Integrate and prioritize equity and social justice

These principles are meant to guide unified, effective action towards sea level rise resilience for California's coastal communities, ecosystems, and economies. The adopted Principles are consistent with and complementary to the Coastal Commission's ongoing work to address sea level rise.

CHAPTER 3

The Unique Challenges of Sea Level Rise Planning for Critical Infrastructure

The following chapter explains the factors that make adaptation planning for critical infrastructure unique, detailing the role and purpose of infrastructure, the physical characteristics of these assets, and the significant costs and consequences of critical infrastructure vulnerability.

Sea level rise planning for critical infrastructure is similar to other types of sea level rise planning in that it involves assessing vulnerabilities and identifying and implementing adaptation strategies. However, several key characteristics of critical infrastructure – such as its size, cross-jurisdictional nature, and the role it plays in providing important public services – make the adaptation planning process different than for residential, commercial, or other types of development.

Proactive adaptation planning and implementation of adaptation strategies are critical for avoiding the economic, environmental, and social costs associated with temporary or long-term losses of infrastructure services. However, just as the nature of critical infrastructure makes adaptation planning so important, the inherent characteristics of critical infrastructure make such planning unique and challenging. Two main facets of critical infrastructure – its purpose and role in our communities and the physical characteristics of these assets – add complexity to adaptation planning, as discussed in this section.

ROLE AND PURPOSE OF CRITICAL INFRASTRUCTURE

Critical infrastructure plays an immensely important role in our communities. Communities rely on roads, rail corridors, and related biking and pedestrian routes for transportation, and they rely on water infrastructure for drinking water, wastewater service, and draining streets of rainwater. Damage to any one of these systems can threaten public safety, wreak havoc on daily life, impact properties far from flood zones, and result in economic impacts that cascade throughout California. Understanding this vital role is key to evaluating the complexities associated with planning for the continued use and adaptation of critical infrastructure over time.

Role of Critical Infrastructure Magnifies Consequences

The critical functions of infrastructure highlight the even greater importance of proactive adaptation planning as compared to other development types. While damage to any development from sea level rise is significant in its own right, the consequences of inaction resulting in damage to critical infrastructure are far more significant given the role that these assets play and the services they provide to a community.

Role of Critical Infrastructure

Proactive planning for critical infrastructure is essential because it serves a variety of necessary and practical functions in communities, the loss of which could have potentially damaging social, economic, political, and public health consequences.

For example, highway systems are major thoroughfares that allow people to access homes, jobs, services, schools, and recreational destinations. They are also the routes for evacuating from natural disasters like tsunamis and wildfires, and they are the routes that emergency vehicles use to respond to emergencies. Damage to these assets that cause even temporary closures can have widespread and consequential impacts on communities. Consider, for example, the impacts associated with the year-long closure of Highway 1 due to a mudslide near Gorda in Big Sur (Sulek, 2018). Among other impacts, motels, restaurants, and businesses south of the mudslide lost a significant portion of their business because people could not drive north to south through Big Sur. Highways 1 and 101, as well as local roads, are currently vulnerable to coastal hazards in many other locations throughout the state, and these vulnerabilities will be exacerbated as sea levels rise. Although many areas have alternate transportation routes (an adaptation strategy in its own right), even temporary flooding or other damage can make navigating roadways difficult or dangerous and can block access in emergency situations when it is needed most.

Image 3. Point Loma Wastewater Treatment Plant in San Diego County.

Similarly, unaddressed vulnerabilities to water infrastructure could result in a loss of service that would severely disrupt the public's day-to-day lives. For example, damage from a storm event, exacerbated by higher sea levels in the future, could temporarily shut down a wastewater treatment plant.[9] The loss of power or damage to individual pieces of wastewater or drinking water infrastructure could result in the loss of the ability to collect, pump, process, and/or treat raw water and sewage for hours, days, or even weeks, depending on the severity of the damage. Importantly, the consequences of flooding at a wastewater treatment plant extends far beyond the flood zone. Because whole communities rely on wastewater infrastructure, a recent study found that the number of people impacted by the loss of wastewater services due to sea level rise impacts could be five times as high as previous predictions of the number of people who experience direct flooding (Hummel *et al*., 2018).

Damage to water infrastructure could also significantly impact public health not only from loss of function but also from mobilization of pollution. For example, significant physical damage to a wastewater treatment plant from storm events exacerbated by sea level rise could cause the release of untreated sewage into the ocean or other adjacent waterways. Even without significant damage, nuisance flooding that overwhelms the capacity of waste and/or stormwater systems could lead to increased frequency of water pollution and other public health impacts.

Further, inadequately adapting critical infrastructure for sea level rise disproportionately impacts low-income communities, communities of color, and other environmental justice communities that have historically been overlooked and under-invested in by government. Environmental justice communities are more vulnerable to disruptions caused by critical infrastructure failures due to less capacity to adapt and greater sensitivity to adverse impacts. For example, interruptions to highway systems or public transit service may result in loss of wages if individuals cannot travel to work, which can be detrimental to those in non-salaried jobs or with limited access to alternate modes of transportation. The inability to access clean water or inoperable wastewater treatment facilities could expose people to poor water quality, potentially jeopardizing their health, particularly if they do not have the funds to purchase

9 For example, Hurricane Harvey, which made landfall in Texas on August 25, 2017 as a Category 4 hurricane, caused as many as 61 public water supply systems and 40 wastewater treatment facilities to become inoperable for some length of time (Texas Commission on Environmental Quality, 2018).

alternate sources of potable water. These consequences add additional strain to environmental justice communities, as described further in the Environmental Justice section in Chapter 4. Altogether, the important role that critical infrastructure plays in daily life means that damage to these assets has significant societal costs that disproportionately impact those with greater sensitivity and less ability to adapt.

Critical Infrastructure Compared to Private Development

At a basic level, adaptation planning for critical infrastructure differs from adaptation planning for private development because the at-risk assets are ones that benefit the public at large. Instead of balancing the private interests of protecting a home or business against the public harm that could be caused by certain adaptation measures, in the case of infrastructure, public needs are being balanced on both sides of the equation.

Consider for example one of the most common conflicts that arises in sea level rise adaptation planning: whether to protect a structure in place, and thus eventually lose the fronting coastal habitat and resources (*e.g.*, sandy beaches, wetlands) to passive erosion[10], or instead to remove the threatened structure and allow natural processes to continue. If the structure in danger is private development, such as a home, a decision to protect the structure would benefit a private individual to the detriment of the public – the homeowner is able to keep their private residence (for at least some amount of time), while the wider public loses the benefits from the fronting coastal resources that otherwise could have existed (for example, recreational areas at beaches, or ecosystem services provided by wetlands). Although each individual case is different, the Coastal Act and Public Trust Doctrine generally prioritize the needs of the broader public, and the Commission has often acted to ensure that private structures are not built, maintained, or protected in a manner that harms public resources or habitats. In some cases, private structures may need to be altered or removed in order to ensure continued use of public trust resources and protection of natural habitats if doing so is consistent with Constitutional protections for private property.

Protecting Public Assets

Adaptation planning for critical infrastructure differs from adaptation planning for private development because the at-risk assets are ones that benefit the public at large.

However, if the structure in danger is a piece of critical infrastructure – for example a wastewater treatment plant or a stretch of Highway 1 – protecting the structure in place for a period of time would likely adversely impact habitat or other public resources but would also provide the public benefit of continued service. In this situation, the Commission or local government will need to analyze the benefits and costs associated with protection in place versus other alternatives and determine how to

10 On an eroding natural shoreline, a habitat such as a beach or wetland will typically retreat inland as sea levels rise. Assuming sufficient space and sediment availability the shoreline profile will migrate inland, maintaining, for example, beach width. However, hard structures such as armoring and infrastructure will block this natural migration, resulting in passive erosion or “coastal squeeze”, or the narrowing and eventual loss of fronting habitat.

best maximize those public benefits and minimize public costs over time. Because the public relies on transportation networks and water management, it may be appropriate and necessary to consider a phased adaptation approach that protects transportation and water structures in place for some amount of time until an alternative adaptation strategy such as realignment, replacement, or relocation can be developed and implemented in the future.

PHYSICAL CHARACTERISTICS OF CRITICAL INFRASTRUCTURE

The inherent physical characteristics of critical infrastructure assets create unique local adaptation planning challenges. Critical infrastructure is often larger than other development and is commonly made up of networked systems and/or lateral components that extend beyond jurisdictional boundaries. These assets are also commonly constructed with sturdier, longer-lasting materials, have higher maintenance costs, and require the use of potentially hazardous materials. In combination, these factors both increase the costs and consequences associated with damage from coastal hazards and increase the costs, planning time, and overall complexity of any type of adaptation strategy designed to avoid or minimize impacts from sea level rise.

Network Size Increases the Scale of the Planning Challenges

The scale of the planning challenge for addressing sea level rise impacts to critical infrastructure is significant simply due to the fact that pieces of critical infrastructure are typically much larger than other kinds of development. Highway 1 runs for more than 650 miles along almost the entire coast of California, and much of the roadway sits within storm flood zones or along eroding bluffs. Highway 101 is similarly located in vulnerable coastal areas throughout portions of Del Norte, Humboldt, and Santa Barbara Counties (California Coastal Commission, 2016). Railroads also run alongside many of these highways and are experiencing similar vulnerabilities from flood and erosion impacts that will increase in the future. Even where these roadways (and railroads) are further back from the coastline, they are still at risk from sea level rise where bridges, viaducts, causeways, or other similar features cross rivers, streams, wetlands, and estuaries. Numerous smaller, local roads, bridges, parking lots, transit routes and other features that are critical for getting to, from, and around coastal communities are also at risk. Statewide, 55 inches of sea level rise would more than double the miles of road currently at risk from flooding during a 100-year storm —from 1,900 miles at risk to 3,500 miles (Heberger *et al*., 2009). About half of the roads, including highways and other road types, at risk are around San Francisco Bay, and another half on the Pacific coast. Adaptation for such extensive and interconnected transportation assets will be a continuing challenge.

Infrastructure Scale

Adaptation planning for critical infrastructure is complex because it is typically much larger than other types of development and includes components that extend over large areas and cross multiple jurisdictional boundaries.

Similarly, water distribution and wastewater collection systems traverse large areas and can take up significant amounts of space. A 2009 Pacific Institute report described 21 wastewater treatment plants on the San Francisco Bay and seven on the Pacific coast vulnerable to 55 inches of sea level rise coupled with a 100-year storm (Heberger *et al*., 2009). Further, although a wastewater treatment plant itself sits on a single site, the mix of pipelines and pump stations form a large network that connects the treatment plant to the community it serves, and many of these related assets are in vulnerable areas themselves. A unique challenge for water infrastructure is that damage to below-ground structures, specifically elements of wastewater collection and water distribution systems, is often difficult to assess. Impacts of sea level rise, including marine flooding, groundwater rise, and localized subsidence can accelerate degradation of the system and reduce the expected life of its components. Broken or corroded components can result in leaks in the water distribution system or inflow and infiltration into the wastewater collection system which can significantly decrease system capacity and increase pollution risks.

Interconnected Systems Add Complexity

Not only are a significant number of critical assets vulnerable to sea level rise, but these types of assets are interconnected. Vulnerabilities in just one place or for one component can potentially cascade throughout the wider system. For example, minor flooding that blocks off a portion of a roadway for even a short amount of time could increase traffic on alternative routes. Over time, this type of nuisance flooding could increase repair and maintenance costs if traffic is routinely diverted to other routes that were not designed to handle the additional vehicles.

The cascading failures associated with wastewater treatment plants are an even greater risk. Wastewater treatment plants are largely designed to avoid cascading failures precisely to minimize the risks of releasing hazardous materials into the environment, or sewage backing up through the system, or even just a service disruption. Back-up generators, overflow tanks, automatic switches and shutoffs, and so on are all meant to contain failures. However, damage to one of the many components that make up the networked system, combined with a faulty or poorly maintained or out of date mechanism, extreme storm conditions, or human error can still overwhelm these redundancies and result in catastrophic failures. For example, the failure of Seattle's West Point Treatment Plant in February 2017 began when heavy rains and high tides sent water back through pipes, flooding the plant. A cascade of power outages, malfunctioning switches, and overtopping tanks then led to a system shutdown (Kamb, 2017). Further, most municipal wastewater treatment systems lack wide-scale redundancy – oftentimes a single plant serves a large number of households – making them particularly susceptible to wide-scale community impacts if service is disrupted for any reason (Hummel *et al*., 2018).

Critical Infrastructure Systems

Adaptation planning for critical infrastructure must account for the interconnectedness of the system components, including where vulnerabilities in one part of the system affect other parts of the system.

Importantly, the networked system and continuous, lateral nature of transportation and water infrastructure pose a particular challenge with respect to implementing adaptation options. Specifically, each segment needs to continue to operate within the system even as adaptation strategies are implemented. For example, it is infeasible and unnecessary to adapt all of Highway 1 at once. A more practical approach would be to implement adaptation strategies for the most at-risk segments, followed by other segments as they become increasingly vulnerable. This means, though, that even as portions of the roadway are elevated or relocated, such new construction may connect to segments that are still vulnerable. This was a particular concern for a recent Commission-approved project that included safety improvements for a segment of Highway 101 adjacent to Humboldt Bay. In this case, a new bridge, overpass, and interchange were designed and elevated to account for some amount of sea level rise, but then connected to other segments of the Highway that are currently vulnerable to flooding and likely to experience even greater flooding impacts in the near future. This example highlights a particularly important note of caution when implementing phased adaptation strategies. Successful long-term planning requires careful attention to ensuring that decisions and investments made for shorter-term phased approaches do not prejudice the ability to realize the longer-term vision for best adapting to climate change from an overall system perspective. To this end, long-term adaptation planning goals should be developed and considered while implementing short- and mid-term solutions.

SIGNIFICANT COSTS AND CONSEQUENCES

Critical infrastructure is a costly investment for communities, and the costs associated with adaptation planning will be significant; however, the costs—both monetary and societal—of failing to adapt such infrastructure are much greater. Unfortunately, the anticipated costs associated with sea level rise impacts to critical infrastructure far exceed the current budgets of asset managers in the state, especially local governments and local districts. Moreover, federal and state funding for sea level rise planning is inadequate to fully support planning for, and implementation and ongoing maintenance of, infrastructure adaptation projects.

Cost of Adaptation

Adaptation planning and on-the-ground implementation require significant investment; however, the costs of failing to adapt such infrastructure—both monetary and societal—are much greater.

For example, the EPA estimates that the nation's sewers are worth more than $1 trillion, and the wastewater collection system of a single large municipality could be worth billions of dollars, with smaller cities facing costs of many millions to replace their systems (Sanitary Sewer Overflow Frequent Questions, 2020). Smaller scale damage to infrastructure due to chronic nuisance flooding will also increase in frequency as seas rise. In many coastal cities, the cumulative cost of frequent events (e.g., nuisance floods) over time may exceed the costs of the extreme but infrequent events (Moftakhari *et al.*, 2017).

Hazard models integrate the effects of sea level rise, tides, waves, storms, and coastal change (i.e., beach erosion or bluff retreat), leading to predictions of more frequent and severe flooding and storm impacts. A 2019 USGS study reports that over $150 billion (2010 dollars) of California property could be impacted by flooding associated with 6 feet of sea level rise and one extreme 100-year storm (Barnard *et al*., 2019). This study also found that inclusion of storm-driven dynamic water levels in future coastal flooding assessments results in the additional projected exposure of $50 billion in property over the next century when compared to sea level rise alone. Annual storms are estimated to impact $119 billion (2010 dollars) in California property by 2100. These estimates do not reflect that local impacts along the California coast can have cascading economic impacts both nationally and globally.

In addition, the costs for adaptation will be substantial. Along the shoreline of San Francisco Bay, adaptation to withstand 6 feet of sea level rise and a 100-year storm could cost up to $450 billion (Hirschfeld and Hill, 2017). Elevating and retrofitting the major commercial ports of California (i.e., in San Diego, Los Angeles/Long Beach, and San Francisco Bay) to prepare for 6 feet of sea level rise is estimated to cost $9-12 billion (Becker *et al*., 2017). Flooding will not only impact port terminals and harbors but will also impact the railroads and roads exiting the ports, disrupting the movement of goods to other regions. These results and funding constraints underscore the urgency for all local, regional, state, and federal agencies and asset managers to coordinate when developing adaptation plans to address the effects of sea level rise and climate change on critical infrastructure. Adaptation planning that prioritizes addressing critical infrastructure can help protect the long-term physical, social, and economic health of the coast and nation.

CHAPTER 4

Key Considerations

The following chapter describes several overarching concepts and recommendations that should be considered in all adaptation planning for critical infrastructure.

KEY CONSIDERATIONS FOR ADAPTATION PLANNING

Taken together, the important role that critical infrastructure plays in daily life, the costs associated with potential damage to infrastructure, and the significant amount of risk posed to a vast amount of critical infrastructure throughout vulnerable areas, all illustrate that proactive adaptation planning is critical for ensuring the health and safety of communities, the state's economy, and the environment. Planning infrastructure adaptation can take decades, multiplying the complexity of the planning process and magnifying the uncertainty, and thus illustrating the need to begin planning now.

There are five key considerations emphasized throughout this Guidance that represent significant challenges and opportunities within the critical infrastructure planning process:

(1) Coordinated Planning

(2) Environmental Justice

(3) Phased Adaptation

(4) Adaptation Costs and Funding

(5) Nature-Based Adaptation Strategies

Assessment of all five key considerations must be undertaken to successfully develop practical and implementable solutions on a local and regional scale and to ensure equity among coastal communities. These key considerations and the associated recommendations align with other state guidance documents and principles, including those in Executive Order B-30-15, the principles entitled *Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action*, and the *Coastal Commission Sea Level Rise Policy Guidance*, among others.

COORDINATED PLANNING

Coordination is especially important when conducting sea level rise adaptation planning for critical infrastructure. Not only does much of California's critical infrastructure – such as highways, railways, and pipelines – cross boundaries between local government jurisdictions and agency districts like those of Caltrans and the State Water Board, infrastructure can also involve multiple regulatory authorities, owners, operators, user groups, and other stakeholders. Planning and projects may also have an impact on Tribal interests (see the Commission's 2018 Tribal Consultation Policy for more information). Furthermore, decisions about critical infrastructure have the potential to impact surrounding land uses, and vice versa. And given its importance, decisions regarding critical infrastructure can have oversized impacts on coastal communities, including all of the various groups, stakeholders, and components thereto. Thus, planning how to adapt critical infrastructure to sea level rise cannot occur in isolation; rather, it must consider the wider land use context, and all stakeholders must be involved in the planning process and in decision-making. Rather than being designed around a single objective, successful adaptation planning must incorporate all applicable initiatives, mandates, and laws, such as state goals around reducing vehicle miles traveled and increasing use of recycled water. Along the California coast, the policies included in Local Coastal Programs and resultant coastal permits must reflect the outcomes of such broad-based coordination while ensuring consistency with the Coastal Act.

Coordinated Planning

Planning for sea level rise is a complex process that requires coordination among state agencies, local governments, regional planning bodies, asset managers, coastal communities, stakeholders, and other interested parties.

Regional Climate Collaboratives

There are several regional climate collaboratives in California that coordinate climate adaptation efforts. These collaboratives support adaptation at a regional scale, build networks, provide venues for cross-jurisdictional and cross-sectoral discussions, and help leverage resources to make planning more efficient. The climate collaboratives on the California coast include: the North Coast Resource Partnership, the Bay Area Climate Adaptation Network (BayCAN), the Central Coast Climate Collaborative, the LA Regional Climate Collaborative (LARC), and the San Diego Regional Climate Collaborative. The Alliance of Regional Collaboratives for Climate Adaptation (ARCCA) brings together the individual collaboratives to coordinate at the statewide scale. Building the relationships and infrastructure to support regional collaboration on climate change is especially challenging in under-resourced communities. To address this disparity, Senate

Bill 1072 (Leyva, 2018) established the Regional Climate Collaboratives Program (RCC) at the California Strategic Growth Council. RCC will support cross-sector collaboration at the regional scale that leads to climate change mitigation, adaptation, and resilience initiatives. In the context of critical infrastructure, regional collaboratives can help bring together relevant stakeholders and provide services like technical assistance and best practices for outreach and coordination.

Other Regional Governance Structures

Local Coastal Programs (LCPs) and Public Works Plans (PWPs) are also tools for coordinated planning. The scope of the California Coastal Act requires LCPs to look broadly at land use designations, zoning, and development standards, and this perspective provides a framework for local governments to ensure a coordinated approach to adaptation of public infrastructure and the development it serves at a neighborhood or community scale. The framework also helps avoid conflicts between infrastructure projects and a community's land use and shoreline protection goals for sea level rise adaptation.

Taking a wide view, local governments should identify critical infrastructure that crosses jurisdictional boundaries and work with those neighboring jurisdictions to ensure a coordinated approach to adaptation. They may, for example, conduct joint sea level rise vulnerability assessments and adaptation plans with jurisdictions that share infrastructure vulnerabilities, which can then inform updates to each jurisdiction's LCP. When considering infrastructure such as roadways and water systems, it is important and necessary to consider how the entire system or network serves the people who live and work there as well as visitors to the coast, and where land use density and intensity of use served by such networks can be accommodated out of harm's way, consistent with the Coastal Act.

PWPs (defined in Chapter 2 of this Guidance) can also be used to facilitate a collaborative planning process for critical infrastructure. Because PWPs are not necessarily tied to a single local jurisdiction, they can be particularly appropriate for addressing adaptation at a regional scale. They can help interconnect multiple local governments, asset managers, and public agencies, which can allow pooling of resources and funding for implementation of a shared vision for a planning area. This approach can provide greater efficiency in planning for large or phased public works projects. Due to this multi-stakeholder and cross-jurisdictional scope, PWP development requires commitment to upfront coordination by all parties to identify long-term goals and review each project with a high level of detail.

Since PWPs must be consistent with the certified LCPs of the jurisdictions in which projects are planned, it may be necessary, especially in the case of cross-jurisdictional PWPs, to amend certain LCPs to form a cohesive standard of review that is consistent with the Coastal Act. Those LCP amendments should be developed prior to or concurrently with the PWP in cooperation with agency partners and other affected stakeholders and interested parties. Case Study #5 in Appendix E of this Guidance provides an example of how a PWP in San Diego County was developed through such a collaborative planning process, and how LCP amendments were developed concurrently with the PWP to implement a regional vision for public works improvements.

Additionally, through development of LCPs and PWPs, the Coastal Commission encourages local governments to work with other federal, state, regional, and local partners to align the policies in LCPs and projects in PWPs with other plans, such as the Circulation and Public Works Elements of General Plans, State Park Plans and Regional Transportation Plans. Updates to Safety Elements and Local Hazard Mitigation Plans are also a good opportunity for long-range planners and asset managers to align plans that include hazard policies to address risks to critical infrastructure.

Joint Power Authorities (JPAs) are another means by which multiple public agencies can work together to address adaptation of critical infrastructure, particularly when the infrastructure requires a regional or cross-jurisdictional approach. A JPA is a group of public agencies that all share the same pre-existing authority and wish to come together to jointly administer that authority. Unlike some other types of governmental organizations, JPAs can raise funds through bonds, user fees, taxes, or assessments levied by participating agencies, which makes them an effective means to fund cross-jurisdictional projects. In the case of critical infrastructure, public agencies could form a JPA to implement sea level rise adaptation projects across multiple jurisdictions, providing they meet the requirements of the California Joint Exercise of Powers Act (California Government Code, §6500-6539.6).

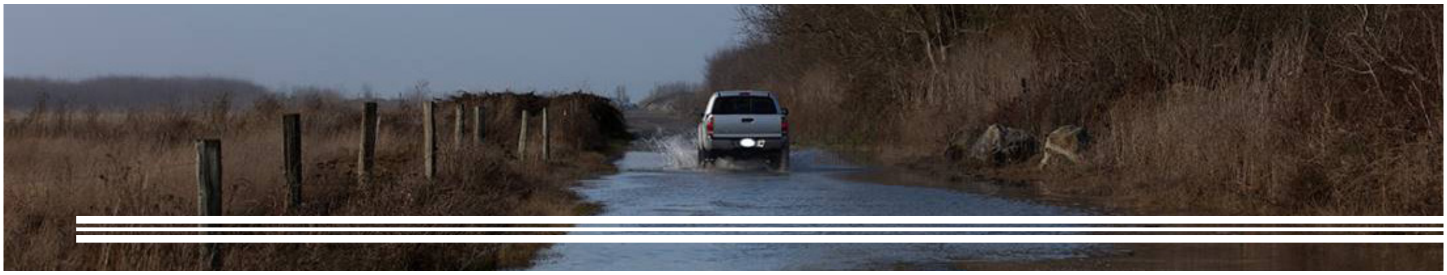


Image 4. Eel River, Ferndale, in Humbolt County. Photo by the Kings Tides Project.

Coordinated Planning Recommendations

The Coastal Commission has the following recommendations to improve coordination in LCP planning to address climate change and sea level rise impacts to critical infrastructure:

1. **Coordinate with nearby jurisdictions** to develop a cohesive vision for the planning region that assures coastal access, recreational opportunities, and resources are provided, protected, and enhanced to meet the needs of all persons, consistent with the Coastal Act.
2. **Engage with regional climate collaboratives** to facilitate coordination, share information, and leverage resources (including through encouraging) additional State support for regional collaboratives.
3. **Align planning documents** of various asset managers and agency partners so they present a cohesive sea level rise adaptation plan and phasing schedule that incorporates shared objectives.
4. **Pool funding and leverage resources** by working with entities with shared adaptation objectives.

5. **Utilize frameworks like PWPs and consider organizational structures such as JPAs and Special Districts** where appropriate to plan and implement regional sea level rise adaptation strategies.

ENVIRONMENTAL JUSTICE

Government Code §65040.12(e)(1) defines environmental justice as "the fair treatment and meaningful involvement of people of all races, cultures, incomes, and national origins with respect to the development, adoption, implementation and enforcement of environmental laws, regulations, and policies." Due to discriminatory land use policies and systematic racism, communities of color, indigenous communities, low-income communities, and other historically marginalized communities, referred to as environmental justice communities, often experience disproportionate environmental burdens and are more vulnerable to adverse impacts from a project. Further, environmental justice communities often lack access to the decision-making process and experience procedural barriers to becoming involved in that process. It is therefore imperative that planners consider the environmental justice impacts and social inequities that sea level rise adaptation strategies for critical infrastructure may cause or exacerbate.

Environmental Justice

Planning for infrastructure adaptation must include robust public involvement and consideration of environmental justice communities, because these communities often experience disproportionate environmental burdens, are more vulnerable to related adverse impacts, and often lack access to the decision-making process.

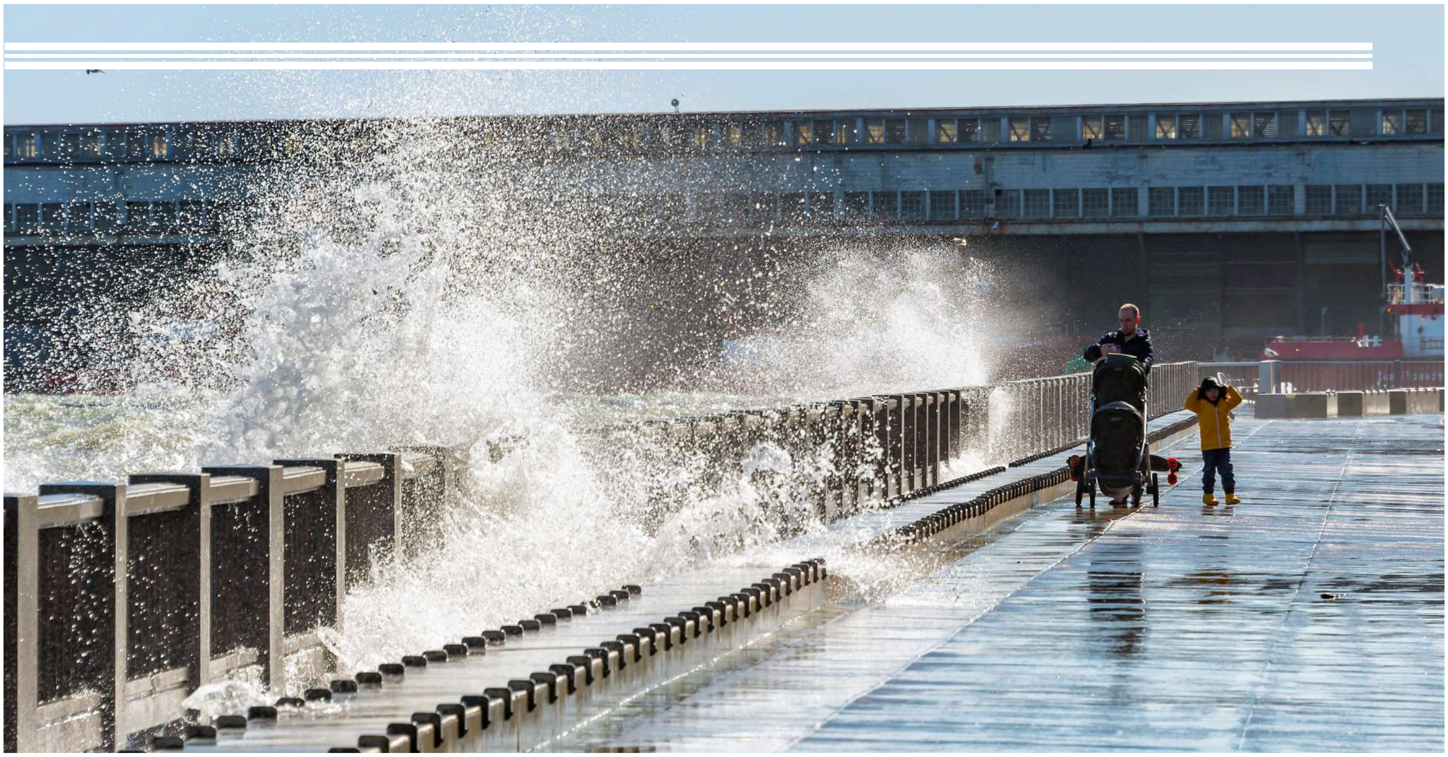
For example, redirecting traffic to use an alternate route or relocating a vulnerable highway segment farther inland without assessing the communities who live nearby or use the current and alternate routes may result in a pollution or displacement burden to these inland communities. Furthermore, when sea level rise threatens access to a highway segment or the functions of wastewater and stormwater infrastructure, any adverse impacts such as loss of wages or a disruption in the day-to-day routine for people will have an even greater impact on low-income workers or individuals who often have less capacity to adapt to these changes. Protecting a wastewater treatment plant using hard shoreline armoring may result in the loss of public access and recreation space as sea levels rise and exacerbate coastal erosion, which may in turn disproportionately burden environmental justice communities who cannot afford to live near the coast and who will lose free and low-cost access to the coast. And funding infrastructure projects such as wastewater treatment plants often include rate payer increases, which typically come in the form of a flat rate increase. This type of cost adjustment disproportionately affects lower-income rate payers and exacerbates existing housing cost burdens. These financial burdens will continue to increase the longer communities wait to implement adaptation actions.

Because adaptation planning for critical infrastructure requires balancing coastal resource protection with the important public services that the infrastructure provides, any decision, such as siting of infrastructure or project financing mechanisms, may disproportionately burden environmental justice communities if the project does not actively avoid or minimize the adverse impacts in these communities nor engage them in the process. As called for in recent State law and guidance, including the Commission's *Environmental Justice Policy* (adopted by the Commission in 2019) and Coastal Act Section 30604(h) (a 2016 amendment to the Act giving the Commission new authority to specifically consider environmental justice when making permit decisions, see Appendix A), adaptation planning should consider the equitable distribution of benefits and burdens to environmental justice communities.

To ensure that adaptation planning for critical infrastructure does not create nor exacerbate disproportionate burdens or benefits, coastal managers need to carefully evaluate environmental justice impacts of adaptation projects, conduct meaningful engagement with environmental justice communities, and develop an equitable and transparent public participation process.

When siting new critical infrastructure or relocating existing development to less hazardous areas, coastal managers need to consider both direct and indirect burdens to environmental justice communities, such as pollution, displacement, loss of coastal access, and rate increases. Siting of infrastructure may perpetuate existing inequalities if polluting infrastructure is placed in an area with industrial uses that already burden environmental justice communities. Project proponents should evaluate the costs and benefits of alternatives with equity in mind to evaluate whether there will be a disproportionate burden on environmental justice communities. Adaptation solutions that avoid or minimize harm to environmental justice communities and increase community benefits should be prioritized.

Image 5. King tides at Embarcadero in San Francisco. Photo by the California King Tides Project.



Additionally, identifying and engaging environmental justice communities throughout the planning process provides an opportunity for stakeholders to inform permitting decisions that may impact their neighborhoods. Meaningful engagement procedures include early and consistent communication with, and involvement of, communities of concern during all phases of planning and permitting, ensuring project information accounts for language barriers and is disseminated in an understandable format, and maximizing public participation by providing multiple opportunities and formats for the public to provide input on a project.

Environmental Justice Recommendations

The Coastal Commission has the following recommendations related to environmental justice:

1. **Consider the equitable distribution of environmental burdens and benefits** in all infrastructure-related sea level rise adaptation plans and projects, including when prioritizing adaptation options.
2. **Include outreach and engagement with environmental justice communities** that are directly and/or indirectly impacted by sea level rise and adaptation projects through all phases of design, planning, permitting, and implementation. Decision making processes should address barriers to participation in environmental justice communities, such as meeting time, lack of childcare, and location. Project information should be accessible to individuals who speak different languages and have varying degrees of education.
3. **Avoid disproportionate burdens to environmental justice communities** in sea level rise adaptation projects for critical infrastructure. Projects should avoid creating or exacerbating adverse coastal resource impacts in environmental justice communities to the maximum extent feasible and mitigate any unavoidable burdens.
4. **Conduct alternatives analyses** for critical infrastructure adaptation projects and include evaluation of the costs and benefits to environmental justice communities, including how projects can be designed to avoid adverse impacts, mitigate harm, and increase benefits.

PHASED ADAPTATION

Phased adaptation – also known as an adaptation pathway approach or trigger-based adaptation – is the use of different adaptation strategies over time as certain sea level rise thresholds are met. For example, adaptation phases can start with protection strategies, such as sand replenishment, or accommodation strategies, such as floodproofing and elevation, and lead to eventual relocation in the longer term as protection and accommodation strategies become infeasible due to increasing hazards, costs, and coastal resource impacts.

Phased Adaptation

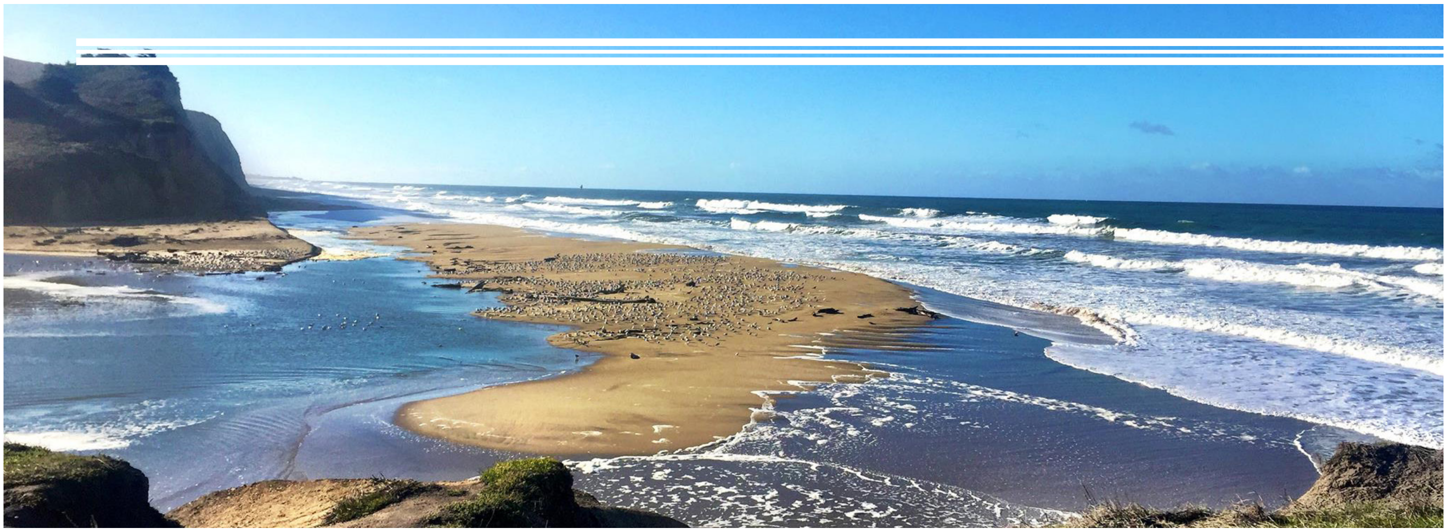
Phasing allows asset managers to undertake adaptation incrementally, which can allow time for long-term planning and identification of funding sources.

State guidance recommends analyzing an extreme rate of sea level rise to inform adaptation planning for critical infrastructure (see Chapter 2, Box 1, and Box 2 for more information on incorporating the H++ scenario into planning efforts). In the current best available science, this scenario is called the extreme or H++ scenario. While it may make sense to accommodate the H++ scenario in a single adaptation project for certain pieces of critical infrastructure, in other cases it may be appropriate to use a phased approach to adaptation. Planners can design multiple phases of adaptation measures, each for an incremental amount of sea level rise, up to and including the H++ scenario. By linking each phase to a particular amount of sea level rise or a particular physical impact of sea level rise, phasing allows adaptation measures to be triggered when they are necessary. This allows the adaptation pathway to be responsive to changes in the observed rate of sea level rise and other changing conditions over time. Additionally, phased adaptation measures allow planners to consider long-term adaptation strategies and impacts while implementing near-term solutions.

Phased adaptation will be an essential approach for protecting critical infrastructure in California given the complexity of adapting infrastructure and the significant vulnerability that is expected. Phasing allows for incremental changes that can ease cost constraints, create additional time needed for planning future phases of adaptation, and be responsive and adaptive to the timing of future conditions. Phasing also allows for the alignment of long-term land use and infrastructure adaptation, so that development and infrastructure in hazardous areas can be phased out concurrently, as hazards become more extreme. Phased adaptation plans can also be updated periodically based on changed conditions and updates to the best available science. Given the significant costs of adapting critical infrastructure, and the uncertainty over the timing of sea level rise, this adaptive approach will often be the best method for systematically addressing sea level rise vulnerability.

Moreover, because annual funding cycles, large project scopes, and other factors may make it infeasible to adapt an entire infrastructure network all at once, incorporating adaptation into existing projects, ensuring segments work together, and developing a plan to continue adaptation over time will be critical. These plans should take a regional approach to ensure that adaptation in one location does not come at the expense of the infrastructure in another, connected location or otherwise constrain future options

Image 6. San Gregorio State Beach in San Mateo County. Photo by the California King Tides Project.



within the infrastructure network. Beyond the distinct funding and planning challenges for implementing adaptation strategies, the factors unique to infrastructure – that people rely on critical infrastructure every day, and that the social, environmental, and economic costs of damage to infrastructure would be significant – further highlight the importance of phased adaptation approaches. Phased adaptation can be incorporated into LCPs by including policies that support or specifically define the near-term phases of adaptation as well as policies that more generally describe future adaptation phases and the need for periodic LCP updates to implement them over time.

Phased Adaptation Recommendations

The Coastal Commission has long supported phased adaptation approaches for ensuring that critical infrastructure is protected while long-term adaptation plans are developed and implemented. The Commission recommends the following:

1. **Consider phased adaptation strategies** to reduce upfront costs and allow for the continuation of essential functions while providing time for the planning needed for development of long-term strategies.
2. **Analyze the extreme/H++ sea level rise scenario** and use phased adaptation as appropriate to address long-term sea level rise impacts.
3. **Define clear and realistic timelines** and benchmarks for different phases.
4. **Decide on a timeframe under which LCP policies will be operable** (e.g. for the next 10-20 years) with a commitment for regular updates to implement future phases of adaptation strategies within the LCP.
5. **Address the most vulnerable infrastructure first while considering the networked infrastructure, and assure that new development and growth occur in safe areas** that can accommodate it without adverse impacts to public access to the shoreline and other coastal resources.

ADAPTATION COSTS AND FUNDING

There are several financial considerations to take into account when conducting sea level rise adaptation planning for critical infrastructure. First, the costs associated with damage to infrastructure from sea level rise – and the costs of conducting adaptation planning – are both significant. There is also uncertainty involved in calculating the full costs and benefits of different sea level rise adaptation approaches. Many of the benefits of sea level rise adaptation projects to coastal resources are difficult to quantify in economic terms. For example, the value of preserving a beach area includes both market values, such as benefits to the local tourism industry and property tax revenues, as well as non-market values, such as providing habitat for wildlife – both of which can be difficult to calculate. The same can be said for the ways in which the beaches and the shoreline define communities and contribute to their social fabric and identity. In addition, the costs of the "do nothing" approach are also difficult to measure. Although the construction cost of projects can be estimated, any work done in a current or future hazard area will be subject to uncertain future hazards, making it very difficult to predict future maintenance and repair or replacement costs. Despite these uncertainties, attempts must be made to fully analyze costs and benefits, including the costs anticipated from maintaining the status quo over time, and some conclusions can be drawn about the cost-effectiveness of adaptation planning in general.

Adaptation Cost

The costs associated with damage to infrastructure from sea level rise – and the costs of conducting adaptation planning – are both significant; however, planning ahead and avoiding hazards may reduce long-term costs and providing funding now is important for long-term infrastructure resilience.

Planning ahead reduces costs

Despite the significant costs of adapting infrastructure to deal with sea level rise, planning ahead is far more cost effective than waiting for impacts to occur (Moser *et al*., 2018). In other words, it is more cost effective to anticipate and avoid climate impacts than to wait for disasters to occur and clean up or rebuild afterward. For example, the *Natural Hazard Mitigation Saves: 2019 Report* found that society saves up to $13 for every dollar invested in hazard mitigation, such as reducing flood, hurricane, wind, earthquake, and wildfire risk (Multi-Hazard Mitigation Council, 2019). An additional report provided case studies on the cost savings of hazard mitigation projects in the utilities and transportation sectors, and reported cost savings ranging from $1.30 to $31 for every dollar invested for most transportation and water infrastructure projects (National Institute of Building Sciences, 2019). Planning ahead for coastal hazards that are predicted to worsen with sea level rise will help protect infrastructure investments and ensure communities maintain critical services without significant disruptions.

Additionally, local governments with resilient infrastructure can be expected to better maintain property values, and thus their property tax base (Gibson, 2017). One study by the First Street Foundation examined the impact of coastal hazards on property values and found that proximity to road flooding could have just as much impact on property values as exposure of the property itself to flooding, which indicates that municipalities that plan for safe and resilient infrastructure will help preserve property values over time (McAlpine *et al*., 2018). Because property taxes are based upon assessed values of properties, proactive planning and adaptation can shield local governments from potentially significant financial impacts by preventing impacts on properties and the infrastructure that serves them, thus maintaining property values and the property tax base.

Advance planning for sea level rise can also ensure that city and county municipal credit ratings remain strong, even in the face of increasing hazard risks with sea level rise. Increasingly, rating agencies are taking climate change exposure and preparedness into account when calculating municipal credit scores. This shift has occurred because exposure to climate risks can affect the property and sales tax revenue that a municipality relies on for its financial stability. While information on municipal credit

Image 7. Marina flooding during King Tides in Huntington Beach, Orange County. Photo by Sean Hiller.

ratings for specific coastal cities in California is not readily available from credit raters, there are clear indications from those raters that proactive sea level rise adaptation planning can benefit local government finances in the long run, and that raters are increasingly looking for local governments to demonstrate climate preparedness. Appendix G offers additional information about the financial value of sea level rise planning.

Relocation may reduce long-term costs

While preparing ahead is always more cost effective than incurring damage from sea level rise hazards, different adaptation strategies come with different cost considerations. In many cases, relocation, or moving at-risk infrastructure inland is one of the surest ways to avoid coastal hazards associated with sea level rise, as well as the service disruptions and damage that may be caused by flooding and erosion. Further, if infrastructure is realigned inland, not only will it be safe, but coastal habitats will have the opportunity to migrate inland and persist as sea levels rise.

Conversely, protecting infrastructure in place with hard armoring will require ever increasing maintenance needs and enlargement of the armoring as sea levels rise, which could become extremely costly over time. New seawalls in California are extremely costly, with additional repair and maintenance costs over time – costs that will continue to rise as these structures are increasingly battered by waves and rising tides (King *et al*., 2011).

Retrofitting infrastructure to floodproof or elevate individual components is also costly, and elevating roadways or constructing new roadways is complex and expensive[11]. Similarly, the use of pumps or other methods of keeping water away from infrastructure will become increasingly costly as sea levels rise.

11 See, for example, the cost benefit analysis included in the alternatives analysis for adaptation of State Route 37 in the *State Route 37 Alternatives Assessment Report for the Ultimate Project (April 2019).*

Evidence suggests that, in vulnerable areas, the cumulative costs of keeping infrastructure safely in place could eventually outweigh the costs of relocation (Cutler *et al*., 2020; Turner *et al*., 2007; King *et al*. 2011). Extrapolating both across the state and over a longer time horizon, continuing to protect infrastructure in hazardous locations, either through armoring or accommodation strategies, is likely to be cost prohibitive. A 2019 study estimated that reinforcing and building new protective structures to protect development along California shorelines vulnerable to inundation by 2040 will cost approximately $22 billion in capital costs, with $2.1 billion per year in maintenance costs (adjusted to 2020 dollars) (LeRoy *et al*., 2019).

While realignment could be costlier upfront than the initial expense of armoring or accommodation strategies, it is likely cost-saving in the long-term. The costs associated with protecting infrastructure in place in vulnerable areas, combined with the environmental and other impacts of doing so, make relocation an important strategy to consider. Case studies of road and water treatment infrastructure relocation projects, including relocation of the Morro Bay Water Reclamation Facility and realignment of Highway 1 near Piedras Blancas, demonstrate how these types of projects have been implemented in the coastal zone (Appendix E).

Funding Mechanisms

A variety of funding tools exist for local governments to plan for and implement infrastructure adaptation projects. While available funding still falls well short of the need, grants, state revolving loan funds, assessments, user fees, property taxes, and public-private partnerships, as described below, represent a sampling of the current options. Note, however, that different funding options may impact different users and communities. For example, utility fees, property taxes, and other funding mechanisms that are passed through to users may disproportionately impact low-income households. Minimizing impacts to environmental justice communities will require consideration of such issues when evaluating different funding options.

- Federal grant programs are available to provide funding for various project stages (e.g., planning, design, construction) and can support capacity building to carry-out projects. For example, there are a number of Federal Emergency Management Agency's (FEMA) Hazard Mitigation Programs, like the Building Resilient Infrastructure and Communities (BRIC) program that provide grants for hazard mitigation projects to address infrastructure at risk, so long as those projects are consistent with the State's Hazard Mitigation Plan. The National Coastal Resilience Fund, administered by NOAA and NFWF, is another example of a federal grant program that can support resilience with an emphasis on nature-based strategies. Additional federal grants can be found on websites such as the U.S. Climate Resilience Toolkit.
- State grant programs are also available to support climate adaptation, including infrastructure planning. For example, the State of California has offered a number of grant programs through bond funding, including $8.06 million in OPC Proposition 68 grants in 2021. Caltrans' Sustainable Transportation Planning Grant Program funds transportation planning projects statewide, and the Coastal Conservancy's grant programs including Climate Ready provide funding for climate change adaptation. Additional state grants can be found in the California Grants Portal.

- State Revolving Funds (SRFs) use subsidized interest rates and additional subsidization to provide low-cost financing for water infrastructure that protects public health and the environment. California's Clean Water SRF program finances wastewater treatment and recycling, non-point source, estuary, stormwater, and combined sewer system projects. Depending on project type, some SRF loans provide financial support in addition to the interest rate subsidization offered on an SRF loan. In addition, in 2018 Congress authorized an additional loan program exclusively for state infrastructure financing authority borrowers like California's Clean Water SRF program. More information about the State infrastructure financing authority WIFIA (SWIFIA) program is available through the U.S. EPA WIFIA website.
- Assessments by community service districts charge property owners in a specific geographic region to fund projects or services that benefit those properties.
- Fees like utility fees will likely be important for funding many infrastructure adaptation programs.
- Property taxes and parcel taxes are mechanisms to fund local adaptation projects. For example, in 2016 voters approved a $12 parcel tax equating to $25 million annually to fund shoreline restoration projects in San Francisco Bay over twenty years.
- Private foundation grants can also support climate change adaptation planning and implementation.
- Adaptation projects with high capital costs could be implemented through public-private partnerships. Public-private partnerships typically involve a long-term arrangement formalized through a contract.

There are also many innovative funding mechanisms for climate adaptation, from new forms of tax increment financing to insurance-linked securities like resilience bonds. For example, California passed Assembly Bill 733 (Berman) in 2017 that allows Enhanced Infrastructure Finance Districts (EIFDs) for climate change adaptation. EIFDs are a form of tax increment financing, meant to capture the added value that a project produces, such as an infrastructure project that can increase local property values. Financing tools that provide near-term capital for projects and pay back revenues over time, such as social impact bonds or insurance-linked securities, are also potential funding mechanisms for adaptation projects. While these tools are not currently as well tested in California as traditional funding, local governments should consider these and other innovative ideas to fund adaptation projects. The AB 2800 Climate-Safe Infrastructure Working Group recommends that making climate-safe infrastructure a policy priority should be reinforced by making it a state funding priority (2018).

Finally, the California Funding Wizard is a searchable database of grants, rebates, and incentives available to pay for sustainable projects. Funding opportunities can be searched by category such as transportation and water.

Adaptation Costs and Funding Recommendations

Given these cost considerations, the Coastal Commission has the following recommendations:

1. **Encourage increased federal and state funding** for sea level rise adaptation strategies for infrastructure. Such support will protect the health and safety of communities now and in the future and will save money by providing for proactive approaches, rather than waiting for more expensive damage to occur and emergency measures to be needed.
2. **Prioritize funding for adaptation strategies that move infrastructure out of hazardous areas**, such as realignment or relocation and other long-term strategies.
3. **Evaluate the costs and benefits of each adaptation alternative over the entire life cycle of the infrastructure** rather than in 20- or 30-year increments, when performing alternatives analyses. All costs and benefits should be considered, including non-market and other difficult to quantify values. Equity and environmental justice considerations should also be evaluated.
4. **Analyze the full life cycle costs of maintaining infrastructure in place**, including costs from damage to facilities, need for upgrades, and loss of recreational areas, habitats, and natural protective features.

NATURE-BASED ADAPTATION STRATEGIES

Nature-based adaptation strategies rely on ecological and physical processes to offer protection to the built, inland, or backshore environment while preserving coastal resources. Unlike hard shoreline protective devices that can exacerbate erosion and contribute to the loss of coastal resources, nature-based adaptation strategies are intended to improve ecological and natural systems while reducing the impacts of coastal flooding and erosion. Coastal habitats that can support nature-based adaptation strategies include wetlands, dunes, sandy beaches, and reefs. Nature-based adaptation strategies include solutions that are composed entirely of natural systems – called “soft strategies” – or natural systems that have been restored or enhanced in combination with constructed features such as marsh sills, buried revetments, and cobble berms – called “hybrid armoring.” Both approaches can help to ensure that ecological value from the natural habitat is maintained or enhanced.

Nature-Based Adaptation Strategies

Unlike hard shoreline protective devices that can exacerbate erosion and contribute to the loss of coastal resources, nature-based adaptation strategies improve ecological systems while reducing the impacts of coastal flooding and erosion.

Nature-based adaptation strategies can provide co-benefits in the form of water quality enhancement, habitats, recreation, flood resiliency, and improved coastal ecosystems. Siting vulnerable infrastructure away from coastal hazards and implementing nature-based adaptation strategies as the first line of defense can also allow for the natural systems to adapt and keep pace with sea level rise.

Recognizing the numerous co-benefits that nature-based adaptation strategies can impart, the State has broadly encouraged the use of these adaptation options. Specifically, Executive Order B-30-15 requires that state agencies prioritize natural infrastructure (OG, 2015), and *Safeguarding California*, the Ocean Protection Council's *State of California Sea-Level Rise Guidance*, the *California State Hazard Mitigation Plan*, and the California Coastal Commission's *Sea Level Rise Policy Guidance* all encourage the use of living shorelines and other nature-based adaptation strategies. The Coastal Act also includes key policies that encourage this alternative to traditional shoreline protective devices, broadly mandating maintenance, protection, and, where feasible, restoration and enhancement of natural coastal habitats. The California Environmental Quality Act and some Coastal Act policies also require agencies to evaluate alternatives to hard shoreline protection and to approve the least-environmentally damaging feasible alternative. Nature-based adaptation strategies will be an increasingly useful way to proactively address sea level rise impacts in line with these Coastal Act requirements, particularly as part of a phased approach.

While nature-based adaptation strategies may contribute to the resilience of coastal infrastructure, there are a number of important factors that should be considered when implementing these strategies. It can be challenging to construct natural systems where they do not currently exist and ensure that the created

Image 8. Dune restoration at Surfer's Point in Ventura County. Photo by Louis White.

habitat provides adequate coastal protection at the same time as ecological, recreational, and other shoreline values. In addition, open coast environments in California are very different than low energy or bay coast environments and may require different strategies to be successful. Factors such as larger tidal ranges, storm surges, and wave action as well as impacts from coastal storms and El Niño events are often exacerbated in open coast environments. Furthermore, areas along the East and Gulf Coasts, where nature-based adaptation strategies have been more extensively implemented, often have different geomorphology and ecology compared to California. Therefore, strategies such as wetland restoration and oyster beds that work for low energy environments in other parts of the country will need to be reevaluated along with other types of nature-based adaptation strategies to account for the conditions of much of California's open coast. Nature-based adaptation strategies may also require a larger footprint or a greater upfront cost than more traditional armoring.

Many case studies, guidance documents, and other tools have been developed to better understand the opportunities and constraints for these kinds of strategies. In 2019, the Federal Highway Administration (FHWA) released a resource titled *Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide*. The Implementation Guide provides transportation managers with key resources in planning and developing nature-based adaptation strategies to improve transportation infrastructure resilience. In addition, a Technical Report prepared for the Fourth California Climate Change Assessment, *Toward Natural Shoreline Infrastructure to Manage Coastal Change in California*, provides guidance for planners that is specific to California and that describes how to reduce reliance on coastal armoring and deploy natural shoreline infrastructure solutions (Newkirk *et al*., 2018). Additionally, NOAA's Office for Coastal Management provides a *Green Infrastructure Effectiveness Database*, which contains peer-reviewed articles, gray literature, and online tools regarding various nature-based adaptation strategies that have been implemented across the country. This database may be most helpful as a starting point when planning for a nature-based adaptation strategy to better understand best practices and lessons learned. Several examples of nature-based adaptation strategies are highlighted in Appendix E and Appendix F.

However, more case studies will be needed to better understand how nature-based adaptation strategies might function on California's open shoreline areas, and to help facilitate wider use of such strategies. A critical step to understanding and facilitating wider use of nature-based adaptation strategies is to implement on-the-ground projects and monitor their performance. To this end, the Commission is encouraging local governments and asset managers to prioritize nature-based adaptation strategies with measurable environmental benefits over strategies that have adverse coastal resource impacts such as traditional shoreline protective devices. These projects can contribute to a growing repository of best practices and guidance documents to share lessons learned and further encourage the use of nature-based adaptation strategies.

Table 1 is adapted from the aforementioned FHWA's *Nature-Based Solutions for Coastal Highway Resilience Report* and applied to the coastal contexts found in California, where higher tidal ranges, higher energy wave climates, and geologic diversity make categorizing solutions more difficult. The table highlights the range of potential nature-based adaptation strategies, organized by hazard type and geophysical context. The strategies highlighted in Table 1 are not based on any quantifiable metric and are not comprehensive; rather, it is meant to capture common approaches determined by the typical geophysical and engineering constraints for each hazard and geophysical context specific to California. Projects requiring a Coastal Development Permit (CDP) will still be reviewed for consistency with the Coastal Act and/or LCPs, and the suggested approaches below may or may not be appropriate or consistent with the Coastal Act/LCPs in particular instances. Coastal managers and potential applicants are encouraged to reach out to Coastal Commission staff early in the conceptual planning process to discuss the potential for nature-based adaptation strategies.

Table 1. Hazard and corresponding potential adaptation strategy with nature-based component (See also Appendix F).

Hazard/Issue	Softer Strategies	Hybrid Armoring Strategies
Erosion (sheltered coast)	• Oyster bed • Eelgrass bed • Tidal bench • Wetland restoration • Regional sediment management	• Cobble berm + sand dunes • Marsh sill • Marsh sill + breakwater • Tidal bench + breakwater • Cobble berm + marsh sill • Sand dunes + finger groins
Erosion (beach)	• Sand dunes • Sand nourishment • Regional sediment management	• Cobble berm • Buried revetment • Buried seawall • Artificial reef
Erosion (bluff)	• Native vegetation stabilization • Drainage improvements • Sand nourishment • Regional sediment management	• Cobble berm • Rock platform + vegetation
Flooding (static water level)	• Wetland restoration • Daylighting/widening/ naturalizing creek/ stream drainages • Adding tidegates, enlarging culverts, or replacing culverts with bridges	• Ecotone levee
Flooding (wave overtopping and runup, sheltered coast)	• Sand dunes • Eelgrass bed • Tidal bench • Oyster bed • Wetland restoration	• Cobble berm • Marsh sill • Ecotone levee • Sand dune + buried seawall • Artificial reef
Flooding (wave overtopping and runup, open coast)	• Sand dunes • Sand berm	• Cobble berm • Sand dunes + buried seawall • Artificial reef

Nature-Based Adaptation Recommendations

The Coastal Commission has the following recommendations related to nature-based adaptation strategies:

1. **Consider nature-based adaptation strategies in all sea level rise adaptation planning efforts** and prioritize such solutions over proposals for hard shoreline armoring, whenever feasible.
2. **Identify existing nature-based shoreline protection** and consider opportunities to maintain, enhance, or expand these existing features.
3. **Prioritize funding for nature-based adaptation strategies** over traditional hard shoreline armoring methods.
4. **Encourage partnerships among state agencies to strengthen and accelerate opportunities for using nature-based adaptation strategies** – including the Ocean Protection Council, Coastal Conservancy, State Lands Commission, State Parks, State and Regional Water Quality Control Boards, Department of Fish and Wildlife, and Coastal Commission.
5. **Continue monitoring the performance of nature-based adaptation strategies and developing case studies, guidance, and best practices** to share lessons learned and encourage wider use of nature-based adaptation strategies.

CHAPTER 5

Transportation Infrastructure

The following chapter describes sea level rise vulnerability and expected impacts to transportation infrastructure, the applicable planning and regulatory framework, and strategies for how to plan for resilient transportation infrastructure

INTRODUCTION TO TRANSPORTATION INFRASTRUCTURE

Highways, local roads, and railways are key components of the transportation system, supporting commerce, travel, emergency response, and economic development state- and nation-wide. More freight enters the United States through California than through any other state, and most is shipped on trucks that rely on the highway system.[12] Highways also provide routes of travel that facilitate public access to the shoreline, thus supporting one of the key mandates of the Coastal Act as well as the largest component of the State's $45 billion coastal economy: tourism and recreation. California also has one of the country's most extensive networks of rail lines, with more than 10,000 passenger and freight route miles. The Los Angeles – San Diego – San Luis Obispo Rail Corridor Agency (LOSSAN) rail corridor alone is the second busiest intercity rail corridor in the country, comprising commuter, intercity, and freight rail services.

12 For example, more than 80% of freight imported in 2012, totaling hundreds of millions of metric tons, was shipped via the highway system.

Highways, local roads, and railways are also integrally related to patterns of land use since they both serve development and encourage development to expand in certain locations. Therefore, as sea level rise adaptation efforts continue to advance throughout the state, the adaptation of land use patterns, public access needs, and transportation systems must be considered, managed, and planned together. Because many transportation routes in the coastal zone have been in place for many decades and are embedded into long-established networks of infrastructure and land uses, it will often require *proactive* regional transportation planning, policymaking, and project initiation to implement successful sea level rise adaptation strategies.

Impacts to these assets from sea level rise have the potential to disrupt transportation, commerce, public safety, and economies at many scales, which in turn will impact the welfare of Californians. Without proactive adaptation, sea level rise will damage roads and rail lines, impeding our ability to use them for evacuation, emergency response, and other purposes. In other words, funding, planning, designing, and implementing a project or suite of adaptation strategies before the impacts occur, and thus before a disruption of service, is critical. Many recent studies, including AB 2800's *Paying It Forward: The Path Toward Climate-Safe Infrastructure in California* underscore that incorporating climate resiliency into transportation plans and projects *now* will cost far less than attempting to contend with the serious ramifications of climate impacts on existing infrastructure in the future (CSIWG 2018). In a related study, *Natural Hazard Mitigation Saves 2017 Interim Report: An Independent Study – Summary of Finding*, it was estimated that federal hazard mitigation grants provided by FEMA, the Economic Development Administration, and Department of Housing and Urban Development, over a 23-year period saved $6 for every $1 spent (Multihazard Mitigation Council, 2017).

Image 9. Road damage on Capistrano State Beach in January 2019. Photo by California King Tides Project.

Failure to begin planning now for the impacts that sea level rise will have on transportation infrastructure will result in impacts to coastal resources. Many segments of highways and railways are located in close proximity to the shoreline and, like other types of fixed development, can act as barriers to the inland migration of wetlands, beaches, and other coastal resources as sea levels rise. Such barriers also impede ecological processes critical for functional habitats for rare, protected, and endangered species. If the State does not proactively plan and act, coastal resources will be lost to inundation as they are caught between rising seas and this lateral infrastructure or other development. This “coastal squeeze” could result in the loss of beaches, wetlands, and other valuable coastal habitats and public accessways, causing profound impacts to the resources that the Coastal Act protects for all Californians. These impacts would have far-reaching effects on California’s economy and quality of life unless proactive adaptation strategies are planned and implemented.

Maintaining highways and railways adjacent to the shoreline may also lead to increased inland development that relies on the de-facto protection provided by these assets. If sea level rise progresses to a point where it is no longer feasible to maintain the highway or railway in place, and the transportation corridor is damaged or realigned, the inland development could become dangerously vulnerable to sea level rise. Direct protection provided by a highway or railway could lead to a false sense of security regarding the long-term safety of vulnerable communities and result in continued investments in those areas without proper consideration and notification of the true risk. Resulting development patterns could make it much more difficult to plan for subsequent community-wide adaptation to sea level rise.

Thus, it is important to approach long-term adaptation planning for transportation infrastructure in conjunction with adaptation planning for adjacent inland communities and vice versa. Coordination among local governments, the California Department of Parks and Recreation, the California Department of Transportation (Caltrans), Regional Transportation Planning Agencies, Metropolitan Planning Organizations, rail owners and operators, transit districts, and others, as well as inclusion of long-term adaptation considerations in local land use planning (e.g., LCPs, General Plans, Capital Improvement Plans) and transportation planning (see Appendix H for a list of examples) is critical. Robust coordination will ensure that adaptation plans reflect local and regional contexts as well as statewide transportation goals and needs.

Furthermore, the adaptation of highways and railways will have varying social, economic, and environmental impacts on individuals and communities that rely on this transportation infrastructure for access to goods, services, jobs, and recreational travel, among other activities. As discussed in Chapter 4, environmental justice communities often experience disproportionate burdens in environmental planning due to historical marginalization and discriminatory land use practices. Therefore, it is important to ensure that the public, including individuals from, and groups representing, environmental justice communities, are engaged and involved during all phases of adaptation, including during planning, environmental review, design, construction, and maintenance of adaptation measures. Local governments and asset managers can prioritize solutions that decrease the inequitable burdens on environmental justice communities by designing LCP policies that identify and engage with vulnerable populations early on, identify direct and indirect adverse impacts on environmental justice communities, and prioritize solutions that decrease the burdens to these populations.

The following sections discuss highway and railway infrastructure vulnerability and management in the context of LCP development and implementation, as well as coastal permitting. Many of the concepts presented in the highway section can also apply to local roads, but the focus is on highways as a key driver of development patterns. Appendix B provides model policies that may be tailored, depending on local context, to address transportation infrastructure in light of sea level rise over multiple time horizons.

HIGHWAY VULNERABILITY

Several statewide studies have been conducted to assess the vulnerability of California's highways to sea level rise. For example, in 2019, Caltrans completed a series of Climate Change Vulnerability Assessments to identify segments of the State Highway System vulnerable to climate change impacts including precipitation, temperature, wildfire, storm surge, and sea level rise. An assessment was conducted for each of the twelve Caltrans districts statewide, and each study included an analysis of sea level rise, indicating that with 5.5 feet of sea level rise, 130 miles of state highways will be vulnerable to sea level rise and accelerating soil erosion and cliff retreat. Of the fifteen coastal counties, Humboldt and Orange counties have by far the highest fractions of at-risk highway segments. In addition to the reports, Caltrans created an online interactive mapping tool that depicts the geospatial data used in the studies. As a next step, Caltrans recently completed Districtwide Adaptation Priorities Reports, which aim to prioritize the order in which assets found to be exposed to climate hazards will undergo detailed asset-level climate assessments.

Many other studies have examined highway vulnerability at a local or regional scale, analyzing vulnerabilities from flooding, inundation, erosion, and other relevant sea level rise impacts. The Coastal Commission's *2016 Statewide Sea Level Rise Vulnerability Synthesis* compiled the results of local vulnerability assessments that had been conducted to date. The Caltrans climate change vulnerability assessments and the Coastal Commission's *Vulnerability Synthesis* reported the following highway vulnerabilities in each coastal county.

- **Del Norte:** Some regions of Highway 101 (e.g., Crescent Beach and Wilson Creek and Beach), including sections with bridges and parking lots, have experienced flooding or landslides and have been noted as highly vulnerable to future sea level rise.
- **Humboldt**: Portions of Highway 101, such as the segment along southern Humboldt Bay and the segment between Eureka and Arcata and SR 255, are highly vulnerable to future sea level rise and in some cases would flood today if it were not for the protection of aging dikes or levees.
- **Mendocino**: Highway 1 winds along the coast for over 90 miles, portions of which are vulnerable to flooding and bluff erosion, including sections near Westport, Seaside Beach, and the Garcia River.

- **Sonoma**: Several portions of Highway 1, Highway 101, and Lakeville Highway (US 116) are vulnerable in this county, especially those constructed on former estuaries and tidelands (North Bay Climate Adaptation Initiative 2014). One particularly vulnerable area is the residential and highway infrastructure development located at Gleason Beach, about 5 miles north of Bodega Bay, where the Commission approved a highway realignment project in 2020 that will move Highway 1 inland and away from the eroding bluff.
- **Marin**: Highway 1 runs along the inland shores of Bolinas Lagoon and Tomales Bay and is already susceptible to flooding. Bolinas Lagoon contains wetlands between the sea and Highway 1 that experience winter flooding and will be inundated by sea level rise in the near-term, and access to homes and recreational areas in Muir Beach will likely be compromised by flooding on Highway 1 in the long-term (Sea-Level Marin Adaptation Response Team 2015).
- **San Francisco**: The Great Highway, which runs along the outer coast of San Francisco, has long been at risk from erosion, necessitating interim responses, such as emergency revetments and beach nourishment. The Ocean Beach Master Plan recommends that the southern portion of the Great Highway, which is most vulnerable to erosion, is rerouted inland and transitioned into a coastal trail. This plan is reflected in a 2017 San Francisco LCP update of the Western Shoreline Area Plan, and the City is currently developing plans for long-term phased adaptation.
- **San Mateo**: Highway 1 is threatened in portions of San Mateo County, particularly in the south. At Surfer's Beach in Half Moon Bay, a segment is vulnerable to erosion, and the Coastal Commission approved the installation of a rock revetment to protect the highway under the condition that a long-term plan be initiated that considers various adaptation options, including beach sand replenishment and moving the segment inland. Similarly, chronic emergency repairs of Highway 1 near Pescadero have been allowed by the Commission over recent years also under the condition that Caltrans prepare an evaluation of long-term highway adaptation options in the area.
- **Santa Cruz**: Highway 1 is threatened in portions of Santa Cruz County, particularly along the north coast. For example, studies for the Scott Creek restoration and bridge replacement project have revealed significant potential sea level rise impacts over the next 100 years that need to be incorporated into plans and designs for ecosystem restoration and infrastructure resilience.
- **Monterey**: Highway 1 at Elkhorn Slough between Moss Landing and Castroville is one of the most threatened areas along the Monterey County coast, along with the highway south of Carmel-by-the-Sea and near Bixby Creek Bridge. Additionally, several sections of the highway in this county are at risk due to increasing bluff erosion even with relatively small amounts of sea level rise; for example, 2.5 miles of Highway 1 are vulnerable to bluff erosion associated with 0.5 feet of sea level rise.
- **San Luis Obispo**: In the northern region of this county, an approximately 3-mile long eroding portion of Highway 1 was relocated up to 500 feet inland near Piedras Blancas Lighthouse Station. Sea level rise is also expected to increase the vulnerability of Highway 1 in Morro Bay, Pismo Beach, and the northern region of the county.

- **Santa Barbara**: Highway 101 runs along portions of the county shoreline, particularly in the south. Bluff erosion and intensifying storm flooding are expected to pose increasing threats to some segments of both the highway and railway systems. State Road 217 connecting UC Santa Barbara and the Santa Barbara airport along the coast to Highway 101 inland is also vulnerable to flooding and inundation.
- **Ventura**: In the northern region of this county, Highway 101 runs along the shoreline at the foot of sometimes-steep hillsides, and in the southern portion of the county, Highway 1 begins its route seaward of the Santa Monica Mountains. Portions of Highway 1 along the south coast of the county, as well as portions of Highway 101 along the north coast, are currently vulnerable to flooding. A spate of emergency repairs necessary to keep Highway 1 open over the last several years in the southern end of the County has Caltrans working in partnership with various stakeholders to explore potential management strategies for using floodplain sediment to replenish beach areas as a potential adaptive response to the ongoing erosion threats.
- **Los Angeles**: In the northern region of this county, Highway 1 runs along the shoreline seaward of the Santa Monica Mountains, protected by revetments in many places that could cause “squeeze” of beaches. Highway 1 and other routes (e.g., SR-90, and I-405) are vulnerable to combinations of sea level rise and storm flooding in locations like Marina del Rey. Highways around the Ports of Los Angeles and Long Beach have also been identified as vulnerable to flooding, which has the potential to disrupt extremely valuable commerce. For example, Route 47, Interstate 710, and Highway 1 all merge at the Port of Los Angeles and are exposed to future sea level rise.
- **Orange**: Highway 1 runs along much of this county’s shoreline, and routes through extremely low-lying areas that are vulnerable to flooding, including Seal Beach, Huntington Beach, and Newport Beach. For example, Highway 1 at Warner Avenue and other areas of Sunset Beach currently experience flooding with high tides and rain events. Some areas such as Highway 1 in Huntington Beach and along the Newport coast south of Crystal Cove face erosion threats that will require adaptation planning.
- **San Diego**: Highway 5 runs north-south in this county, often along a route that is a substantial distance inland from the shoreline and as such this county does not have as many highway segments exposed to potential sea level rise as other counties. However, in places with high natural erosion rates such as the area south of San Onofre, and where the highway approaches inland waterways, such as the north county coast lagoons and Mission Bay and San Diego Bay, the highway is vulnerable. SR 75 along the south end of San Diego Bay and on Silver Strand is vulnerable to both flooding and beach/shoreline erosion. Several Coast Highway sections are also located in close proximity to the ocean and have been identified as vulnerable to future sea level rise.

In many instances the Commission's and Caltrans' assessments are aligned and provide valuable guidance; however, in both cases many analyses do not address the latest best available science from the 2018 State of California Sea-Level Rise Guidance recommending medium-high (6.5-7 feet) and extreme (~10 feet) sea level rise projections for infrastructure such as critical roadways. Caltrans' highest projection used was 6 feet and the Commission's synthesis was based on analyses that used National Research Council 2012 numbers of 56-66 inches (~4.6 to 5.5 feet) by 2100. In both cases, the assessments used a number of projections and models. For additional guidance on using the best available science to select a sea level rise projection for specific development based on local hazard conditions, see the Commission's Sea Level Rise Policy Guidance *Appendix B: Developing Local Hazard Conditions Based on Regional or Local Sea Level Rise Using Best Available Science*.

Many metropolitan planning organizations (MPOs), regional transportation planning agencies (RTPAs), local governments, and other groups are also completing vulnerability assessments and adaptation plans for transportation infrastructure in various locations and at various scales (*e.g.*, regional, local) throughout the state. See, for example, the Commission's LCP Grant Program for grant-funded examples of vulnerability assessments and adaptation plans by numerous local governments in the coastal zone. These reports provide additional information on potential exposure of transportation infrastructure to sea level rise and potential vulnerabilities, priorities, and adaptation options.

Actions to repair and protect many sections of state and local highways from flooding and erosion, for both the shorter- and longer-term, are undertaken on a continuous basis by Caltrans and other owners of the transportation systems in the coastal zone. Many sections of coastal highways have been armored through short-term emergency actions, but increasing attention is being given to adapting vulnerable areas through nature-based adaptation strategies, including hybrid armoring approaches (for more information, see section below on nature-based adaptation strategies). Some of the county-specific examples above highlight locations where Caltrans' projects are complete or underway to realign at-risk segments of highways inland, including projects at Gleason Beach in Sonoma County and Piedras Blancas in San Luis Obispo County. For detailed information on these projects, see Appendix E.

Most of the vulnerability assessments described above focused on overland flooding from sea level rise. Going forward, it will be important to also understand the potential effects of groundwater rise on transportation infrastructure. Rising seas are expected to cause groundwater tables to rise, becoming shallower or emerging and causing ponding or runoff. Previous studies have shown that these impacts can reduce the service life of road pavement (Knott *et al.* 2017). Moreover, rising groundwater could constrain the types of adaptation strategies that can be considered for affected transportation infrastructure; for example, while shoreline protective devices may be effective to address overland flooding and inundation from sea level rise, they may not be effective against groundwater rise, depending on the characteristics of the site. This difference highlights the need to understand all coastal hazards related to sea level rise to inform adaptation planning for transportation infrastructure.

HIGHWAY GOVERNANCE AND PLANNING

Highway governance occurs at the federal, state, regional, and local levels. The transportation programs, policies, and directives described in this section should be taken into consideration when conducting LCP planning.

At the federal level, President Biden's recent Executive Order *Tackling the Climate Crisis at Home and Abroad* directs the Department of Transportation and the Secretary of Transportation to achieve climate resiliency in the transportation system. The U.S. Congress directs the U.S. Department of Transportation – which includes the Federal Highway Administration – to fund states for the construction and preservation of federally designated highways. Almost all of California's highways are part of the federal highway system. The FHWA has published a number of guides and pilot studies on climate resilience, including the *Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide*, and the *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*.

Highway Governance

Highway governance occurs at the federal, state, regional, and local levels. LCP policies related to highways should be developed in coordination with relevant transportation programs, policies, and directives while ensuring consistency with the Coastal Act.

At the state level, the California Legislature sets statewide transportation policies, an overall budget, and expenditure priorities, and it delegates authorities to other state agencies and entities. Caltrans owns, operates, maintains, and repairs the state highway system, and its major project lists are reviewed and adopted by the California Transportation Commission. Each Caltrans district develops corridor plans by providing an overview of the current and projected conditions of the corridor to inform improvements needed in the planning process. The Caltrans Office of Smart Mobility and Climate Change (OSMCC) develops statewide tools, data, and resources needed to integrate active transportation, climate change, and land use considerations into transportation planning and project development. The Complete Streets Program, for example, encourages multi-modal transportation, and the *Smart Mobility Framework* is a planning guide on smart growth. Caltrans also published *Guidance for Incorporating Sea Level Rise* in 2011, which is expected to be updated in 2021. See Appendix H for a description of additional Caltrans planning efforts.

State agency partnerships are also helping to advance work on the resilience of transportation infrastructure. Notably, the Coastal Commission and Caltrans have a long-standing interagency agreement designed to facilitate collaboration between the two agencies on mutual issues of concern, such as sea level rise adaptation, other climate change impacts, completion of the California Coastal Trail, and efficient project delivery. Recently, the Coastal Commission and Caltrans co-developed a framework for addressing sea level rise for transportation infrastructure along the coast, and memorialized that framework through an agreement called the *Plan for Improved Agency Partnering*. The Coastal Commission and Caltrans identified and agreed upon points of engagement to ensure that Coastal

Commission input on sea level rise is addressed at all stages of the highway planning and project design processes. This collaboration builds on years of work between the two agencies related to addressing coastal hazards. Caltrans and the Coastal Commission are also currently collaborating on projects such as the update to the Caltrans 2011 *Guidance for Incorporating Sea Level Rise into Project Initiation Documents*, to be completed in 2021. Working with the Commission, Caltrans has also developed a SLR guidance webpage for reference by Caltrans staff.

The California Department of Parks and Recreation ("State Parks") is also a major coastal landowner that manages significant infrastructure and facilities assets that aid in public access to the coast. As a result, State Parks is also an important partner in addressing impacts to this infrastructure from sea level rise. Managing roughly one quarter of the state's coastline, State Parks has 111 oceanfront park units and 17 additional park units that lie within the coastal zone. Many of State Parks' access roads, parking lots, campgrounds, restrooms, and trails are already seeing coastal hazard impacts, and many are connected to Caltrans assets. These impacts will increase with increased coastal hazards, and thus proactive and sustained coordination between the Commission, Caltrans, and State Parks is critical. As with Caltrans, State Parks has multiple planning components that make up its overall planning structure for its park units. The State Parks General Plan Handbook describes the department's planning structure and components, including General Plans, Management Plans, and Specific Project Plans, among others. These specific planning documents, in addition to the strategies set forth in the department's recent Sea Level Rise Adaptation Strategy, represent important touch points for interagency coordination on long-term sea level rise adaptation planning and strategy implementation.

At the regional scale, two main types of agencies plan and fund highway projects in California—MPOs and RTPAs. MPOs, of which California has 18, are federally required for every urbanized area in the state with a population over 50,000 and are comprised of representatives from the region's local governments and transportation authorities. They prepare 20-year Regional Transportation Plans (RTPs) that project the region's transportation needs and priorities in that timeframe, as well as four-year Transportation Improvement Programs that identify specific transportation projects for federal funding. Senate Bill 375 (2008) requires each MPO to develop a Sustainable Communities Strategy as part of its RTP that combines planning for the regional allocation of housing needs with transportation planning to meet state greenhouse gas reduction targets (stemming from AB 32) set by the California Air Resources Control Board (CARB). California also has 26 RTPAs, which function in rural areas of the state. Cities and counties interact with their MPO or RTPA by nominating transportation projects for funding. California also has hundreds of transit agencies – such as the Bay Area Rapid Transit and Los Angeles County Metropolitan Transportation Authority – that function at various scales (regional or local) and deliver transit services that often rely on the highway system.

At the local scale, cities and counties are required to include a Circulation Element in their General Plans. The Circulation Element's purpose is to strategically address the need for the movement of people, goods, energy, water, sewage, and storm drainage, as well as communication infrastructure. The Circulation Element must contain "the general location extent of existing and proposed major thoroughfares, transportation routes, terminals, any military airports and ports, and other local public utilities and facilities, all correlated with the land use element of the plan" (Cal. Gov. Code Sec. 65302(b)).

Image 10. Realignment diagram of Highway 1 near Gleason Beach in Sonoma County. Photo by [Caltrans](#).

Because Circulation Elements are required to correlate with General Plan Land Use Elements, the LCP update process should also inform potential updates to a city or county's Circulation Element, and vice versa. For example, entire Circulation Elements are sometimes certified as part of a local government's LCP. The Circulation Element also must be consistent with the applicable RTP, and like the RTP, must also implement the greenhouse gas reduction targets of AB 32. Thus, substantial updates to Circulation Elements after 2011 are required to provide for a balance of multimodal transportation, suitable for all users and suitable for the land use context.

In the coastal zone, land use planning is carried out through a partnership between local governments and the Coastal Commission. LCPs must be certified by the Coastal Commission for consistency with the California Coastal Act. Highway projects in the coastal zone must receive a coastal development permit from the relevant city or county with a certified LCP, or from the Commission if the project falls within the Commission's retained jurisdiction. If the project is located in both jurisdictions, the development may be authorized through a consolidated CDP, a certified Public Works Plan (PWP), or alternate Coastal Act approval process.

A PWP provides an alternative to project-by-project CDP review for large scale and/or phased public works projects. PWPs describe a group of projects in sufficient detail to allow the Commission to determine their consistency with the Coastal Act or applicable certified LCPs (the former if the LCP is not certified; the latter if it is). Once the Commission approves a PWP, no coastal development permit is required for a specific project described within it; rather, when a project in the PWP is ready to commence, the Commission reviews the project to determine whether it is consistent with the PWP, or if special conditions are necessary to make it consistent. Once deemed consistent, the project can be undertaken, and that process provides it the authorization for such development that is required under the Coastal Act. Thus, PWPs can be an effective mechanism for incorporating a suite of adaptation strategies and transportation infrastructure projects – including those that cross jurisdictional boundaries

Box 3. Duty to Maintain Public Road Access

State and local authorities are required to maintain public roads and highways that are under their jurisdiction, and failure to maintain them in a safe and passable condition – including those that are being affected by sea level rise – could raise liability issues for those agencies. It is beyond the scope of this Guidance to describe in detail the laws that govern state and local governments' duties to repair or upgrade public roads and highways in order to deal with sea level rise, or to analyze possible liability for failure to maintain or upgrade them. However, agencies with responsibility for roads and highways will need to consider these issues in determining whether and how to maintain, improve, or adapt them to provide continued, safe access. Such consideration will likely involve at least a few issues.

First, there are statutory duties to maintain highways. State law requires Caltrans to "improve and maintain the state highways" (Cal. Streets & Highways Code § 91), and "maintenance" is defined to include the obligation to maintain a roadway "in the safe and usable condition to which it has been improved or constructed", but does not include reconstruction or other improvement (Cal. Streets & Highways Code § 27). The law also requires maintenance or repair "necessitated by accidents or by storms or other weather conditions," although clarifies that Caltrans has discretion to determine the amount and type of maintenance needed, depending on funding and traffic levels (Cal. Streets & Highways Code § 27). Cities and counties have a similar obligation to maintain roadways under their jurisdiction (Cal. Streets and Highways Code §§ 941, 1921).

Second, the failure to maintain a highway could cause injuries to persons or property or could lead to a landowner being unable to access their property. Either situation could raise liability concerns for the agency that failed to maintain the roadway.[1] Finally, rising seas will cause increased flooding and erosion on low-lying roadways, and at some point it may not be feasible, from either a financial or engineering perspective, to maintain the road. However, state law strictly limits the situations in which public roadways may be abandoned, and neither frequent flooding nor the expense of maintaining a highway that suffers repeated damage are currently identified as permissible reasons for closing and abandoning a road. Rather, streets may generally only be abandoned if they are no longer necessary for present or prospective public use.[2] These obligations may directly impact the ability of local governments and asset managers to develop and implement sea level rise adaptation measures, and will need to be addressed in the future.

[1] See Govt. Code § 835 ("a public entity is liable for injury caused by a dangerous condition of its property" if certain factors are met); Clay v. City of Los Angeles (1971) 21 Cal.App.3d 577 (holding that city must either repair roadway washed out by a flood, which cut off a landowner's access to their property, or else go through the process of formally abandoning the roadway and pay the landowner compensation for loss of access).

[2] Streets and Highways Code §§ 8324, 8330, 8331; Vehicle Code § 21101; Zack's, Inc. v. City of Sausalito (2008) 165 Cal.App.4th 1163

– into an integrated plan for a specific transportation network or corridor. It is essential that PWPs be developed through coordination with public agencies with jurisdiction in the corridor and other affected agencies, stakeholders, and interested parties. If development proposed under a PWP is not consistent with applicable certified LCP policies and is consistent with the Coastal Act, it may be necessary, especially in the case of cross-jurisdictional PWPs, to amend certain LCPs as a part of the PWP certification process. Those LCP amendments should be developed prior to or concurrently with the PWP and in cooperation with agency partners to achieve mutual objectives and shared goals related to adaptation planning. Case Study #5 in Appendix E describes how this process was carried out in the case of the North Coast Corridor (NCC) Public Works Plan/Transportation and Resource Enhancement Program (PWP/TREP) and the accompanying LCP amendments. In all cases, transportation planning efforts should be coordinated with and complimented by Sustainable Community Strategies, Regional Transportation Plans, and Local Coastal Programs, and other planning documents as appropriate.

The Relationship Between Highways and Local Coastal Programs

As described above, highways are a key component of the development patterns along the California shoreline, and are integrally related to community development and the constraints and opportunities local communities face when planning for sea level rise. In some locations, highways constitute the first line of development and may serve as de facto shoreline protection for inland communities. Such highways, if maintained in place, could become exorbitantly expensive to continue to operate and could cause whatever lies seaward of them, such as beaches or wetlands, to be lost as sea levels rise. Temporary, periodic, or permanent closures of highway segments sited in vulnerable areas can also seriously disrupt local and regional mobility, which in turn can affect community safety and local economies, especially where there is no suitable alternative transportation route. Particularly given the long lead time necessary to plan and modify transportation corridors, it is essential for sea level rise adaptation planning efforts to address highway and other transportation infrastructure systems in the wider context of surrounding development patterns, community needs, and coastal resources.

LCP Policies on Highways

LCPs should include policies that encourage the adaptation of highways to sea level rise in a way that supports resilient and sustainable communities, protects coastal resources, and ensures the long-term safety and viability of the transportation network.

In California's coastal zone, LCPs contain the land use policies and zoning codes that regulate development, including development involving highways and other transportation infrastructure. Many local governments are in the process of updating their LCPs to address sea level rise. Because highway projects must conform to any applicable certified LCPs, local governments should work with Caltrans and other relevant transportation planning authorities to write policies and regulations that facilitate and encourage the adaptation of highways to sea level rise in a way that supports resilient and sustainable communities, protects coastal resources, and ensures the long-term viability of the transportation network consistent with the Coastal Act. For example, LCPs can include policies that require measures to keep highways safe in their current location while also protecting coastal resources, policies that call for nature-based adaptation strategies that provide protection, enhance coastal processes, and advance positive environmental outcomes, or policies that call for the elevation or relocation of vulnerable highway segments. Because of their local focus, LCPs are particularly critical tools for identifying and laying out adaptation approaches that reflect local conditions, including how to balance the transportation and other needs of the community with the coastal resource protection goals of the Coastal Act.

LCP policies related to highway development can direct the expansion of development into safe areas rather than areas expected to be impacted by sea level rise, thus broadly encouraging and participating in the adaptation and sustainability of local land use patterns to sea level rise.

Policies can also be developed in a way that meaningfully engages vulnerable populations and environmental justice communities,[13] considers equitable distribution of benefits and burdens on environmental justice communities, and uses a transparent decision making process – thus aligning with both the Coastal Commission's adopted Environmental Justice Policy and federal and state highway planning requirements to meet Title VI requirements of the Civil Rights Act of 1964.

LCP policies can also encourage multi-agency and multi-jurisdictional coordination necessary across various planning documents and through project design, delivery and operation, and they can incorporate other transportation-related planning goals, such as measures to implement Complete Streets and Sustainable Communities Strategy goals like increasing public transit and other non-automobile options that reduce greenhouse gas emissions. Thus, local governments, in cooperation with Caltrans and other transportation asset managers (e.g., State Parks), have the opportunity to develop policies related to highway adaptation that dovetail with comprehensive community and regional strategies to address sea level rise and other climate change-related impacts rather than acting at cross-purposes.

Many entities are involved in planning and implementing highway projects and should be engaged in LCP policy development to the extent feasible. While the interested parties will vary from location to location, some of the common partners that local governments should coordinate with include: state partners (e.g., Caltrans, State Parks), other local governments impacted by the transportation infrastructure at hand; local Metropolitan Planning Organizations and other local or regional agencies involved in the development of a Sustainable Communities Strategy; various transit districts; emergency response managers that rely on transportation routes; tribes; Chambers of Commerce, local business groups and neighborhood associations; environmental justice stakeholders; and other owners and operators of the infrastructure.

13 The term "environmental justice communities" is used to refer low-income communities, communities of color, and other historically marginalized communities that have been disproportionately burdened by or less able to prevent, respond, and recover from adverse environmental impacts and discriminatory land use practices.

By engaging in a robust coordination process, LCP policy development can occur in a way that is responsive to the many inter-related, sometimes competing issues related to transportation planning. For example, rerouting a segment of transportation infrastructure to avoid coastal hazards from sea level rise could potentially create tensions with goals to reduce vehicle miles traveled (VMT) if the new route is significantly longer. If sea level rise hazards were to be considered in a vacuum, the planners might arrive at adaptation solutions that do not adequately incorporate important concerns such as VMT, community impacts, and infrastructure safety. Coordination with all relevant stakeholders will ensure a more complete understanding of the implications of each potential adaptation strategy and enable LCPs to be developed in a way that not only ensures consistency with hazards policies, but also achieves other relevant mandates and goals that have long-term public interest and resource protection values.

While developing policies that address transportation corridor vulnerability, local governments should also consider the degree of vulnerability of the assets of interest. Highway segments that are vulnerable in the near-term, or that will cause near-term impacts to coastal resources or community development should be addressed with urgency, whereas highway segments where climate change impacts are expected to manifest in the longer-term may be ripe for trigger-based adaptation, or longer-term adaptation pathways.

Several case studies are provided in Appendix E which describe how a phased approach has worked in achieving consistency with the Coastal Act, as well as the associated time and resources involved in producing successful projects. Given the importance and prevalence of highways along the entire California coast, it is important to update LCP policies to address both specific segments and longer corridors of highways and to approach adaptation of transportation facilities well before negative impacts to coastal resources and highway service are expected to occur. The timeframe to achieve that goal will depend on the level of vulnerability of the specific highway facility, segment, and corridor, the sensitivity of coastal resources that may also be threatened in connection with that vulnerability, and the essential functions met by the specific corridor.

RAILWAY VULNERABILITY

The ownership, jurisdiction, and management over California's railroad system is complex because the infrastructure crosses land owned by or under the jurisdiction of multiple cities, counties, and state and federal agencies. Although principles of federal preemption sometimes limit the role of state and local governments in regulating railroad activities, there are still important opportunities for the Commission, asset managers, and local governments to coordinate with railroad companies and with Caltrans' Division of Rail and Mass Transportation who are involved in various planning and investment activities related to railroad infrastructure along the coast.

Image 11. Indianola Cutoff, Eureka, Humbolt County. Photo by the California King Tides Project.

Within the coastal zone, approximately 70 miles of rail track or bridge abutments are currently vulnerable, or are projected to become vulnerable, to coastal hazards with up to 6.6 feet of sea level rise.[14] This vulnerability is largely concentrated in specific regions along the coast, including high erosion threats in Santa Barbara, Orange, and San Diego counties, tidal flooding risk in Humboldt Bay and Elkhorn Slough, and storm flooding risk in Ventura and Los Angeles counties. In addition to these concentrated areas, discontinuous segments of vulnerable rail infrastructure are spread throughout the state, which if flooded or damaged would disrupt entire corridors. Thus, the total mileage of vulnerable track is far more than 70 miles statewide.

With 6.6 feet of sea level rise and 100-year storm conditions, Santa Barbara County will have approximately 17 miles of track in danger of erosion, and 5 miles in danger of coastal storm flooding. Under this same scenario, over 10 miles of track in Los Angeles County will be vulnerable to storm flooding. In San Diego County, approximately 2 miles of track will be in danger of erosion, and close to 10 miles will be in danger of storm flooding. In some cases, these vulnerable segments represent a significant portion of a city's shoreline, as is the case for the cities of San Clemente and Del Mar, or are critical to a port as distribution lines. When viewed as a part of a corridor on a regional scale, the total miles of line affected may be much more in some locations. For example, in Santa Barbara County, more than 8 miles of vulnerable rail infrastructure are distributed over almost 60 miles of coastal track, meaning that use of the entire 60 miles of rail line could be compromised if those vulnerabilities are not addressed.

14 This total was calculated primarily using USGS CoSMoS modeling with the projection of 6.6 feet of sea level rise under 100-year storm conditions. For areas where CoSMoS data was unavailable (i.e., certain Northern California locations), Pacific Institute modeling with the projection of 4.6 feet of sea level rise under 100-year storm conditions was used.

As with highways, the rail lines in many of these vulnerable locations are the first line of development between a city or county's developed shoreline and the rising sea. Conducting long-term planning in these locations presents an array of challenges and opportunities depending on the approach. If rail infrastructure is maintained in place and armored over time as sea levels rise, the beach or other shoreline habitats will eventually be lost, and surf breaks or other offshore resources could similarly be affected. Alternatively, if a rail line is removed, realigned, or relocated, and the shoreline is left to erode naturally, it may impact the community's development located inland of the former rail line.

While in its early stages, rail-specific vulnerability and adaptation planning is in progress at the State and local level. The State Rail Plan, last updated in 2018, contains sea level rise analyses for certain highly vulnerable segments of rail throughout the state. Caltrans has also begun the next update to the State Rail Plan, which will include more comprehensive sea level rise analyses of the State's rail infrastructure. In addition, planning is occurring at the local level. For example, the Orange County Transportation Authority (OCTA) is conducting a rail infrastructure study along the LOSSAN rail corridor entitled, *Orange County Rail Infrastructure Defense Against Climate Change Plan*. The study is funded by Caltrans' Sustainable Transportation Planning Grants program and is expected to be completed in 2021. Using historical data, the study will assess and evaluate climate change impacts from sea level rise, soil erosion, heat, and wildfires within the rail right-of-way and train stations along a 25-mile section of the LOSSAN corridor from the Irvine Station to the end of the Orange County line in the City of San Clemente. It will also propose potential rail corridor improvements in the study area.

Many local jurisdictions that have conducted vulnerability analyses showing risks to rail infrastructure have begun asking how they can best engage rail owners, operators, and managers, and otherwise coordinate planning and permitting related to the vulnerable rail lines that traverse their jurisdictional limits. Specifically, local jurisdictions are considering how they should update their LCP policies to establish or reinforce their role in addressing railroad infrastructure in the face of sea level rise. Jurisdictional complexities associated with railroads, and in particular the doctrine of federal preemption, raise important questions related to both the Commission's and local jurisdictions' authorities to address highly vulnerable stretches of rail line. Nonetheless, the unavoidable significant threats posed by sea level rise and other climate changes to the rail systems, and the communities through which they pass, cannot be ignored. The following discussion describes the complexity associated with rail planning, management, and operation in coastal California and describes issues associated with permitting and regulatory jurisdiction over rail infrastructure. It also describes ways that local governments can be involved in rail planning and points to the need for more coordination of that planning at the local, regional, state, and federal levels.

RAILWAY OWNERSHIP, MANAGEMENT, AND PLANNING

Rail lines have different owners, operators, and regulators, and operations generally consist of both passenger and freight services. In California, freight rail services are provided by two Class I (large) railroads: Union Pacific and BNSF Railway Company. The state also has 26 Class III (small) railroads, and sometimes these smaller railroads are owned by a parent company, such as Genesee & Wyoming California. The National Rail Passenger Corporation (Amtrak) operates four long distance services and the state sponsors three corridor services. There are also five commuter railroads, and most of these passenger services operate over trackage owned by the Class I railroads.

The Federal Railroad Administration oversees state-developed rail plans and planning projects and federal grant and loan programs for passenger rail systems such as Amtrak. The Federal Transit Administration provides additional financial and technical services to state and local transit systems such as commuter railroads.

At the state level in California, the California State Transportation Agency (CalSTA) is a cabinet-level agency that includes Caltrans, the California Transportation Commission (CTC), and the California High-Speed Rail Authority (CHSRA). Caltrans is responsible for planning and maintaining the State's transportation system. Its primary planning document for rail is the California State Rail Plan, most recently updated in 2018 and currently in revision, which includes some information on planning for sea level rise. The CTC is responsible for programming and allocating funds, as well as advising the Secretary of Transportation and the California State Legislature on issues related to transportation planning and funding. The CHSRA is responsible for planning and implementing the State's long-term high-speed rail vision.

Regionally, all state-supported intercity rail routes are managed and administered by Joint Powers Authorities (JPAs). JPAs are authorized to make and enter contracts, own and lease property, manage and build facilities, and incur debts. For example, The Los Angeles – San Diego – San Luis Obispo Rail Corridor Agency (LOSSAN) is a JPA originally formed in 1989 that works to increase ridership, revenue, capacity, reliability, coordination, and safety on the coastal rail line between San Diego, Los Angeles, Santa Barbara, and San Luis Obispo. It is governed by an 11-member Board of Directors composed of elected officials representing rail owners, operators, and planning agencies along the rail corridor. The LOSSAN Agency is staffed by the Orange County Transportation Authority, one of many public sector transportation planning and mass transit service providers in the state.

In general, railroads are integrated systems. The private railroads and public passenger rail operators are responsible for working together to build and maintain the assets as well as transport goods and provide ridership services. They are also inextricably tied to the other transportation systems in the state. The industry is heavily regulated by the Interstate Commerce Commission Termination Act of 1995 (ICCTA). The Act establishes the Surface Transportation Board (STB) and grants the STB extensive authority over permitting and economic regulation of the railroad industry. STB oversight includes transportation by rail carriers and the remedies provided with respect to rates, classifications, rules, practices, routes, services, and facilities. The STB also oversees and has jurisdiction over the construction, acquisition, operation, abandonment, or discontinuance of tracks and rail facilities that serve the interstate rail network, even if the infrastructure is located entirely in one state.

RAILWAY GOVERNANCE AND PLANNING

Federal Preemption, the Coastal Act, and LCPs

The broad authority and discretion granted to the STB under the ICCTA limits state and local jurisdiction over rail activities under the doctrine of federal preemption. The U.S. Constitution states that federal law is the supreme law of the land, which means that it "preempts" (or applies instead of) conflicting state law; likewise, state law generally preempts conflicting local law and ordinances, and sometimes preempts entire areas of local regulation. Application of the federal preemption doctrine to rail operations is nuanced and complex. The ICCTA preempts any state or local regulations that have the effect of managing or governing rail transportation activities that are part of the general system of rail transportation and related to the movement of passengers or freight in interstate commerce. Questions of federal preemption of rail activities arise regularly, and the STB has broad jurisdiction and authority over preemption determinations.

However, there is no blanket preemption over state or local environmental regulations for rail activities, including those taking place in the coastal zone. Instead, preemption determinations are made on a case-by-case basis. The two primary tests for whether ICCTA preemption applies are whether the state or local law is one of general applicability, with only an incidental impact on rail transportation, and whether any such law nevertheless imposes an unreasonable burden on interstate commerce.[15] The Coastal Act is a state law of general applicability in that nothing in the Act or the Commission's regulations is directed specifically at regulating rail projects or operations. A similar argument can be extended to city or county LCPs, and their policies and ordinances because they are implementing the Coastal Act, unless policies specifically seek to regulate railroads. Any railroad company should check with the Commission (and local governments with a certified LCP) before undertaking development activities in the coastal zone to obtain a preliminary review to determine if the particular action in question may require a coastal development permit, is otherwise outside the scope of the ICCTA preemption, and/or is subject to federal consistency review by the Commission under the Coastal Zone Management Act (see discussion below related to federal consistency review).

15 In re Bos. & Me. Corp. & Town of Ayer, Mass., No. 33971 (S.T.B. Apr. 30, 2001) relied upon in Association of American Railroads v. South Coast Air Quality Mgmt. Dist., 622 F.3d 1094, 1097 (9th Cir. 2010).

Although state and local governments may not impose permitting or other preclearance requirements on most private railroad projects, there are several circumstances in which federal law will not preempt state and local regulation of railroads. These are not common scenarios but do arise from time to time, and determining applicability requires a fact-specific, case-by-case inquiry. They include when:

(1) a project involves mass transportation provided by a local government;[16]

(2) transportation on a rail line is *intra*state and is not performed or carried out as part of the *inter*state rail network;[17]

(3) the work at issue does not interfere with the operation of the railroad;[18]

(4) an operator of the rail line is a subdivision of the State;[19] or

(5) state regulation is performed in order to implement federal law.[20]

The tests and lines of analysis associated with these exceptions are nuanced; thus, a case-by-case review is necessary should any of these scenarios arise.

The STB has also specifically identified several types of activities that are not preempted, reconfirming that railroads have a duty to report to and work with state and local agencies on proposed rail activities. As the STB has stated,

> "Railroads, while exempt from traditional permitting and zoning processes, are not necessarily exempt from other generally applicable laws. Like any citizen or business, railroads have some responsibility to work with communities to seek ways to address local concerns in a way that makes sense and protects the public health and safety."[21]

For example, the STB has stated that railroad companies should:

- "Share their plans with the community, when they are undertaking an activity for which another entity would require a permit." For example, railroads should provide some materials that would otherwise be required during an environmental permitting process, if the process and permit were not preempted. This could include providing detailed environmental monitoring plans or sharing final plans prior to construction, or as-built plans prior to operations with the state or local planning agency.
- "Use state or local best management practices when they construct railroad facilities." For example, implementing construction best management practices related to water quality.

16 49 § U.S.C. 10501(c)(2).

17 Transit Solutions Group, LLC-Operation Exemption-Nashville and Eastern Railroad, No. 34832 (S.T.B. Mar. 2, 2006).

18 Jones v. Union Pacific Railroad Co., 79 Cal.App.4th 1056, 1060 (2000).

19 Friends of Eel River v. N. Coast R.R. Auth., 3 Cal.5th 677 (2017).

20 Association of American Railroads v. South Coast Air Quality Mgmt. Dist., 622 F.3d 1094, 1098 (9th Cir. 2010).

21 In re Bos. & Me. Corp. & Town of Ayer, Mass., No. 33971 (S.T.B. Apr. 30, 2001).

- "Implement appropriate precautionary measures at the railroad facility, so long as the measures are fairly applied." For example, requiring and testing that construction materials do not contain carcinogens or other environmental contaminants.
- "Provide representatives to meet periodically with citizen groups or local government entities to seek mutually acceptable ways to address local concerns."
- "Submit environmental monitoring or testing information to local government entities for an appropriate period of time after operations begin." For example, requiring consistent and ongoing monitoring of certain conditions (e.g., water quality, design performance) and providing periodic monitoring reports to the relevant state or local entities.[22]

In this way, many types of activities that would otherwise be included as permit conditions issued by a state or local entity, such as construction best management practices and monitoring requirements, can nonetheless be accomplished through proper coordination between the railway and state and local entities. Monitoring and reporting on sea level rise conditions could reasonably fall within this line of activities, and thus local governments should work closely with the railways in their jurisdictions to seek consensus on the types of monitoring and reporting activities that the railway could conduct to help address local or regional sea level rise concerns. There is also nothing that prevents local governments from entering voluntary agreements with railroads in order to address similar issues.

Federal Consistency Review versus Coastal Development Permits

The Coastal Commission also retains federal consistency review authority over many rail activities, development projects, permits, and licenses impacting the coastal zone. The Commission conducts such consistency review under the Federal Coastal Zone Management Act for federal agency projects or for other projects that require a federal license or permit or obtain federal funding or assistance. The Commission retains this authority even when a local government has a certified LCP in the jurisdiction where the project is proposed. All applicable activities are reviewed for consistency with Chapter 3 of the Coastal Act, although an LCP may provide relevant background and context that the Commission can consider. Local governments can be involved in this consistency review process for rail projects that are in, or affect, their jurisdiction by submitting comment letters to the Commission, meeting with Commission staff, and testifying at Commission hearings related to the consistency review. The City of Del Mar, for example, has been involved in the Commission's federal consistency proceedings related to bluff stabilization projects that protect the coastal rail line in that city.[23]

22 Footnotes omitted. See In re Bos. & Me. Corp. & Town of Ayer, Mass., No. 33971 (S.T.B. Apr. 30, 2001) for more information.

23 See, e.g., https://documents.coastal.ca.gov/reports/2020/8/W13b/W13b-8-2020-Report.pdf, p. 19, discussing the City of Del Mar's comments submitted to the Commission.

The entity seeking consistency review must notify the Commission of the proposed project and must work directly with the Commission, regardless of whether there is a certified LCP in the project location. Permits for railroad construction, exemption from service requirements for rail transportation, applications for rail line abandonments, removal of trackage, and disposition of rail rights-of way all require licenses and permits from the STB and thus require consistency review from the Commission. In addition, the Commission can request permission from the federal government to review projects that are subject to other types of federal permits or licenses, and it also reviews rail projects that receive federal assistance, such as grants.

As described above, determining whether rail projects are preempted, trigger federal consistency review, or require a CDP is complex, and Commission staff and rail project proponents often disagree on jurisdictional authority. The Commission's informal collaborative agreement with the San Diego Association of Governments (SANDAG) on projects within the San Diego section of the above-mentioned LOSSAN rail corridor is one example of how the Commission has navigated these jurisdictional questions. In reviewing past consistency certifications for SANDAG and the North County Transit District (NCTD) in the LOSSAN corridor, the Commission has historically agreed to set aside disagreements over whether a coastal development permit is needed if a project can be evaluated through the federal consistency process, and thus has procedurally relied on the consistency procedure for project review in those cases. In one important example, the Commission concurred with the consistency certification for and certified the North Coast Corridor Public Works Plan and Transportation and Resource Enhancement Program (NCC PWP/TREP) on August 13, 2014, which serves as a master federal consistency certification to ensure the entire suite of rail, highway, transit, bicycle, pedestrian and other community and resource improvements described therein will be appropriately linked, phased, and implemented in a manner consistent with applicable Coastal Act policies. In so doing, the Commission essentially agreed to continue this procedural approach of relying on federal consistency for rail activities in this area to ensure protection of coastal resources. However, no such similar agreements are in place in other parts of the LOSSAN corridor or in other rail corridors in the coastal zone in the rest of the state. This example instead represents just one approach for how the Commission is ensuring that rail projects in the coastal zone are consistent with Coastal Act requirements. The Commission has also asserted its CDP authority over projects associated with rail operations, such as parking lots and stations. For example, the Commission approved a CDP in the County of Santa Barbara to construct a parking lot, bathroom, boarding platform, and pedestrian crossing to service an Amtrak line at the old Surf Station depot in Lompoc.

Given the high consequences of risks to rail infrastructure from sea level rise for many local jurisdictions, especially those with significant portions of rail infrastructure serving as the first line of development along the coast, both the Commission and local governments need to be involved in determining how rail infrastructure is planned, sited, and designed, and ultimately how such infrastructure will be adapted to sea level rise. Regardless of the historical disagreements surrounding permit authority over rail infrastructure, the ICCTA does not give the railroad sector blanket authority to act without any permit or review in the coastal zone. Given its prominent presence along much of the state's coastal landscape, new development and redevelopment of rail infrastructure should be closely monitored and reviewed by state and local jurisdictions. Any railroad should submit its proposals for development activities in the coastal zone to the Commission (and local governments with a certified LCP) for a preliminary review to determine if the particular action in question may require a coastal development permit, is otherwise outside the scope of the ICCTA preemption, and/or is subject to federal consistency review. At the local level, cities and counties should coordinate closely with rail authorities to share pre-construction plans and discuss monitoring and reporting requirements, among other things. Local jurisdictions may include policies in their LCPs that address these activities and include coordination and monitoring requirements related to sea level rise impacts on near- and mid-term infrastructure projects and long-term rail corridor planning. The model policies included in Appendix B provide some ideas and options to address rail infrastructure in light of sea level rise over multiple time horizons. As always, the model policies should be tailored depending on local context.

ADAPTATION STRATEGIES FOR TRANSPORTATION INFRASTRUCTURE

As discussed in Appendix C, there are many adaptation strategies to consider when conducting sea level rise planning for critical infrastructure. Although the adaptation strategies that are most appropriate for a particular piece of transportation infrastructure will depend on the specific circumstances, each type of strategy – including protection, accommodation, retreat, and hybrid strategies – generally has benefits and impacts that can help guide decision-making around when each one should be used.

Box 4. Planning for the Whole Corridor

In all cases, policies and strategies should support a whole-corridor approach to long-term planning, encouraging review and analysis of an entire segment of the transportation system rather than evaluating and implementing individual projects and assets without regard for neighboring vulnerabilities or connectivity issues that may arise in the future with sea level rise. Defining what makes up a corridor will vary. *Caltrans Corridor Planning Process Guide* states “[a] corridor can be defined as a linear geographic area with one or more modes of transportation that facilitates the movement of people and goods, supports the economy, and connects communities. Origins and destinations, land use, place types, and existing and future development that surround the transportation infrastructure influences how the corridor and its limits are defined.”

By looking at the sum of the parts and the long-term, systemic operation of the corridor as a whole, proper planning can develop adaptation pathways with a mix of short-, mid-, and long-term projects for the whole corridor’s adaptation. Holistically addressing all assets implicated can also reduce or eliminate inefficiencies and planning “blind spots.” For example, if a stretch of roadway is given a lower priority because it is not immediately impacted, but it is connected by a bridge that is given a high priority because the impacts are immediate to that structure, the best long-range solution may be to address both parts of the corridor at the same time. In such a situation, both assets are inextricably interconnected, so the solutions for addressing the potential impacts to them will be as well.

In all cases, planning should reflect short-, mid-, and long-term timescales that are commensurate with the state's best available sea level rise projection parameters (i.e., present day through 2100 and beyond). In many cases, nearer-term planning horizons (e.g., 20-30 years) may be used to support prioritization for project funding and selection; however, this prioritization work must be done in the context of the longer-term sea level rise vulnerability analyzed through 2100 and beyond. This will aid planners in selecting appropriate shorter-term or smaller projects that will not disrupt or impede but will compliment longer-term adaptation success for a whole corridor. This planning approach also serves to reduce cost inefficiencies by limiting the selection of less effective methods for addressing vulnerabilities over the mid- to long-term.

The model policies in Appendix B of this Guidance provide a general framework that prioritizes certain approaches to adaptation planning as well as certain adaptation strategies over others. For new transportation infrastructure, the policies reflect the goal of avoiding areas where sea level rise will affect the infrastructure over its useful life. For transportation infrastructure that is already established, the policies generally promote a "phased" or "adaptation pathways" approach. This approach recognizes that adaptation options will need to change over time to account for planning timelines, changing conditions, and uncertainty, such as is described in the "Planning for the Whole Corridor" section above. In general, the model policies in Appendix B prioritize planning for relocation of the infrastructure to safe areas or elevation to avoid the need for hard shoreline protection that harms coastal resources. In some cases, it may be feasible and appropriate to employ nature-based adaptation strategies as a more environmentally friendly way to minimize the impacts associated with sea level rise over the short- to medium-term while planning for relocation. The policies also recognize that shoreline armoring is already being used to ensure safety for transportation infrastructure and will likely continue to be part of a mix of responses necessary to address increasing risks associated with sea level rise in some cases. Because of the coastal resource impacts associated with hard shoreline protection, the model policies state that any time hard shoreline protection is allowed and approved, it must be accompanied by requirements for planning and implementing a long-term solution that minimizes coastal resource and community impacts.

In all cases, the appropriate set of adaptation strategies will need to reflect the specific circumstances of the community and project, including short- and long-term vulnerabilities, relevant coastal resources in the area, and transportation needs and goals. The following sections discuss the following adaptation planning concepts in more detail: realignment, accommodation, shoreline protective devices, and nature-based adaptation strategies.

Realignment

Moving at-risk transportation infrastructure inland – also called realignment – is one of the surest ways to avoid coastal hazards associated with sea level rise. Transportation infrastructure often runs parallel to the shoreline and, in many locations along the California coast, is the first line of development inland from the sea. Increased erosion, flooding, and inundation from sea level rise will threaten this infrastructure, potentially causing service disruptions and costly damage unless action is taken.

Protecting highway and railway infrastructure in place with hard armoring will require ever increasing maintenance needs and enlargement of the armoring as sea levels rise, which could become extremely costly over time. Additionally, whatever band of recreational open space and coastal habitat that lies between the transportation infrastructure and the sea – such as beaches, estuaries, and wetlands – will become narrower until it is eventually lost as sea level rises. Moreover, trying to maintain transportation infrastructure located in high hazard areas can lead to other public safety concerns. In contrast, if transportation infrastructure is realigned inland, not only will the infrastructure be safe, but coastal habitats will have the opportunity to migrate inland and persist as sea levels rise – a benefit that is especially important considering the fact that one of the purposes of coastal transportation infrastructure is to provide public access to these coastal habitats and resources. While realignment could be costlier upfront than the initial expense of installing a shoreline protective device, it is likely cost-saving in the long-term. The cost-savings of hazard avoidance has been documented in several studies (see Appendix G). In addition, implementation will also be driven by feasibility as influenced by local land use and topography, among other important factors. Understanding the trade-offs associated with any realignment decision will be paramount, including factoring in the future landscape under sea level rise conditions when calculating mitigation costs and options.

Realignment

Realigning highways to avoid hazards associated with sea level rise helps ensure the long-term safety of the highway while avoiding the coastal resource impacts that would occur if the highway were to be maintained in place.

Several segments of coastal highways have been realigned in California. In all cases, these realignment projects required extensive planning and coordination among Caltrans, the Coastal Commission, State Parks, local governments, and other stakeholders. Those that went beyond minor inland relocations took many years to plan, fund, and implement. For example, in 2020, the Coastal Commission approved a Caltrans project to realign a 0.7-mile long segment of Highway 1 at Gleason Beach in Sonoma County to avoid coastal erosion as influenced by sea level rise – a milestone that resulted from almost fifteen years of planning and coordination between Caltrans, State Parks, Sonoma County, Coastal Commission staff, the local community, and a variety of other interested parties. The overall project allows for restoration of coastal processes and the removal of eroded shoreline armoring along the highway and adjacent structures. In 2014, the Commission approved the inland realignment of a 2.8-mile long section of Highway 1 north of the Piedras Blancas Lighthouse in San Luis Obispo County in response to ongoing shoreline erosion and anticipated future hazards, and the temporary shoreline armoring that had been protecting the highway was removed. The project required extensive coordination between the Coastal Commission, Caltrans, State Parks (which took over management of the land west of the realigned highway), San Luis Obispo County, and other stakeholders. Going forward, coordination between Caltrans, the Coastal Commission, State Parks, and other state and local decision makers to identify corridors where realignment approaches can best be applied should occur earlier, ideally when relevant LCP(s) are being updated and when Caltrans and State Parks District plans are being developed.

The Coastal Commission has also required consideration of realignment of highway and railway infrastructure in other contexts. For example, the Coastal Commission and its staff have been working with SANDAG to address coastal bluff erosion near the railroad along the Del Mar bluffs. In January 2020, as part of coordination related to emergency bluff stabilization measures undertaken in 2019, Commission staff and SANDAG staff discussed the need to accelerate the development of medium- and long-term planning elements for the railroad corridor, including a plan and timeline for development of a phased, long-term adaptation plan for relocating the railroad off the bluffs. This plan will be included in SANDAG's update to the 2015 San Diego Regional Transportation Plan, which is expected in October 2021.

Additionally, in 2015 the Commission approved temporary armoring of a segment of Highway 1 near Surfer's Beach in Half Moon Bay with the requirement that Caltrans initiate a planning process to identify a long-term solution that examines the feasibility of various alternatives for maintaining the viability of the highway and California Coastal Trail, including nature-based strategies and potential realignment. The ideal scenario is that planning for long-term safety of highway and railway segments in the face of sea level rise commences prior to the need for armoring, but approving temporary armoring with the requirement that realignment is considered as part of long-term planning has been appropriate in contexts where there was an immediate need for protection to ensure the continued functionality of the infrastructure and insufficient time for advanced planning. This policy approach, along with model policies on realignment, is included in the model policies in Appendix B.

It is important to note, however, that in cases where realignment of a roadway is infeasible, other alternative strategies traditionally known as "accommodation strategies" may be considered. 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, or building structures that can easily be moved and relocated. For example, in the transportation context, an accommodation strategy could be to elevate a stretch of

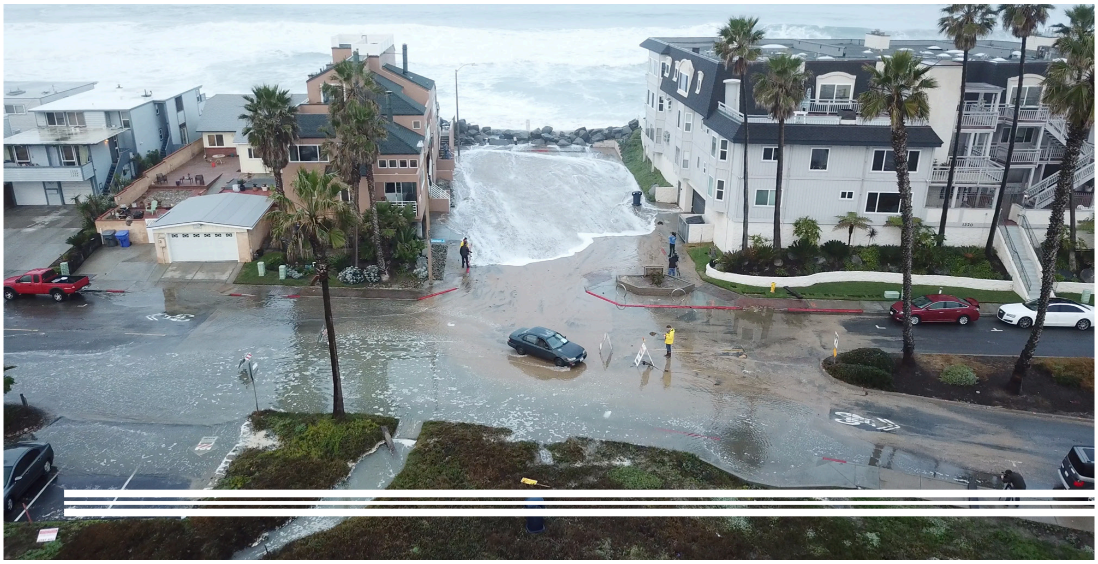


Image 12. Imperial Beach in San Diego County. Photo by Scripps Institute of Oceanography, UC San Diego.

roadway to form a causeway. As with protection strategies, some accommodation strategies could result in negative impacts to coastal resources (e.g., elevated structures may block coastal views or detract from community character), and so careful analysis should support any planning and permitting decision. However, accommodation strategies such as causeways may be more protective of coastal resources than armoring.

Shoreline Protective Devices

Shoreline protective devices such as revetments or seawalls have many well-known and well-documented impacts on coastal resources. They often halt or slow natural shoreline processes such as erosion, retaining sediment that would otherwise have normally contributed to beach formation. Additionally, shoreline protective devices physically eliminate beach and shoreline recreation areas where they are placed and prevent beaches, wetlands, and other habitats from migrating inland with sea level rise, causing them to narrow and eventually disappear (often referred to as “coastal squeeze”). These impacts adversely affect coastal resources such as coastal ecological processes, habitat for rare, protected and endangered species, beach width, public access, use of public trust lands and resources, recreation, and visual resources. As a result, the Coastal Act restricts the circumstances in which shoreline protective devices are approvable. Specifically, Section 30253 of the Coastal Act requires new development to:

> “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.”

Other provisions of Chapter 3 require the protection and enhancement of ecological values, public access, recreation, and visual and other coastal resources. Because shoreline protective devices generally harm one or more of these resources, these provisions limit the situations in which such devices may be permitted.

Shoreline Protective Devices

Protective devices for transportation may be a reasonable short- to mid-term adaptation strategy when they are the least environmentally damaging alternative in the context of phased adaptation, and when designed to safeguard coastal access, mitigate for all impacts to coastal resources, protect public trust resources, and ensure equitable access to, and benefits from, coastal resources over time.

Still, the Coastal Act recognizes that shoreline protection can be permitted in certain circumstances. For example, Section 30235 lists types of development that may be protected by shoreline protection, even if such protection has adverse impacts on coastal resources. Specifically, protective devices 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."

In situations involving the protection of these types of uses or structures, armoring may lawfully be allowed and may represent a reasonable short- to mid-term adaptation strategy. This may be especially true for protection of existing critical infrastructure where the armoring is the least environmentally damaging alternative within the context of phased adaptation responses. However, to the extent that LCP policies – or projects approved pursuant to them – allow for shoreline armoring, local governments must ensure that such policies and projects safeguard coastal access, mitigate for all impacts to coastal resources affected by armoring, protect public trust resources, and ensure equitable access to, and benefits from, coastal resources over time, all consistent with Coastal Act provisions.

Thus, the Coastal Act provides a nuanced framework that guides how shoreline protective devices may be used, including to protect critical transportation infrastructure. Consistent with this framework, the model policies in Appendix B generally emphasize the need to engage in proactive adaptation measures in order to avoid the need for hard shoreline protection.

Nature-Based Adaptation Strategies

As discussed in Chapter 4, an emerging approach for coastal protection is the use of nature-based adaptation strategies. Nature-based adaptation strategies can contribute to the persistence and enhancement of natural coastal processes and ecological benefits, while also offering protection services to inshore or inland areas. Unlike traditional shoreline protective devices, nature-based adaptation strategies are designed to restore or enhance coastal resources while reducing the impacts of coastal flooding, wave runup, and erosion, thereby minimizing or avoiding impacts to coastal resources. Coastal habitats that can function as nature-based adaptation strategies include wetlands, dunes, sandy beaches, and reefs. Nature-based adaptation strategies encompass a spectrum from "soft" or "green" strategies to harder "hybrid" or "gray" strategies. Soft strategies are composed of natural habitats that do not fix the shoreline, as these natural features are meant to move and change dynamically in response to sea level rise or other climate changes. Hybrid armoring includes strategies that combine a hard protection element, such as a buried revetment that will fix the shoreline, with a nature-based feature, such as overlying dunes. Although individual definitions may vary, this Guidance generally considers nature-based adaptation strategies to be those strategies that seek to restore, maintain, or enhance ecological value through designs that incorporate natural features, thus minimizing impacts to coastal resources as compared to traditional hard armoring methods.

Nature-Based Adaptation

Nature-based adaptation strategies protect infrastructure while ensuring that coastal resources are protected, maintained, restored, or enhanced. As such, many state policies encourage the use of nature-based adaptation strategies.

Critically, nature-based adaptation strategies can enhance the resilience of California's transportation infrastructure from sea level rise and other coastal impacts while at the same time ensuring that coastal resources are protected, maintained, restored, or enhanced. Transportation benefits of nature-based adaptation strategies include less extensive road closures associated with flooding events, reduced damage to bridges, attenuated roadway embankment erosion, and decreased vulnerability to shoreline retreat (Webb *et al*. 2018). Additionally, nature-based adaptation strategies can provide co-benefits in the form of enhancements to water quality, habitat, recreation, flood resilience, and improved coastal ecosystems. Due to these numerous co-benefits, state-level guidance and orders – including Executive Order B-30-15, *Safeguarding California*, the OPC *State of California Sea-Level Rise Guidance*, the *California State Hazard Mitigation Plan*, and the *California Coastal Commission Sea Level Rise Policy Guidance* – encourage the use of nature-based adaptation strategies where feasible. Nature-based adaptation strategies can also help transportation agencies meet federal requirements to improve "the resilience and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation."[24]

Use of nature-based adaptation strategies to increase resilience of transportation infrastructure is becoming more common, though it should be noted that constraints exist. For example, high-energy wave environments along much of the coast could challenge the effectiveness of nature-based adaptation strategies, particularly those that do not include any armoring. Nature-based adaptation strategies may also require a larger footprint or a greater upfront investment than more traditional armoring. At the same time, however, these approaches may provide greater returns on the initial investment over the long-term. Case studies, guidance documents, and other tools have been developed to better understand the opportunities and constraints for these kinds of strategies. In 2019, the Federal Highway Administration released an *Implementation Guide on Nature-Based Solutions for Coastal Highway Resilience*. The Guide provides transportation managers with key resources in planning and developing nature-based adaptation strategies to improve transportation infrastructure resilience. In addition, a Technical Report prepared for the Fourth California Climate Change Assessment, entitled *Toward Natural Shoreline Infrastructure to Manage Coastal Change in California*, provides guidance specific to California for planners on how to reduce reliance on coastal armoring and deploy natural shoreline infrastructure solutions (Newkirk *et al.* 2018). Specific opportunities for vegetated dunes and cobble berms in Monterey and Ventura Counties were identified that could be useful for highway infrastructure planning. Additional case studies are provided by Judge et al. (2017). Several case studies of nature-based adaptation strategies that have been used in California are highlighted in Appendix E.

In line with these state and federal requirements and recommendations, the model policies in Appendix B encourage the implementation of nature-based adaptation strategies where feasible.

24 23 CFR § 450.216, Development and content of the long-range statewide transportation plan and 23 CFR § 450.324, Development and content of the metropolitan transportation plan.

CHAPTER 6

Water Infrastructure

The following chapter describes sea level rise vulnerability and expected impacts to water infrastructure, the applicable planning and regulatory framework, and strategies for how to plan for resilient water infrastructure

INTRODUCTION TO WATER INFRASTRUCTURE

Water infrastructure, like other critical infrastructure, is interconnected with power, transportation, and communications systems, and is vital to local economies as well as public health. Stormwater, wastewater, and water supply systems perform critical functions and face parallel vulnerabilities to sea level rise given the similar component types and facility designs. Water infrastructure interconnects in a variety of ways—for example, some communities are pursuing reuse of treated wastewater to supplement water supply in various ways (Figure 4).

Water infrastructure components can include single-site facilities that are discernible as separate and distinct components, as well as corridor facilities, such as pipelines, that traverse lands to connect the infrastructure network together. Adding more complexity to water infrastructure design, facilities are developed in a range of scales, from small stormwater capture and treatment projects on individual sites to regional wastewater treatment plants. Depending on the extent of the area to be served, along with physical and environmental constraints, water infrastructure can vary widely in how systems are designed and configured.

It is vital to plan for resilient critical infrastructure before a disaster occurs, and such planning provides the opportunity to most cost-effectively maintain community services before, during, and after major events. Failure to plan effectively may result in unnecessary costs for the maintenance, protection, and reconstruction of vulnerable critical infrastructure. After evaluating vulnerability and establishing policies to be used throughout hazardous areas, communities can begin the process of identifying and evaluating adaptation strategies for specific areas. In most cases, especially for an LCP's Land Use Plan (LUP) and Implementation Plan (IP), multiple adaptation strategies will be needed, and every community will need to assess its risks and its potential options based on site-specific or system-specific conditions. In many cases, there will be more than one option for how to address the risks and impacts associated with sea level rise that is consistent with the Coastal Act.

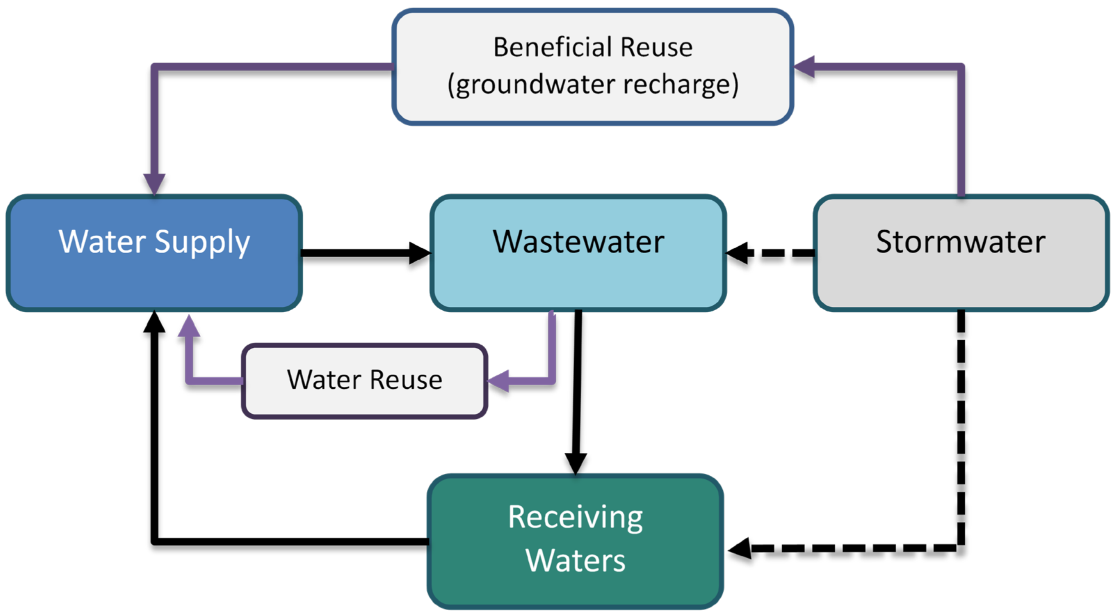


Figure 4. Conceptual diagram of holistic approach to water management using water supply, wastewater, and stormwater systems. (Adapted from EPA 2012 Water Reuse Guidelines)

VULNERABILITY OF WATER INFRASTRUCTURE

Climate change impacts will challenge the effectiveness of water supply, stormwater, and wastewater infrastructure in the coastal zone. While public utilities will struggle to address all types of climate change impacts—ranging from extreme drought to extreme precipitation—this Guidance addresses sea level rise-related risks. Sea level rise will increase risk to water infrastructure from hazards such as saltwater intrusion, tidal inundation, rising groundwater, coastal erosion, and storm flooding.

How rising seas threaten water infrastructure depends on its location and context. Figure 5 describes some of the effects of sea level rise hazards and consequences for water systems in general. Storm flooding, erosion, tidal inundation, and saltwater intrusion will affect water infrastructure in a variety of contexts. For example, saltwater could corrode wastewater infrastructure, flood system components, cause sewer and stormwater drainage system backups, compromise stormwater treatment systems, and/or degrade groundwater quality as the tides extend further inland as a result of sea level rise. In addition, erosion along the immediate shoreline directly threatens any water infrastructure located in these coastal areas.

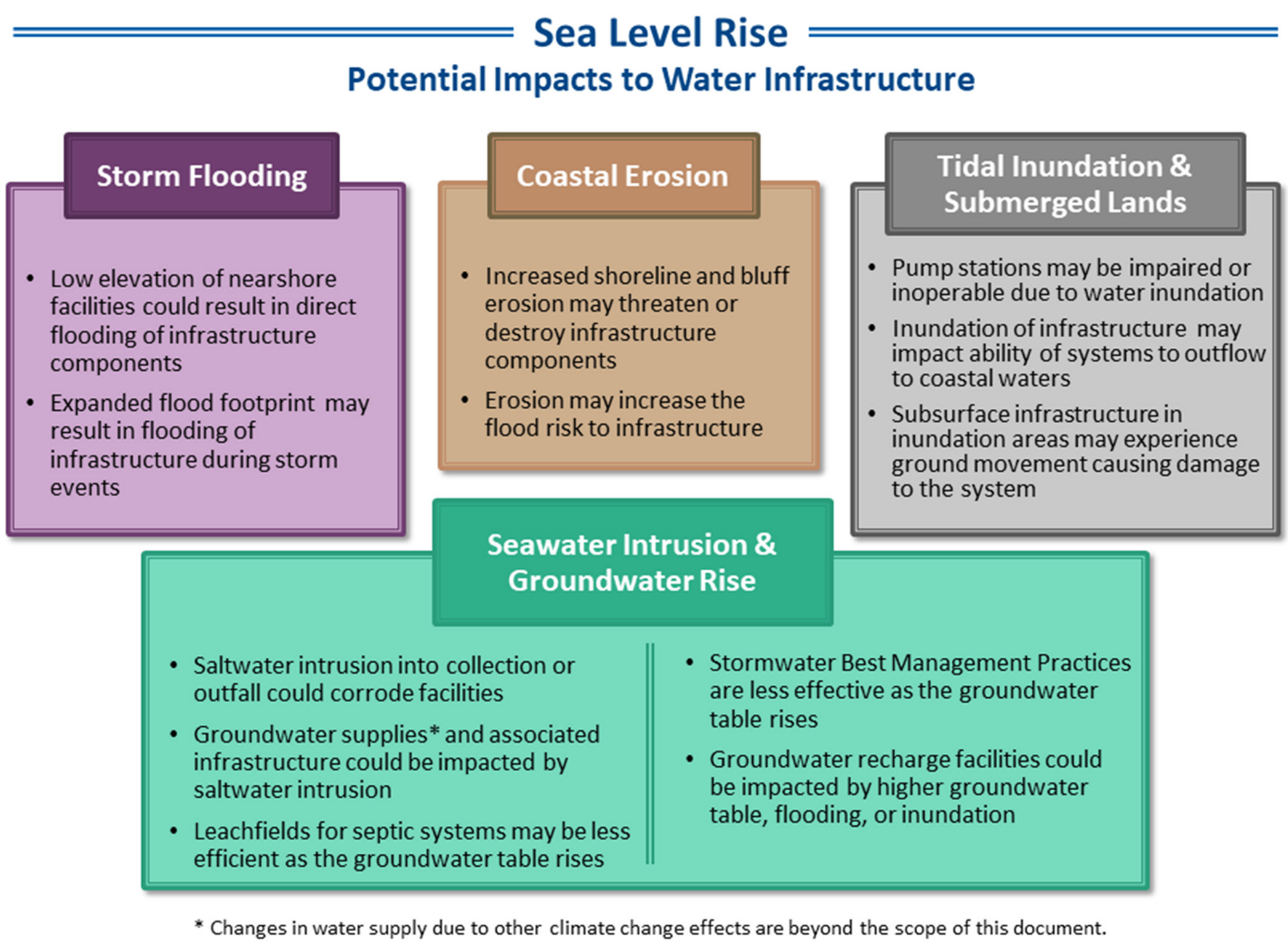


Figure 5. Hazards exacerbated by sea level rise and their potential consequences to water infrastructure. Azevedo de Almeida, B. & Mostafavi, A. (2016) identify various impacts of sea level rise on infrastructure in coastal areas and examine the adaptation measures suggested in the existing literature.

When any part of the water management system breaks down, there can be far-reaching and significant effects on coastal resources as well as coastal and inland communities. Thus, communities need a full understanding of how risks to all system components could cause impacts under a range of climate conditions. It is likely that different components of the systems will have different sea level rise threat exposures and consequences.[25] It also matters whether components face potential failure due to increased storm flooding versus chronic, regular tidal inundation due to sea level rise. An understanding of these risks will support a community's prioritization and planning for water infrastructure projects.

Most of California's coastal counties have water-related infrastructure that is vulnerable to current or future coastal hazards, and communities will need to consider and address these risks when preparing for the sea level rise impacts of flooding, erosion, and saltwater intrusion.[26] The Coastal Commission's 2016 *Vulnerability Synthesis* project found that water infrastructure threats exacerbated by sea level rise are widespread, ranging from threats to small septic fields to large-scale wastewater management systems throughout the state. Due to the nature of how water networks are managed, no single statewide entity has consolidated data on the underground piped collection and distribution systems, which leaves identifying locations of many susceptible areas to local operators and jurisdictions.

Wastewater Systems and Vulnerability

Wastewater systems (*e.g.*, septic and sewer systems) collect wastewater from homes, businesses, and industries and deliver it to facilities for treatment before it is either reused or discharged to waterways or land. Wastewater system infrastructure includes any number of configurations of collection, conveyance, treatment, and outfall facilities. On-site wastewater treatment systems (OWTS), or septic systems, collect small amounts of wastewater to treat near its source.

Wastewater system components often include not only collection pipes, but also interceptors and pump stations, treatment facilities, storage facilities, discharge facilities, power sources (*e.g.*, biogas/cogeneration), and telecommunications. Wastewater treatment facilities sometimes include or connect to water recycling facilities that treat wastewater for a variety of uses (*e.g.*, irrigation, groundwater recharge, aquifer storage and recovery, or use as a seawater barrier). OWTS discharge effluent into

Wastewater Systems

Wastewater system infrastructure includes collection, conveyance, treatment, and outfall facilities for wastewater sewage collected from residential, commercial, and some industrial uses. It also includes on-site wastewater treatment (OWTS) facilities such as septic systems, and may include connecting to water recycling facilities.

25 Unpressurized stormwater and wastewater lines are typically more sensitive to inundation and flooding (storm events can exceed the conveyance capacity of some systems), but pressurized potable water lines are often less sensitive to temporary flooding. See, for example, the City of Pismo Beach Draft Sea Level Rise Vulnerability Assessment.

26 California Coastal Commission Statewide Sea Level Rise Vulnerability Synthesis.

leach fields or dry wells, whereas larger-scale wastewater treatment plants often discharge into rivers, bays, or the ocean. Centralized treatment facilities typically use physical, biological, and chemical processes to purify wastewater before land disposal of solids, discharge to receiving waters through outfall structures, or discharge in other ways for beneficial reuse (*e.g.*, groundwater injection and reservoir augmentation).

Sea level rise can cause increased tidal inundation, stormwater flooding, and rising groundwater, all of which may damage facilities and increase the inflow and infiltration of fresh and saline water into wastewater pipes. Due to the age of much of the wastewater network and the seismically active California coast, it is likely that some wastewater pipes have cracks or are open to infiltration that may potentially overload the wastewater treatment system and lead to untreated overflows. A recent study found that

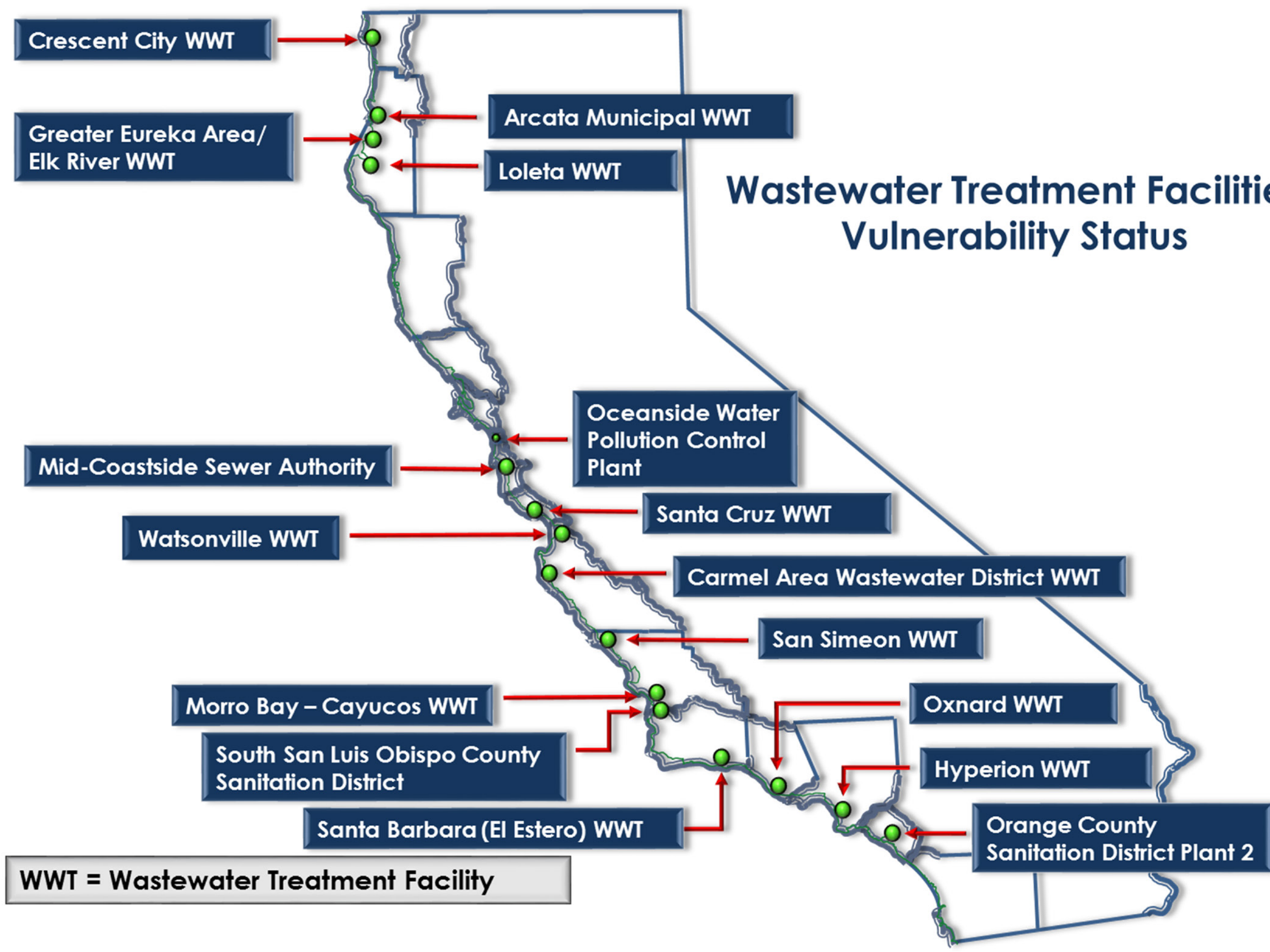


Figure 6. Wastewater Treatment Facilities with Vulnerability Summarized in Appendix D-3.

sea level rise-related marine and groundwater flooding threaten wastewater treatment infrastructure, and this may impact five times as many people as residential flooding from sea level rise (Hummel *et al.*, 2018). In addition, people who reside outside of hazardous areas are at risk from disruption of the wastewater system due to sea level rise if they rely on wastewater infrastructure located in hazardous areas.

The vulnerability of wastewater treatment plants has received much attention due to statewide regulatory frameworks and the importance of centralized wastewater treatment in protecting water quality at a broader scale. Wastewater treatment plants often rely upon gravity to move waste to treatment facilities. Thus, coastal wastewater treatment plants are typically located at lower elevations near the shore and many are quite vulnerable to flooding.[27] Figure 6 identifies the California wastewater treatment facilities (excluding San Francisco Bay) with infrastructure components vulnerable to sea level rise-related impacts. Appendix D provides more detailed information for each facility.

Treatment facilities are only one element of wastewater systems, and augmenting Appendix D with additional studies of other system components including pumping stations, collection lines, and treated wastewater discharge would create a more complete picture of the hazard risk for community systems. Individual cities and counties in California have begun to inventory these types of vulnerabilities, but no statewide, comprehensive list currently exists.

Stormwater Systems and Vulnerability

Stormwater systems include modifications of land as well as constructed facilities for the purpose of conveying and/or treating stormwater runoff flows. Given their function and design, stormwater systems also convey dry weather runoff flows where human activities generate water runoff unrelated to storm events. Stormwater facilities may include infiltration basins, gutters, storm drain inlets, pipes, ditches, canals, earthen or concrete channels, pumps, energy dissipators, and outfalls. They may also include facilities for stormwater capture for later use, such as a pond, underground storage tank, or cistern. Stormwater systems generally discharge collected flows through outfalls into natural waterways including creeks, lagoons, sloughs, and bays that flow to the ocean, or directly into the ocean itself.

Stormwater Systems

Stormwater system infrastructure includes collection, conveyance, treatment (e.g., infiltration basins, stormdrain filters), and outfall facilities for dry weather and stormwater flows in urban and suburban areas.

27 The Pacific Institute's study of California's sea level rise vulnerability estimated that a 100-year flood event with 55 inches of sea level rise could result in impacts on 28 wastewater treatment plants: 21 on the San Francisco Bay and 7 on the Pacific Coast (Heberger et al., 2009).

Stormwater drainage is typically separate from the sewage system in California, and discharges to receiving waters without treatment at any centralized facility (Figure 7). San Francisco is the only coastal city in California with a combined sewer system that collects and treats both wastewater and stormwater in the same network of pipes.[28] Publicly owned or operated systems of stormwater drainage infrastructure, referred to as Municipal Separate Storm Sewer Systems (MS4s), are generally designed for flood control, not for reduction of pollutants or for maintaining natural hydrologic processes, although most if not all such systems along the coast include some components that address the latter.

Stormwater infrastructure, whether small- or large-scale, serves the general purpose of collecting and transporting runoff, and may also include structural Best Management Practices (BMPs) to remove pollutants and/or reduce discharges to waterways. As stormwater runoff flows across the land, it may pick up and carry away natural and human-made pollutants (i.e., nonpoint sources pollution). The discharge of runoff may also cause adverse impacts to the hydrology of receiving waterways. Structural BMPs can reduce the impacts of polluted runoff and minimize runoff discharges through infiltration, evapotranspiration, retention, or detention of runoff, or by capturing runoff for later use. These systems can also involve treatment (such as filters) to remove pollutants of concern.

To protect coastal waters from pollutants, minimize adverse hydrologic impacts to waterways, and attenuate flood hazards, stormwater systems are generally designed to infiltrate or treat stormwater runoff flows produced by storms of a certain size (i.e., rainfall intensity and duration). Storms of a greater size than the system's design capacity contribute runoff that cannot be infiltrated or treated, which may also result in flood hazard conditions.

Comprehensive stormwater management considers flows at a watershed level, beginning with stormwater control measures on each developed site, and then expanding as part of a larger-scale community stormwater collection and conveyance system. Given the spatial distribution of these systems as well as varying physical and environmental conditions, a variety of measures may be implemented to filter and treat runoff and minimize changes in the natural runoff flow regime, thus helping to prevent adverse impacts to coastal resources.

Since treatment of stormwater runoff does not usually occur through the local wastewater treatment system, individual stormwater control measures are typically designed for infiltration or flow-through treatment. Infiltration-based measures may include permeable pavement systems, rain gardens, bioretention basins, infiltration boardwalks, vegetated swales or buffer strips, infiltration trenches or basins, and other vegetated areas (U. S. Environmental Protection Agency, 2017). Stormwater management that uses infiltration-based measures typically attempts to reduce overall stormwater runoff volume and treat the runoff that remains before it reaches the storm drain system and outfalls that discharge to coastal waters.

28 A combined sewer system typically treats (i.e., removes) some of the pollutants in runoff that wash off the streets and roofs, before discharging the runoff into the bay and ocean. When prolonged rains drain more stormwater into the combined system than can be accommodated, there is a potential for overflows that discharge both untreated and/or partially treated sewage and stormwater runoff into coastal waters.

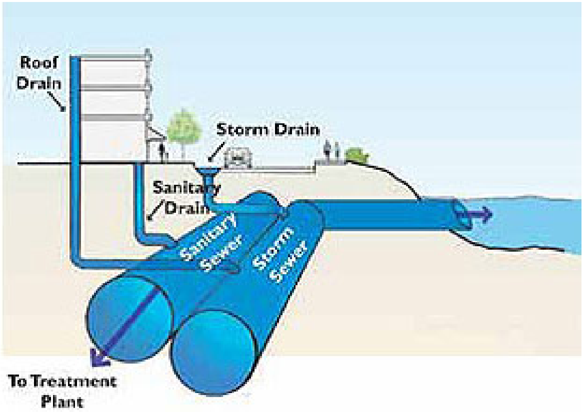


Figure 7. Schematics of (A-Above Left) Separate Sewer Systems and (B-Above Right) Combined Sewer Systems. (Source: [San Francisco Better Streets Plan])

If infiltration of runoff is not feasible (e.g., due to shallow groundwater level) and/or may potentially result in adverse impacts (e.g., due to geologic instability, flooding, or pollution of groundwater or surface water), alternative stormwater control measures that do not infiltrate into the ground may be used for runoff flow control and/or runoff treatment control. Stormwater control measures that combine flow control and treatment may include, for example, on-site features such as a green roofs, detention basins, and rainwater capture systems for non-potable water uses. Treatment control measures may include, for example, storm drain inlet filters, oil/grit separators, sand filters, wet vaults, continuous deflection (vortex) separators, flow-through planter boxes, lined vegetated swales, and biofiltration basins.

Stormwater conveyance system components (e.g., storm drains, conveyance pipes, channels, pumps) are at risk of reduction in capacity to drain stormwater by gravity as sea level and groundwater levels rise. A system's capacity can be reduced as a result of erosion and sediment deposition in the system, corrosion, and pump failure from saltwater infiltration. Erosion can undermine or destabilize portions of the network, and corrosion due to changing water levels or salinity can cause instability or pump failures. Increased surface flooding and rising groundwater levels resulting from sea level rise may lead to the reduced subsurface storage capacity and infiltration effectiveness, or to failure of stormwater runoff flow-control and treatment-control measures, particularly practices that rely on infiltration. Furthermore, failures of one part of the system are rarely confined to an isolated area; failures often have ripple effects throughout much of the network.

In addition to infrastructure system damages, sea level rise will affect the drainage of stormwater runoff flowing into creeks and sloughs that discharge to bays, estuaries, and the ocean, thereby increasing stormwater flooding of lands adjacent to and upstream of creeks and other watercourses. Increased stormwater flooding and erosion can increase mobilization of nonpoint source pollutants, which may potentially expose humans and coastal ecosystems to hazardous chemicals, materials, and pathogens. In less developed areas, nonpoint source pollution may result from land uses other than urban development, including agriculture, forestry, marinas, and hydromodification (i.e., stream channel modifications such as constructing channels, dams, and levees; and dredging and/or filling waterways).

Vulnerability assessments have documented that stormwater infrastructure is at risk from sea level rise. For example, a sea level rise vulnerability analysis of storm drains conducted in the City of Oxnard showed that most of the storm drain outfalls' invert elevations (i.e., bottom of the pipe) in the City's LCP Planning Areas are below the extreme ocean water level under sea level conditions in 2015. When the ocean water level is higher than the invert elevation, it can compromise effective discharge from the outfall, causing inland flooding. These outfalls will become even more vulnerable as sea level rises.[29] As in wastewater systems' vulnerability assessments, information about vulnerable stormwater system infrastructure is not consistently available for the entire coastal zone. Even less is known about stormwater infrastructure vulnerability because it has historically lacked status as a public utility and correspondingly lacked a reliable source of funding to adequately assess and manage its various components.

Water Supply Systems and Vulnerability

Reliable sources of water supply are essential to planning the types, locations, density, and intensity of land uses in a given jurisdiction. Water supplies may be acquired via individual water wells, or through water supply systems operated by public utilities or private water purveyors. Water supply systems obtain water from a variety of sources, including groundwater, surface water, and the ocean through desalination. In some cases, water supply systems can also accommodate recycled water. Many coastal jurisdictions obtain surface water supplies from outside of the coastal zone, and therefore this chapter primarily addresses impacts of sea level rise that are related to groundwater supplies. Although desalination facilities are located in the coastal zone, they are not covered in this Guidance due to the unique and complex issues associated with such facilities.

Water Supply Systems

Water supply infrastructure includes acquisition, conveyance, storage, and treatment facilities that collect water from a source and deliver it to residential, commercial, agricultural, and industrial uses. In coastal communities, most surface water supplies are obtained from outside of the coastal zone; however, groundwater supplies are commonly in use.

At a minimum, water supply infrastructure requires a means of acquisition and distribution (*e.g.*, through pumps, pipes, canals, or ditches) from the source to the end use, as well as water storage facilities (*e.g.*, storage tanks and reservoirs). In addition, much of the water supply requires water treatment to produce potable water from raw water, depending on the quality of the supply and the end uses. Water treatment facilities may be in the form of a water treatment plant (*e.g.*, screening, sedimentation, precipitation, filtration, adsorption, and disinfection), household water treatment system (*e.g.*, filtration systems, water softeners, distillation systems, and/or disinfection), or other targeted treatments. Water system facilities may also include covered or uncovered reservoirs, pressure reducing stations, lift stations, meters, desalination plants including intake and outfall lines, and groundwater recharge areas.

29 Oxnard LCP Storm Drain Technical Memo, 2016; City of Oxnard Planning Division. 2016. *A Sea Level Rise Atlas for the City of Oxnard*.

Water supply infrastructure will also face similar threats to that of wastewater infrastructure in many coastal areas. Saltwater intrusion associated with increased sea level potentially renders existing treatment plants, water intake facilities, and groundwater wells unusable, and reduces the total groundwater supply available to communities in coastal areas.[30] Extreme heat and drought will continue to strain water infrastructure, highlighting the need for decentralized, local, and smaller supply options, especially in vulnerable coastal areas.

Water storage, reuse, and recycling facilities are important water infrastructure components that provide essential community services, including fostering community water security. When these facilities are located in hazardous areas, they may face the same coastal hazards as wastewater and stormwater facilities.

While no comprehensive studies of water supply infrastructure at risk to effects of sea level rise have been completed for California, areas with groundwater vulnerable to saline intrusion have been identified. The Pajaro Valley Aquifer System (Salinas Valley), Santa Clara River Valley (Oxnard), and Coastal Plain of Los Angeles (West Coast) are regions with aquifers vulnerable to saline intrusion as identified by the Department of Water Resources Basin Prioritization process.[31] Individual vulnerability assessments for coastal jurisdictions should contain risk information for water supply infrastructure.

WATER INFRASTRUCTURE REGULATORY FRAMEWORK

Key laws that create the regulatory framework for protecting water quality and coastal resources are the federal Clean Water Act and Coastal Zone Management Act, and the state's Porter-Cologne Act and California Coastal Act.

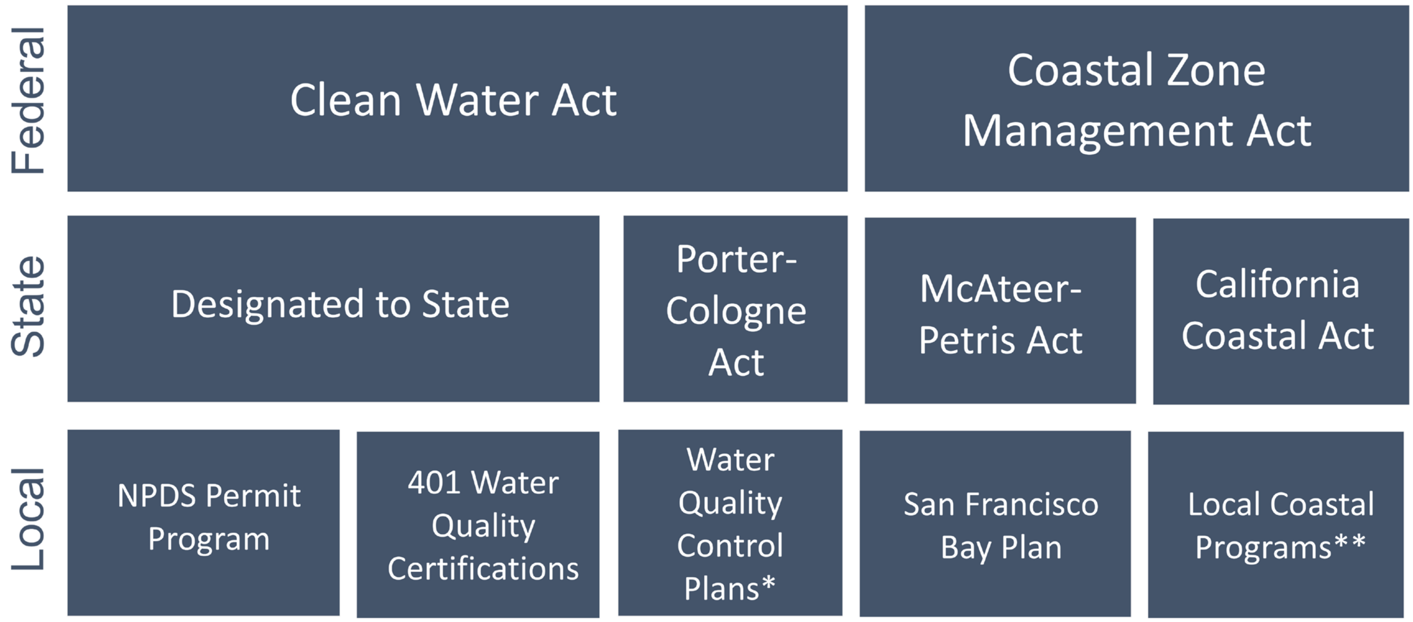
Water Law and California Coastal Program Implementation

While the Coastal Commission and local governments (through their Local Coastal Programs or LCPs) have jurisdiction in the coastal zone to regulate development of water and wastewater infrastructure, other agencies also have core missions regarding water quality and supply, and some of these agencies require permits as well. Figure 8 shows federal, state, and local laws and regulatory frameworks that relate to water management in California. One key regulation is Section 401 of the Federal Clean Water Act (CWA), which gives states and authorized tribes the authority to grant or waive Section 401 water quality certifications for projects that involve discharges to waters of the United States, including most wetlands and other water bodies. The CWA also requires that pollutants discharged into waters from a point source obtain a permit under the National Pollutant Discharge Elimination

30 Note that these impacts from sea level rise may be dwarfed by storage challenges resulting from shifts in the snow-rain precipitation patterns anticipated from climate change.

31 High Priority Basins identified per the Sustainable Groundwater Management Act (SGMA) are required to establish groundwater sustainability agencies, develop groundwater sustainability plans, and manage groundwater for long-term sustainability.

System (NPDES) Program. In the state of California, this federal program is implemented by the State Water Resources Control Board (State Water Board) and the State's Regional Water Quality Control Boards (Regional Water Board), which were created by the Porter-Cologne Act. The Porter-Cologne Act also implements many other provisions of the CWA through required Water Quality Control Plans. As explained in more detail below, the Coastal Act requires the Coastal Commission and local governments to protect water quality when permitting new development that could have water quality impacts.



* Note, the California Ocean Plan applies to ocean dischargers.
** Other certified plans include Port Master Plans, Public Works Plans, and Long-Range Development Plans. The Coastal Commission also directly regulates some development through CDPs and has a role in determining the consistency of federal projects with the Coastal Act.

Figure 8. Federal, state, and local laws and regulatory frameworks that relate to water management.

Wastewater and Stormwater Infrastructure

Public agencies, including cities, counties,[32] joint powers authorities, and special districts (such as sanitary, sanitation and community services districts) typically provide water services in coastal communities. These agencies, as well as some private industries, must obtain NPDES permits to operate wastewater treatment facilities with surface water discharges. In California, the Environmental Protection Agency (EPA) Pacific Southwest Region 9 issues all NPDES permits on tribal lands and for any discharges into federal ocean waters. NPDES permits specify discharge limits, monitoring and reporting requirements, and other provisions to ensure that the discharge does not harm public health or the environment.

32 Most on-site wastewater treatment systems, especially septic systems, are regulated by local agencies such as counties.

In light of growing sea level rise threats to coastal wastewater and stormwater systems, collaboration with the State and Regional Water Boards, public works agencies, and other relevant stakeholders will be important for addressing sea level rise impacts on wastewater and stormwater infrastructure. The recently adopted *Making California's Coast Resilient to Sea-Level Rise: Principles for Aligned State Action* provides a framework for this collaboration.

Stormwater drainage systems owned or operated by a public entity, are referred to as Municipal Separate Storm Sewer Systems (MS4s). California's State and Regional Water Boards issue and enforce National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges from MS4s through the state's Municipal Stormwater Program. At the local scale, the Coastal Commission's Water Quality Program works to integrate effective nonpoint source water quality protection measures into coastal development projects and local governments' LCPs, in accordance with Coastal Act requirements.

Water Supply Infrastructure

The State and Regional Water Boards regulate public water systems, oversee water recycling projects and permit water treatment devices. The Sustainable Groundwater Management Act (SGMA) passed in 2014 requires land use plans to consider groundwater sustainability plans and to assess the impact of land use on groundwater.

Relevant Coastal Act Provisions

Coastal Act Sections 30250, 30254, and 30412 address public services and treatment works facilities directly. Coastal Act Section 30250 requires that new development be located in areas with adequate public services, including adequate water supply as well as wastewater and stormwater facility capacity. Coastal Act Section 30254 requires that new or expanded public works facilities be "designed and limited" to accommodate only the development that can be permitted consistent with the policies of the Coastal Act or LCP. For example, when applied to LCPs, new or expanded public works facilities should be sized so that they do not induce growth beyond the level of development that is achievable under the certified LCP, including full buildout subject to all planning and resource constraints (e.g., presence of ESHA, scenic resources).

Section 30412 delineates the respective authorities of the Coastal Commission and State and Regional Water Boards with respect to the permitting of treatment works. For example, the Commission, and local governments through LCPs, have jurisdiction over the siting and visual appearance of treatment works, but may not act in ways that conflict with Water Board determinations relating to water quality or water rights.

Coastal Act Section 30412 also requires coordination between the Coastal Commission and the State and Regional Water Boards and defines the respective jurisdictions of the agencies with regard to determining water rights and other issues. Specifically, Water Boards have primary responsibility for the coordination and control of water quality, and the Coastal Commission may not take actions that are in conflict with determinations of the Water Boards related to water quality or the administration of water rights. However, the Coastal Commission and local governments, through their LCPs, otherwise retain their control over development pursuant to the Coastal Act, including by ensuring that development does not harm water quality. The main water quality protection policy of the Coastal Act (Section 30231) requires minimizing the adverse effects of wastewater discharges, controlling runoff, and preventing groundwater depletion in order to protect human health and the biological productivity and quality of coastal waters. Notably, this goal is consistent with the goal of the NPDES Program to improve water quality, including by limiting and monitoring discharges.

Key Coastal Act policies with relevance for critical infrastructure and sea level rise adaptation more broadly are provided in Appendix A.

Environmental Justice

As discussed in Chapter 4, adaptation planning for water infrastructure can result in disproportionate burdens to environmental justice communities.[33] To ensure that environmental justice communities are adequately represented and involved in all stages of planning for water infrastructure adaptation, local governments should develop LCP policies for water infrastructure that require early identification and engagement with vulnerable populations through a transparent decision making process. The State Water Board encourages local governments to identify economically distressed areas[34] (EDA) and disadvantaged communities[35] (DAC) for funding and planning assistance that will assist low-income households and areas with fewer resources and access to safe, affordable drinking water. Identification of DAC and EDA or use of other quantitative methods should be complemented by engagement with environmental and social justice stakeholders who will be affected by the planning process in order to identify populations not captured by census data, such as homeless populations and low-income households in high income census tracts.

Additionally, local governments should consider solutions that decrease the burdens to environmental justice communities while ensuring that all individuals have access to clean water. LCP policies can: 1) encourage direct outreach to and meaningful engagement with disadvantaged communities and populations; 2) encourage multi-agency and multi-jurisdictional coordination necessary across various planning documents and through project design, delivery and operation; 3) evaluate impacts to

33 The term “environmental justice communities” is used to refer low-income communities, communities of color, and other historically marginalized communities that have been disproportionately burdened by or less able to prevent, respond, and recover from adverse environmental impacts and discriminatory land use practices.

34 Economically Distressed Area (EDA) – means a municipality with a population of 20,000 persons or less, a rural county, or a reasonably isolated and divisible segment of a larger municipality where the segment of the population is 20,000 persons or less, with an annual median household income that is less than 85% of the statewide median household income, and with one or more of the following conditions as determined by DWR: (1) financial hardship; (2) unemployment rate at least 2% higher than the statewide average; or (3) low population density (Water Code section 79702(k)).

35 Disadvantaged Community (DAC) – means a community with an annual median household income that is less than eighty (80) percent of the statewide annual median household income (Water Code section 79702(j) which cross references to Water Code section 79505.5).

environmental justice communities in alternatives analyses and design projects to avoid or mitigate impacts to those communities; and 4) incorporate other equitable public health, safe drinking water,[36] and coastal resource protection planning goals. Such policies may consider a tiered rate structure with discounted rates for lower-income residents and a comprehensive public outreach program to ensure residents are notified of and enrolled in these programs.

PLANNING FOR RESILIENT WATER INFRASTRUCTURE

Hazards and extreme weather events associated with drought, extreme heat, storm flooding, tidal flooding (often with King Tides), wildfire and mudslides, are already challenging water management in California. The growing threat of sea level rise makes it even more vital to plan for resilient critical infrastructure before a disaster occurs, and such planning provides the opportunity to most cost-effectively maintain community services before, during, and after major events. Failure to plan effectively may result in unnecessary costs for the maintenance, protection, and reconstruction of vulnerable critical infrastructure. After evaluating vulnerability and establishing policies to be used throughout hazardous areas, communities can begin the process of identifying and evaluating adaptation strategies for specific areas. In most cases, especially for an LCP's Land Use Plan (LUP) and Implementation Plan (IP), multiple adaptation strategies will be needed, and every community will need to assess its risks and its potential options based on site-specific or system-specific conditions. In many cases, there will be more than one option for how to address the risks and impacts associated with sea level rise that is consistent with the Coastal Act.

Expected Life of Water Infrastructure Components

Long-term planning of water infrastructure hinges on assumptions about the expected life (design life) of the component facilities, such as collection systems, treatment plants, and equipment. Typically, infrastructure is one of the first things to be constructed as part of new or expanded urban or suburban development. In older, established communities, wastewater and storm water systems have been in place for many years. Much of California's modern water infrastructure was developed in the 1950s and 1960s and may be in need of significant repair or replacement. To this end, the need to upgrade older water infrastructure and facilities poses an opportunity to incorporate sea level rise science and phased adaptation planning into the improvement project.

The components of wastewater systems vary in expected useful life and design, but overall these systems are long-lived (Table 2). However, much of the water treatment and distribution infrastructure in California was constructed prior to the 1940s, and now needs repair or replacement (American Society of Civil Engineers, 2019). Another important factor to consider in planning is that the dynamic and corrosive nature of coastal environments can cause infrastructure failure before nationwide lifespan averages (Azevedo de Almeida and Mostafavi, 2016).

36 Affordable water is critical for people on limited incomes and is a critical component in the state's Human Right to Water strategy that identifies access to safe, clean, and affordable drinking water as a public health imperative.

Wastewater Treatment Infrastructure

Table 2. Expected life of wastewater treatment infrastructure components. (Source: U.S. EPA 2002 *Clean Water and Drinking Water Infrastructure Gap Analysis*). Note, range of useful life does not reflect how corrosive coastal environments may reduce expected lifespan of infrastructure components as sea level rises.

Component	Useful Life (Years)
Collections	80-100
Treatment plants – concrete structures	50
Treatment plants – mechanical & electrical	15-25
Force mains	25
Pumping stations – concrete structures	50
Pumping stations – mechanical & electrical	15
Interceptors	90-100

Stormwater Infrastructure

The inherent variability of stormwater control measures results in a large variability in their expected lifespans. For example, the expected useful life for an infiltration trench is 10 years (Port of San Francisco and San Francisco Public Utilities Commission 2016), and permeable pavement systems are expected to persist for 15-20 years (EPA 2008). Depending on the level of service and maintenance, the expected useful life of catch basins and detention basins could range from 50-100 years, and the expected useful life of culverts and outfalls could range from 75-150 years (Sacramento State Environmental Finance Center 2019).

In addition, frequent inspection and maintenance is required for on-site infiltration and treatment control measures, with the frequency (e.g., weekly, monthly, quarterly, annually, or every 3-5 years) depending on the type of stormwater control measure (EPA 2015).

Water Supply Infrastructure

Similar to many wastewater system components, drinking water infrastructure faces a growing need for updates or maintenance of water mains, water service lines, filtration plants, and pumps (Table 3). Today, there is a particular need to rehabilitate old infrastructure, especially that of transmission and distribution lines, as leaky pipes are estimated to waste 14 to 18 percent of treated drinking water every day across the nation (EPA 2018).

Table 3. Expected life of water supply infrastructure components (Source: State Water Resources Control Board Typical Equipment Life Expectancy Table). Note, ranges of useful life do not reflect expectations of increasingly corrosive coastal environments as sea level rises.

Component	Useful Life (Years)
Intake Structures	35 – 45
Wells and Springs	25 – 35
Galleries and Tunnels	30 – 40
Transmission mains	35 – 40
Reservoirs and Tanks	30 – 60
Mains & Distribution Pipes	35 – 40
Hydrants	40 – 60
Treatment Plant Equipment	10 – 15

Designing for Coastal Resource Protection

The design, maintenance, repair, and long-term resilience of a community's water infrastructure is critical because it provides necessary water supplies, reduces flood risks to development, collects and treats wastewater to protect public health and the environment, and generally includes design features to protect water quality and water supplies.

The services provided by water infrastructure align with the resource protection and hazards policies of the Coastal Act by attenuating flood hazards and collecting and treating wastewater in a manner generally protective of coastal water bodies and water quality. In addition to the service aligning with the Coastal Act, the design of the water infrastructure facilities themselves must be consistent with the hazards and resource protection policies of the Coastal Act. In general, the Coastal Act requires that development be sited and designed so that it will not have significant adverse effects, either individually or cumulatively, on coastal resources. Coastal resources directly relevant to water infrastructure include (but are not limited to) watercourses (e.g., rivers, streams, creeks), water bodies (e.g., wetlands, estuaries, lakes), groundwater resources, water quality, and sensitive habitats. Siting and design of water infrastructure may also impact public access and scenic and cultural resources.

Given the inherent spatial and facility diversity, water infrastructure has the potential to adversely impact coastal resources. Water infrastructure may be located in or adjacent to habitat or recreational areas and may also adversely impact coastal resources by reducing groundwater recharge rates, impairing the biological productivity of wetland and aquatic habitats, and adding sediment or pollutant loads to coastal waters. When protected from hazards with hard shoreline protective devices like seawalls, additional impacts on habitats will occur as they are squeezed between rising seas and hardened backshores. However, if infrastructure erodes or floods, water quality can be degraded.

Water quality impacts are of paramount concern in the context of long-term planning for water infrastructure, particularly where the water infrastructure discharges into natural drainageways (e.g., creeks, lagoons, sloughs, bays, or the ocean). Coastal receiving waters and adjacent habitats may be adversely impacted depending on the treatment and quality of the discharged water.

The Coastal Commission has developed guidance for local governments on developing the water quality protection elements of an LCP's LUP and IP. The Commission's water quality guidance includes a set of model policies and standards intended to minimize adverse water quality and hydrologic impacts to coastal water resources, both during construction and over the life of a project (see the *Model LCP Water Quality Guidance*). Additional information can be found in the "Water Quality Protection" chapter of the Coastal Commission's *LCP Update Guide*. While these guidance documents are not specific to sea level rise planning, many of the recommendations for coastal water resource protection strategies are applicable. For example, the guidance on Post-Development Runoff Plans recommends giving precedence to a Low Impact Development (LID) approach to stormwater management and recommends the use of alternative runoff control measures where on-site infiltration is not appropriate or feasible. These measures will become even more important as sea level rises.

Wastewater Infrastructure

To address the sea level rise vulnerability of large-scale infrastructure projects such as wastewater treatment plants, the Coastal Commission generally requires as part of its review that project proponents identify the predicted effects of sea level rise during the expected operating life of the facility and identify how the project will avoid, minimize and/or mitigate those adverse effects. Long-term planning, including life expectancy analysis, is an important first step for wastewater treatment plants that will most likely require phased approaches to adaptation.

Many of these facilities will rely on protection or accommodation measures in the near-term, but some of these approaches will not be sufficient or consistent with the Coastal Act, depending on the context and especially over long-term planning horizons. In places where reliable performance is not sustainable, or protection strategies are not consistent with the Coastal Act due to coastal hazards such as erosion, flooding, or saltwater intrusion, long-term plans should explore relocation alternatives. Identifying necessary alternative sites for treatment plants is consistent with Coastal Act Section 30412(d), which requires the Coastal Commission to require reservations of sites for the construction of treatment works and discharge points that are adequate for the protection of coastal resources.

In past actions, the Coastal Commission has addressed the long-term planning for wastewater treatment plants. The development of phased-adaptation approaches to date has been through limited-term permits. For example, the Coastal Commission's coastal development permit (CDP) for South San Luis Obispo County Sanitation District's Wastewater Treatment Plant (WWTP) in May 2017 identified a long-term path forward for moving the WWTP out of the way of coastal hazard risks. The CDP authorized installation of South San Luis Obispo County Sanitation District's redundancy equipment and other related development, including flood-proofing, to address immediate water quality risks. It also conditioned approval on a hazard monitoring plan that included: (1) regularly monitoring flood and other coastal hazards at the site, and implementing management responses to those hazards both on and off-site (e.g., lagoon management and levee expansion); (2) identifying how those hazards are impacting the operations of the WWTP; (3) identifying changes necessary to allow continued appropriate and required functioning of the plant; and (4) identifying flood/hazard 'triggers' to establish when actions (such as retrofits, upgrades, and plant relocation) need to be pursued in response to specific flood/hazard events or flood management activities.

In some cases, the Coastal Commission has denied permits for wastewater treatment plant improvement projects due to hazards. For instance, in 2013, the Coastal Commission denied a permit for redevelopment of the Morro Bay Wastewater Treatment Plant in its existing location just inland of the beach, in part due to unavoidable coastal hazards at the site (see Appendix E). The Coastal Commission found the proposed project was inconsistent with the City's LCP, including policies related to allowable uses and land use priorities, hazard avoidance and response, sustainable public infrastructure, and public viewshed protection. The City and its WWTP partner, the Cayucos Sanitary District, then embarked on an analysis of potential alternatives designed to move these critical municipal functions out of harm's way. Ultimately, in 2019 the Coastal Commission voted unanimously to approve a new wastewater treatment and water reclamation facility in Morro Bay located more than 3 miles inland of the old site, and for the decommissioning, removal, and restoration of the existing site adjacent to the beach.

Image 13. Arcata Wastewater Treatment Plant in Humbolt County. Photo by the California King Tides Project.

Stormwater Infrastructure

Strategies to maintain the function of stormwater infrastructure under a changing climate will depend on the local geomorphology and the types of hazards. In low-lying areas, communities will need to plan for drainage to avoid flooding, especially if sea level rise, storm surge, waves, or high tides heighten flood risk. Communities relying on stormwater infiltration might also need to modify or relocate stormwater measures if rising groundwater or saltwater intrusion from sea level rise reduces their effectiveness. In areas where bluff erosion is a concern, especially as sea level rise and wave action increase erosion rates, stormwater runoff might need to be diverted inland if infiltration would contribute to bluff instability. In places reliant on tide gates, rising sea levels will reduce tidal influence and stormwater drainage into the ocean will be difficult without additional pumping capacity.

By considering sea level rise in individual site and community-wide stormwater management plans and actions, communities can ensure appropriate designs and locations for stormwater infrastructure. Stormwater management facilities (structural measures, pipes, tide gates, etc.) should be sized and designed to function under projected future conditions over the anticipated life of the development given projected sea level rise. Regarding existing stormwater management facilities, in some cases, communities will need to increase maintenance frequencies or retrofit components. Communities might need to reconfigure stormwater collection systems and outfalls based on changing conditions as well.

Another strategy for reducing risk to stormwater systems is reducing runoff that might intensify flooding in areas vulnerable to sea level rise. A low impact development (LID) approach to stormwater management has the goal of replicating the natural water balance through infiltration, evapotranspiration, capturing for later use, detention, or retention of stormwater close to where it falls. LID is an effective strategy to reduce runoff flows and can also be used to recharge aquifers. For example, the Los Angeles Department of Water and Power and its partners actively capture and recharge approximately 29,000 acre-feet per year of stormwater. According to the Los Angeles Department of Water and Power Stormwater Capture Master Plan, the potential exists for local stormwater capture through LID projects (e.g., centralized facilities like spreading grounds and distributed stormwater best management practices including rain barrels and cisterns, permeable pavers, rain gardens, bioswales, and infiltration basins beneath street medians and parkways) to store 150,000 acre-feet of rainwater per year by 2035. By prioritizing the use of LID strategies, local governments can reduce stormwater runoff volumes and peak flow rates, preventing flooding caused by impaired stormwater drainage associated with sea level rise.

Image 14. Stormwater infrastructure in Monterey County. Photo by Doug McKnight.

Water Supply and Reuse

An important element of building climate change resilience in California is developing multiple sources of water supply. While not all climate change threats to water infrastructure relate to sea level rise, water resilience projects in the coastal zone can provide valuable benefits in addition to preparing for sea level rise, potentially yielding improved ecosystem health, water quality, flood protection, and water supply.[37] Governor Newsom's Executive Order N-10-19 directs state agencies to identify and assess a suite of complementary actions to ensure safe and resilient water supplies, flood protection and healthy waterways for the state's communities, economy, and environment. Water resilience projects will reflect unique constraints and opportunities based on the region, and many include water recycling or reuse. For example, the new water reclamation facility approved in Morro Bay described in Appendix E includes new wells for groundwater injection/replenishment and potable reuse to maximize the long-term health and sustainability of groundwater and surface water and related resources as much as possible, including with respect to potential sea level rise and increased saltwater intrusion.

California is widely recognized as a national leader in water recycling. The State Water Board's Recycled Water Policy (effective April 8, 2019) includes numeric goals for the use of recycled water and narrative goals for recycled water use in groundwater depleted and coastal areas. By reusing wastewater and graywater, water supply can be enhanced and made more resilient to drought conditions. The purpose for the reused water may vary—for example, it can be used for landscaping, to flush toilets, agriculture, aquifer storage and recovery, groundwater recharge to fight saltwater intrusion, or water conservation—and many communities are studying and/or applying these options (e.g., the cities of San Diego, Los Angeles, Watsonville, Santa Cruz, Carmel, Cayucos, and Morro Bay). Another benefit of water reuse is to address saltwater intrusion by injecting treated wastewater into aquifers to protect potable groundwater. Capturing stormwater runoff (*e.g.*, using rain barrels or cisterns) for later on-site use (such as watering landscaping or flushing toilets) is another potential water conservation strategy. The state is encouraging investments in these types of climate resiliency projects to create a water resilience portfolio.

Nature-Based Adaptation Strategies for Water Infrastructure

Nature-based adaptation strategies are designed to enhance or restore natural processes while providing protection benefits such as erosion and flood risk reduction. These strategies include hybrid armoring approaches, in which natural systems are restored or enhanced in combination with constructed features such as marsh sills, buried revetments, and cobble berms. Nature-based adaptation strategies may have lower life cycle costs, provide more benefits to communities and ecosystems, and be more adaptable over time than other alternatives.

37 The 2018 update to the California Water Plan laid out a vision of managing water resources for sustainability that calls for integration of water resources to maintain surface and groundwater supply, water quality, flood protection, and the environment.

Some communities have also used nature-based adaptation strategies for treating pollutants. For example, the City of Arcata developed the Arcata Marsh and Wildlife Sanctuary to treat sewage using a treatment system of wetlands and oxidation ponds. These methods can provide remarkable cost savings compared with traditional artificial treatment systems, but sea level rise poses a new threat to such low-lying facilities (Bovarnick, Polefka, and Bhattacharyya, 2014).

In some locations, instead of using seawalls or revetments, dune restoration or wetland construction could provide backshore protection against erosion and flooding. For example, in February 2021 the Coastal Commission approved sand nourishment and a vegetated dune to protect and restore a severely eroded shoreline area associated with the Pillar Point Harbor's West Trail, where stormwater drainage improvements would allow for removal of an existing shoreline outfall and redirection of filtered stormwater to portions of Pillar Point Marsh to help enhance terrestrial-wetland transition zones.

There is an urgent need for more pilot projects in California to create opportunities for research to understand the efficacy of nature-based adaptation strategies and to explore opportunities for supporting habitat as sea levels rise. These projects require careful consideration to comply with Coastal Act policies protecting existing habitats as well as public access. NOAA, the U.S. EPA, the U.S. Army Corps of Engineers, and several other institutions have released guidance documents encouraging the use of natural systems in coastal management.[38] A companion study for the California Fourth Climate Assessment also provides guidance and case studies about where certain types of nature-based adaptation strategies could be used, along with providing high-level blueprints (Newkirk *et al.,* 2018).

Adaptation Challenges

Physical Constraints

Wastewater and stormwater drainage systems[39] have historically relied on gravity to move water in the system, and these systems often discharge into waterways such as the ocean. While gravity flow may be a common design method for conveyance of wastewater and stormwater systems, such systems can use alternative components such as pressurized pipes for constrained locations, and pumping otherwise, including where necessary to avoid hazardous coastal areas. In addition, future technology innovations and actions to reduce wastewater effluent could reduce location constraints on wastewater systems (Ewing, 2014).

38 NOAA provides trainings green infrastructure; see NOAA's Office for Coastal Management's Digital Coast Training webpage. The U.S. EPA provides a range of tools and resources on their Green Infrastructure webpage and Green Infrastructure/Coastal Resiliency webpage. The U.S. Army Corps of Engineers provides resources on their Engineering with Nature webpage.

39 Note that while on-site wastewater treatment, or individual septic systems, can also post water quality threats when not properly maintained, most waste from septic systems in California is pumped out and hauled to publicly-owned treatment plants. Even when well maintained, on-site wastewater treatment systems can face flood and tsunami risk or fail as groundwater rises with sea level (ASCE 2019).

In the case of stormwater management, constraints on the suitability or infiltration capacity of stormwater components may require new sites to be considered. LCPs can address the need to revisit siting constraints with triggers and set new design standards for infrastructure components in areas subject to sea level rise-related flooding or groundwater rise.

Adaptation Effects on Coastal Resources

Adaptation strategies are intended to provide effective solutions to reduce the risks to critical infrastructure from coastal hazards. However, adaptation measures are themselves *new development* that must be reviewed for their potential to adversely impact coastal resources and their consistency with the Coastal Act and LCPs. Figure 9 conceptually demonstrates how adjustments to infrastructure systems also affect coastal waters. Adaptation strategies that limit the amount of pollutants that enter coastal waters through stormwater runoff and wastewater discharges can also have other impacts on coastal resources. For example, protective structures for infrastructure might eliminate beach habitat or block public access to the shoreline.

Planners need to consider how adaptation strategies affect other coastal resources. Thus, adaptation planning in LCPs must go through a careful process of review to ensure that the proposed adaptation measures are consistent with the Coastal Act. This review would need to consider consistency with policies regarding coastal hazards (Section 30235 and 30253), Environmentally Sensitive Habitat Areas (Section 30240), marine resources and water quality (Section 30230-30231), and other relevant Coastal Act policies. See Appendix A for more detail on these Coastal Act policies.

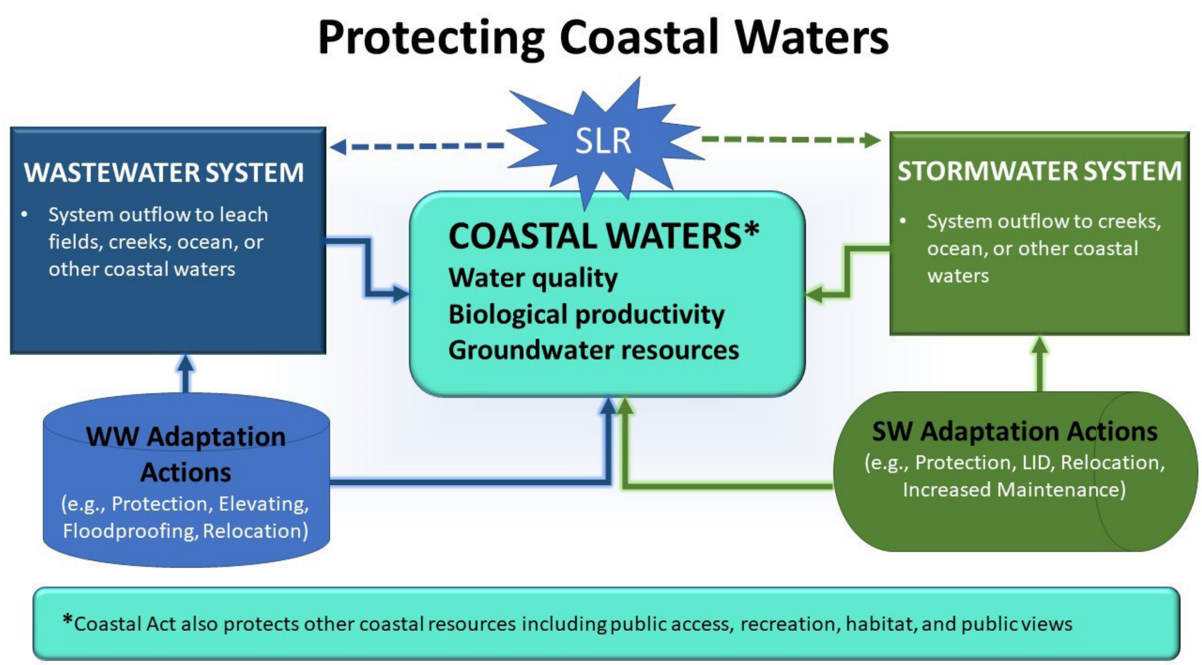


Figure 9. Conceptual diagram of sea level rise impacts, adaptation actions, and coastal waters.

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APPENDICES

APPENDIX A.
Relevant Coastal Act Policies

Like all coastal development, decisions made regarding critical infrastructure will need to fulfill the requirements of the Coastal Act. This includes all decisions made regarding the siting and design of new critical infrastructure; the repair and maintenance activities for current critical infrastructure, including replacement or upgrades of individual sections or components of current infrastructure; and the adaptation strategies designed to address current or future vulnerabilities related to coastal hazards and sea level rise for critical infrastructure. Taken together, the Chapter 3 policies of the Coastal Act mandate protection, maintenance, and where feasible, enhancement and restoration of coastal resources including public access, recreation, marine environments, water quality, land resources, public views, and safe development. Additionally, the Coastal Act also mandates the evaluation of environmental justice issues in all permit decisions. LCP policies for critical infrastructure and adaptation strategies to address sea level rise will also need to implement the coastal resource protection, environmental justice considerations, and safe development policies of the Coastal Act. Key Coastal Act policies with relevance for critical infrastructure and sea level rise adaptation are discussed in this section.

PUBLIC ACCESS AND RECREATION

Sections 30210-30214 and 30220-30224 address public access and recreation. These policies mandate that maximum access and recreational opportunities shall be provided consistent with public safety needs, public and private property rights, and protection of natural resources. Further, these policies require, in part, that development shall not interfere with access, that new development shall provide access to the shoreline and along the coast, and that suitable coastal areas and oceanfront lands should be protected for recreational and water-oriented activities.

Decision-making regarding transportation infrastructure in particular should account for protecting access to and along the coast. Importantly though, adaptation strategies that rely on armoring or otherwise protecting development in place, including the roadways that provide access, will limit the ability of beaches and recreational areas to move inland as sea levels rise, thus resulting in an overall loss of public access and recreational areas along the shoreline. Long-term planning for critical infrastructure will need to account for public access to the coast now and in the future, including as sea levels rise.

MARINE ENVIRONMENT

Sections 30230 through 30236 address protection of marine environments and water quality, broadly requiring maintenance, enhancement, and, where feasible, restoration of marine habitats and protection of marine species. These policies relate to the need for adaptation to address vulnerabilities – for example to avoid any impacts to water quality as a result of damage to wastewater and other types of critical infrastructure – and dictate the types of adaptation strategies that will be allowable. In particular, adaptation strategies that may result in negative impacts either immediately, such as fill of wetlands, or in the future, such as armoring that prevents the migration of marine habitats as sea levels rise, will need to be carefully considered.

Sections 30230 and 30231 of the Coastal Act address marine resources, water quality protection goals, and protection of the long-term biological productivity of coastal waters. Siting and design of critical infrastructure will need to both avoid immediate impacts to marine resources and consider how the presence of development could impact the long-term health of marine resources, including as they naturally change as sea levels rise. Similarly, adaptation strategies that address existing critical infrastructure vulnerabilities should evaluate the implications of maintaining such infrastructure in its current hazardous location and how that may impact marine resources. Alternative adaptation strategies that rely on “green” options such as nature-based adaptation strategies may align with these marine resource protection policies, though such strategies will still need to evaluate the chance for unintended consequences. Sections 30230 and 30231 state:

> **Section 30230:** 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:** 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 limits fill in coastal waters except in certain circumstances, and only where there is no less environmentally damaging feasible alternative. In general, this policy would disallow placement of rock or other materials as a shoreline device meant to protect critical infrastructure, though dune restoration, beach nourishment, or other nature-based infrastructure or living shorelines may qualify as permitted restoration activities. Section 30235 (described below) may also allow for some fill in specific circumstances. Section 30233 states, in part:

> (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:
>
> > (1) New or expanded port, energy, and coastal-dependent industrial facilities, including commercial fishing facilities.
> >
> > […]
> >
> > (4) Incidental public service purposes, including, but not limited to, burying cables and pipes or inspection of piers and maintenance of existing intake and outfall lines.
> >
> > […]
> >
> > (6) Restoration purposes.
> >
> > (7) Nature study, aquaculture, or similar resource-dependent activities.

Section 30235 limits the use of shoreline protective devices to only a narrow set of circumstances, including where necessary to serve coastal dependent uses or to protect existing structures or public beaches in danger of erosion. As described in the Coastal Commission's Sea Level Rise Policy Guidance (2018), the Commission interprets the term "existing", as used in this policy, as meaning structures that were in existence on January 1, 1977 – the effective date of the Coastal Act. Taken together with Section 30253, which requires new development to be sited and designed to minimize risks from hazards without in any way requiring construction of armoring, Section 30235 essentially "grandfathers" protection for development that predates the Coastal Act. Section 30235 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 also relates to measures to address coastal hazards, specifically addressing the circumstances in which river and stream alterations are allowed. As with Section 30235, the Commission interprets the term "existing" in this policy as meaning structures in existence on January 1, 1977. This section states:

> Channelizations, dams, or other substantial alterations of rivers and streams shall incorporate the best mitigation measures feasible, and be limited to (1) necessary water supply projects, (2) flood control projects where no other method for protecting existing structures in the floodplain 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.

LAND RESOURCES

Sections 30240 through 30244 address protection of land resources including environmentally sensitive habitat areas (ESHA), agricultural lands, and archaeological and paleontological resources. As with the marine environment section, these policies provide limitations to allowable development, including the types of adaptation strategies that may be used to address sea level rise vulnerabilities. As sea levels rise, resulting in changes to habitat areas and agricultural lands, these policies may also influence decision-making regarding certain land uses and critical infrastructure needs.

Section 30240 addresses protection of ESHA, requiring development to prevent significant degradations and to allow for continuance of those areas in the future. Because development, and any armoring that protects development, would limit the natural migration of habitat as sea levels rise, this policy affects decisions regarding siting and design of critical infrastructure as well as the adaptation strategies to address infrastructure vulnerabilities. Section 30240 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.

Section 30241 of the Coastal Act requires the maximum amount of prime agricultural land to be maintained in agricultural production and Section 30242 limits the conversion of lands suitable for agriculture to non-agricultural purposes unless agricultural use is not feasible or unless such conversion would preserve prime agricultural lands or concentrate development. In several locations throughout the Coastal Zone, agricultural lands are vulnerable to sea level rise but currently protected by transportation infrastructure (such as Highway 101 in Humboldt Bay). Adaptation strategies for this and similar areas will need to consider how to balance the short- and long-term impacts associated with damage to critical infrastructure, wetland migration, and impacts to agricultural lands.

Development

Sections 30250 through 30255 address development considerations. These policies require minimization of risks to new development, protection of scenic and visual qualities, maintenance and enhancement of public access, and prioritization of coastal-dependent development.

Section 30250 generally requires new residential development to be located within or close to existing developed areas or areas with adequate public services and where it will not result in adverse impacts to coastal resources. As sea level rise impacts communities and coastal resources over time, critical infrastructure will also need to change to continue serving community needs.

Section 30251 requires the scenic and visual qualities of coastal areas to be protected as a resource of public importance. This policy also requires permitted development to minimize alteration of natural landforms. Adaptation strategies such as armoring or elevation will need to evaluate and minimize any impacts to scenic and visual resources.

Section 30253 requires new development to minimize adverse impacts to a variety of resources. Notably, this policy requires development to be safe from hazards without requiring construction of protective devices. In light of sea level rise, this policy means that new development must be sited and designed considering current and future inundation and storm flooding impacts, seasonal and long-term shoreline and bluff erosion, and changing groundwater dynamics over the life of the proposed development. Section 30253 states:

> 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.
>
> (c) Be consistent with requirements imposed by an air pollution control district or the State Air Resources Board as to each particular development.
>
> (d) Minimize energy consumption and vehicle miles traveled.
>
> (e) Where appropriate, protect special communities and neighborhoods that, because of their unique characteristics, are popular visitor destination points for recreational uses.

Section 30254 relates specifically to public works facilities, which include some critical infrastructure, and generally states that new or expanded facilities should not induce development but rather should be limited to accommodate the needs of development permitted consistent with the Coastal Act. Like Section 30250, decisions made regarding critical infrastructure consistent with this policy should consider changing community needs in response to sea level rise. Section 30254 states:

> New or expanded public works facilities shall be designed and limited to accommodate needs generated by development or uses permitted consistent with the provisions of this division; provided, however, that it is the intent of the Legislature that State Highway Route 1 in rural areas of the coastal zone remain a scenic two-lane road. Special districts shall not be formed or expanded except where assessment for, and provision of, the service would not induce new development inconsistent with this division. Where existing or planned public works facilities can accommodate only a limited amount of new development, services to coastal-dependent land use, essential public services, and basic industries vital to the economic health of the region, state, or nation, public recreation, commercial recreation, and visitor-serving land uses shall not be precluded by other development.

OTHER PUBLIC WORKS POLICIES

In addition to the Chapter 3 policies of the Coastal Act that provide the standard of review for LCP adequacy and permissibility of proposed development, several other Coastal Act policies relate to critical infrastructure.

Section 30412 provides guidance on implementation of the Coastal Act in relation to the programs of the State Water Resources Control Board and Regional Boards. This section clarifies that the intent of the Coastal Act is not to change the authority of other state agencies, and specifies that rather than setting standards for water quality treatment, discharge, and use, the Coastal Commission's review of wastewater treatment plants is limited to questions of siting, visual impacts, and appropriateness of service areas. In practice, this has meant that the Commission defers to the State and Regional Water Boards for setting water quality effluent standards and itself reviews a proposed project's land use elements to ensure consistency with the Coastal Act's coastal resource protection requirements. Section 30412 states, in part:

> (b) The State Water Resources Control Board and the California regional water quality control boards are the state agencies with primary responsibility for the coordination and control of water quality. The State Water Resources Control Board has primary responsibility for the administration of water rights pursuant to applicable law. The commission shall assure that proposed development and local coastal programs shall not frustrate this section. The commission shall not, except as provided in subdivision (c), modify, adopt conditions, or take any action in conflict with any determination by the State Water Resources Control Board or any California regional water quality control board in matters relating to water quality or the administration of water rights.
>
> Except as provided in this section, nothing herein shall be interpreted in any way either as prohibiting or limiting the commission, local government, or port governing body from exercising the regulatory controls over development pursuant to this division in a manner necessary to carry out this division.

(c) Any development within the coastal zone or outside the coastal zone which provides service to any area within the coastal zone that constitutes a treatment work shall be reviewed by the commission and any permit it issues, if any, shall be determinative only with respect to the following aspects of the development:

(1) The siting and visual appearance of treatment works within the coastal zone.

(2) The geographic limits of service areas within the coastal zone which are to be served by particular treatment works and the timing of the use of capacity of treatment works for those service areas to allow for phasing of development and use of facilities consistent with this division.

(3) Development projections which determine the sizing of treatment works for providing service within the coastal zone.

The commission shall make these determinations in accordance with the policies of this division and shall make its final determination on a permit application for a treatment work prior to the final approval by the State Water Resources Control Board for the funding of such treatment works. Except as specifically provided in this subdivision, the decisions of the State Water Resources Control Board relative to the construction of treatment works shall be final and binding upon the commission.

Section 30605 lays out provisions for development of Public Works Plans (PWPs) as a means to promote efficiency and to avoid project-by-project permit review. Instead, PWPs lay out proposed projects that are reviewed by the Commission for consistency with Chapter 3 policies (or the relevant certified LCP). Once a PWP is certified, any subsequent review of specific projects contained in the PWP is limited to imposing conditions. In this way, PWPs may be helpful tools for identifying, laying out, and then implementing specific sea level rise adaptation strategies for a critical facility. Section 30605 of the Coastal Act states, in part:

To promote greater efficiency for the planning of any public works […] projects, and as an alternative to project-by-project review, plans for public works […] may be submitted to the commission for review in the same manner prescribed for the review of local coastal programs as set forth in Chapter 6 (commencing with Section 30500). […]

Public Works, as defined in Coastal Act Section 30114, 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 […]

ENVIRONMENTAL JUSTICE AND PUBLIC PARTICIPATION

Coastal Act Section 30604(h) allows the Coastal Commission or the issuing agency to consider environmental justice implications when acting on a coastal development permit. The Commission has also adopted an *Environmental Justice Policy* to guide and inform its implementation of Section 30604(h) in a manner that is fully consistent with the standards and goals of Chapter 3 of the Coastal Act and certified LCPs.

Section 30107.3 defines environmental justice to include:

> […] the fair treatment and meaningful involvement of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.

Together, these sections describe how the Commission will work to ensure equitable access to the coast, work with disadvantaged communities to promote their meaningful participation in the decision-making process, and ensure that disadvantaged communities are not disproportionately affected by the development of critical infrastructure.

APPENDIX B.

Model Policies

INTRODUCTION TO MODEL POLICIES

This appendix includes model language for policies related to transportation infrastructure and water infrastructure separately below.

Given the critically important functions of transportation infrastructure, it is imperative that Local Coastal Programs (LCPs) include policies that address the vulnerabilities of such infrastructure to sea level rise. By approaching planning processes in a collaborative, cross-jurisdictional way that includes all relevant stakeholders and related transportation planning documents, LCPs can fit into a statewide framework that ensures protection of coastal resources and consistency with the Coastal Act as sea levels rise while also addressing other priority issues like reducing vehicle miles traveled and greenhouse gas emissions, promoting multi-model transportation and complete streets, and ensuring the fundamental safety of infrastructure. Long-term, phased planning approaches that consider how transportation networks fit into wider land use contexts will be critical tools for successfully implementing sea level rise adaptation over time. The discussion and model policies in this appendix are meant to serve as a tool and guidance to local governments and partner agencies and organizations as they undertake these planning processes.

In addition, while California continues to advance in use of technologies for treating and discharging/reusing wastewater, managing stormwater at higher water quality standards, and protecting groundwater, there is growing awareness of risks to existing systems due to deferred maintenance and changing climate conditions. Given the significant populations both inside and outside of coastal hazard areas that are dependent on vulnerable water infrastructure, the significant investments and long-term planning horizons involved with system upgrades, and the significant coastal resource and social impacts of failing to adapt, it is imperative that local governments undertake comprehensive sea level rise planning for water infrastructure. Planning for sea level rise offers opportunities to safeguard coastal resources while providing resilient water infrastructure that can maintain public services as sea level rises.

Please note that these model policies are offered as a tool for local governments that wish to use them. They are meant to serve as ideas or starting points from which to develop policies appropriate for local conditions. They are *not* a checklist of items the Coastal Commission would expect to see in an LCP. Words like "shall" are used in model policies because they are examples of how LCP policies would be written in cases where the local government determines it is necessary to require a particular development standard. The model policies could be rewritten in any number of ways to account for local conditions and priorities, provided that they are still consistent with the Coastal Act. For example, local governments could change "shall" to "should" if warranted, along with any other wording and subject matter changes that are appropriate for the jurisdiction.

MODEL POLICIES FOR TRANSPORTATION INFRASTRUCTURE

There is no single approach for adapting transportation infrastructure to sea level rise. In many cases it will be appropriate to use a range of adaptation strategies that are applied over time in phases, and the phased strategies will depend on the specific physical situation, coastal resource implications, and community needs. However, every community should consider the following principles in their LCP:

- Approach sea level rise adaptation planning for transportation infrastructure through collaborative regional planning processes that bring together all relevant partners and stakeholders.
- Coordinate land use planning documents (e.g., LCPs, Local Hazard Mitigation Plans, General Plans, Public Works Plans, Capital Improvement Plans) and transportation planning documents (See Appendix H) so that they provide a cohesive approach to sea level rise adaptation.
- Consider planning tools such as Public Works Plans (PWPs) to lay out and coordinate cross-jurisdictional projects necessary to implement a sea level rise adaptation plan.
- Address disproportionate burdens and benefits to environmental justice communities and incorporate meaningful engagement practices and equitable public participation processes throughout the entire planning process.
- Use the best available science and sea level rise projections to evaluate transportation infrastructure in vulnerability assessments.

- Conduct long-term vulnerability assessments and adaptation planning to assess potential impacts of hazards, the feasibility and the social, environmental, and economic costs of adaptation strategy alternatives over time, and triggers for phased adaptation.
- Initiate adaptation planning efforts before impacts from coastal hazards begin to occur.
- Consider network connections of transportation infrastructure and the impacts that disruption from sea level rise would have systemwide.
- Prioritize siting infrastructure to avoid hazards, and where hazard avoidance is not feasible, prioritize nature-based adaptation strategies over hard shoreline armoring. When hard shoreline armoring is used, require mitigation for adverse coastal resource impacts and long-term planning to identify a long-term solution that is most protective of coastal resources.
- Consider phased, trigger-based solutions and adaptation pathways.
- Prioritize multiple benefits from projects, such as reducing greenhouse gases (GHG), encouraging multimodal transportation, and enhancing public access to the shoreline.

Local governments should add or update LCP policies related to coastal hazards and transportation at the same time as they work to meet state and regional transportation planning requirements related to climate change. LCPs should include sea level rise planning strategies that protect public access and other coastal resources while minimizing hazards, consistent with the Coastal Act. The following model policies are provided as a tool to assist local governments in developing their own LCP policies that support sea level rise adaptation for the transportation infrastructure in their jurisdictions. Using the model policies, where relevant, can help ensure Coastal Act consistency, but jurisdictions remain free to modify the policies or develop different policies, so long as they remain consistent with the Coastal Act.

The model policies and chosen adaptation pathways for a particular location will depend on the local jurisdiction’s unique context, priorities, goals, public input, geography, and other factors. Not all of the following policies would apply in a given context. In addition, some policies are duplicative in nature; however, they are provided here to give local governments multiple language options that convey similar policy concepts. While many of the policies apply to any transportation infrastructure type, some may apply only to highway or roadway infrastructure, and others apply solely to railway infrastructure.

Planning Process

1. **Long-Term Transportation Planning**. [Insert name of local government] shall coordinate with [Caltrans and/or relevant transportation agencies/asset managers] and other relevant state, regional, and local transportation planning entities on long-term, corridor-wide planning for adaptation to sea level rise and coastal hazards, including, but not limited to, through the development of new or updated District System Management Plans, Corridor Plans, the State Highway System Management Plan, Transportation Concept Reports, Regional Transportation Plans, Sustainable Communities Strategies, the California State Rail Plan, Regional Rail Plans, Local Coastal Programs, and Circulation Elements/General Plans. Such planning should do all of the following:

- » Account for the relationship between transportation infrastructure and land use and development patterns (such as utility infrastructure), particularly from a whole-corridor perspective, and the need for both land uses and transportation infrastructure to jointly adapt to sea level rise impacts.
- » Consider a full suite of potential adaptation strategies, including nature-based adaptation strategies, adaptive management strategies, realignment, elevation, and short-term use of shoreline protective devices. Plans should consider these strategies to the level of detail appropriate for the document, and should be developed further as subsequent plans and projects are developed.
- » Account for multimodal transportation and other relevant transportation goals including Active Transportation (e.g., Complete Streets), GHG emission reduction targets and efforts, and Sustainable Communities initiatives.

2. **Advance Planning for Transportation Infrastructure.** Segments of transportation infrastructure that are vulnerable or that are expected to become vulnerable to coastal hazards, including those associated with sea level rise, shall be identified in time to plan, fund, and implement adaptation projects before significant impacts to coastal resources and public safety occur. [Insert name of local government] shall work with Caltrans and other transportation asset owners and managers to conduct such advance planning in order to avoid the need for emergency shoreline protective devices, to protect coastal resources, and to provide enough time to complete comprehensive planning and implementation processes.
3. **Adaptation Strategy Alternatives.** When developing sea level rise adaptation plans and specific projects, a full suite of potential adaptation strategy alternatives shall be considered, including nature-based adaptation strategies, active management strategies, relocation, elevation, and short- or potentially longer-term use of armoring (and/or combinations of such strategies). In general, strategies that avoid hazards related to sea level rise, such as relocation or elevation, shall be prioritized, and nature-based adaptation strategies that minimize impacts to coastal resources and provide measurable environmental benefits shall be employed as feasible to protect existing infrastructure and allow phased long-term adaptation. In all cases, the selected strategy shall:

- » Maximize protection of coastal resources, including public access, recreation, marine and terrestrial resources, and visual resources;
- » Ensure safety and stability of infrastructure;
- » Minimize vehicle miles traveled to the extent feasible;
- » Avoid or mitigate project burdens to the maximum extent feasible in environmental justice communities; and
- » Adapt transportation service to meet shifting community needs over time.

Adaptation strategies shall, to the extent feasible, address the potential impacts of sea level rise on transportation infrastructure before they begin to occur and shall incorporate appropriate periods of lead time that allow for planning, funding, and implementation. Potential shifts of some portion of existing highway traffic to other modes of travel (including safely sited rail systems) should also be included in alternatives analyses. Any fiscal analysis performed as part of an alternatives analysis, including an analysis of the "no project" alternative, shall estimate the anticipated future costs caused by increased coastal hazards, if applicable, including from damage to facilities, need for upgrades, and loss of recreational areas, habitats, and natural protective features.

4. **Phased Adaptation.** Phased and trigger-based adaptation measures will be considered when planning for the adaptation of transportation infrastructure to sea level rise impacts over time. Phased measures may include hard shoreline protective devices for limited periods of time, elevation, and/or relocation, if otherwise consistent with relevant LCP and, if applicable, Coastal Act policies. Phases shall be designed to address expected amounts of sea level rise and associated impacts while avoiding or minimizing impacts to coastal resources, and specific triggers shall be identified after which each subsequent phase shall be implemented. The entire phased approach should be designed to minimize impacts to access and mobility as well as to environmental, recreational, and public access resources over the planning horizon.

5. **Planning for New or Expanded Transportation Infrastructure and Development**. New and expanded transportation infrastructure shall be designed to accommodate and serve development and uses that are consistent with the Coastal Act and LCP, including provisions regarding safety from coastal hazards. Such new and expanded transportation infrastructure should not encourage development in vulnerable areas; rather, it should encourage development in areas safe from sea level rise and coastal hazards. [Insert name of local government] shall ensure consistency between land use and transportation planning by prioritizing network-scale vulnerability assessments and appropriate land use planning before committing to potential expansion or replacement of transportation infrastructure in vulnerable areas. No new or expanded transportation infrastructure located within vulnerable areas shall occur until a network-wide vulnerability assessment and adaptation plan have been developed which assures alignment between the LCP and other relevant local, regional, and statewide documents and planning efforts.

6. **Intergovernmental Coordination**. For transportation infrastructure that crosses jurisdictional boundaries, coordination shall occur between local governments, regional transportation entities, rail managers, and state and federal agencies with jurisdiction over or interests in that transportation corridor. Such coordination shall ensure that adaptation strategies are identified and implemented on appropriate scales to both protect coastal resources and transportation infrastructure.

7. **Align Local Planning Documents**. [Insert name of local government] shall ensure that LCPs and other relevant planning documents, including Capital Improvement Plans, Local Hazard Mitigation Plans, Climate Action Plans, and other relevant plans provide a coordinated, cohesive, and mutually supportive approach to transportation infrastructure adaptation.

8. **Public Works Plans.** [Insert name of local government] intends to work with Caltrans and other transportation asset owners and managers to conduct advance planning toward development of a Public Works Plan for phased transportation infrastructure projects within a defined network/corridor that crosses jurisdictional boundaries. Segments of transportation infrastructure that are vulnerable or that are expected to become vulnerable to coastal hazards, including those associated with sea level rise, shall be identified and prioritized to provide time to plan, fund, and implement adaptation projects before significant impacts to coastal resources and public safety occur. A full suite of potential, corridor-wide adaptation strategies and multi-modal transportation options shall be developed in cooperation with local governments, regional transportation entities, rail managers and state and federal agencies with jurisdiction over or interests in the transportation corridor. No expansion or replacement of transportation infrastructure located within vulnerable areas shall occur until a network-wide vulnerability assessment and Public Works Plan or similar instrument have been developed which assures alignment between the Local Coastal Program and other relevant local, regional, and statewide documents and planning efforts.

9. **Prioritize Vulnerable Infrastructure Segments**. The [Insert name of local government] has identified that [insert description of transportation infrastructure] is vulnerable to coastal hazards and sea level rise and requires adaptation planning. The [Insert name of local government] shall work with [Caltrans and/or relevant transportation agency/asset manager] and other relevant stakeholders on adaptation planning and implementation of measures that address the long-term vulnerability of the segment through identification and evaluation of alternative adaptation strategies in concert with related land use adaptation plans. [Insert date by which planning milestones will be met, if desired]

10. **Advance Planning for Nature-Based Adaptation Strategies**. [Insert name of local government] shall work with relevant partners to identify locations where nature-based adaptation strategies may be feasible and appropriate. Such strategies should use an ecosystem planning approach that identifies opportunities to improve impaired ecological systems, ecological functions, and their values in concert with climate change adaptation measures.

11. **Environmental Justice Planning**. [Insert name of local government] shall work with local stakeholders to identify vulnerable populations and environmental justice communities – including low-income communities, communities of color, California Native American Tribes, and other historically marginalized communities – that rely upon transportation infrastructure and/or live near existing highways or proposed sites for highway development. Meaningful engagement of such communities in the adaptation planning process shall be prioritized

and started early to involve stakeholders in all stages of the planning process. [Insert name of local government] shall consider environmental justice impacts of proposed projects by evaluating cumulative environmental impacts to those populations from proposed infrastructure adaptation plans and projects and incorporating measures to address inequitable distribution of benefits and burdens.

Preempted Railway Project Coordination Policy Note:

An important reminder is that there are circumstances in which federal law does not preempt state and local regulation of railroads. Preemption determinations are made on a case-by-case basis. See the FEDERAL PREEMPTION, THE COASTAL ACT, AND LCPs section of this report where preemption is discussed.

12. **Preempted Railway Project Coordination**. When railway owners, operators, or managers undertake a railroad facility development project that is preempted from state or local coastal permitting requirements, [insert Caltrans and/or name of local government] shall coordinate with the relevant railroad or other entities to ensure they (1) share their plans with the community; (2) use best management practices to minimize resource impacts; (3) implement appropriate precautionary measures; (4) provide representatives to meet periodically with citizen groups or local government entities to seek mutually acceptable ways to address local concerns; and (5) submit relevant environmental monitoring or testing information to local government entities for an appropriate period of time after operations begin.

Specific Issue Areas

13. **Environmental Justice Impacts.** [Insert name of local government] shall evaluate cumulative impacts to environmental justice communities from proposed highway plans and projects, including project alternatives, and evaluate whether adaptation proposals will result in inequitable distribution of benefits and burdens. [Insert name of local government] shall choose a final project plan or design that incorporates measures to avoid or mitigate project burdens in environmental justice communities to the maximum extent feasible.
14. **Meaningful Public Participation.** Projects that include transportation infrastructure shall provide opportunities for meaningful and equitable public participation throughout the entire planning process, making special efforts to reach disproportionately burdened communities, including scheduling meetings at times and locations most convenient to community members and providing translation and interpretation services at meetings if projects will affect non-English speaking populations.

15. **Vehicle Miles Traveled**. Sea level rise adaptation planning for transportation infrastructure shall prioritize adaptation options that minimize vehicle miles traveled to the extent feasible, except when it is determined that an option that results in a greater amount of vehicle miles traveled has greater public benefit than another, when factoring in environmental, economic, and equity considerations. The provision of public transit and multimodal transportation should always be prioritized as an approach to reduce vehicle miles traveled.

16. **Scenic Highway 1**. In rural areas of the coastal zone, adaptation measures for Coastal Highway 1 shall be designed to safely maintain the highway as a scenic two-lane highway and shall incorporate measures that protect, provide, and, where feasible, enhance, public scenic views.

17. **California Coastal Trail**. Consideration shall be provided for the maximum connectivity and continued functionality and utility of the California Coastal Trail in transportation adaptation projects. Planning for trail alignments should anticipate the effects of sea level rise to ensure continued public access and connectivity near the shoreline, including potential inland relocation over time. Opportunities for partnering with public agencies and other stakeholders shall be fully explored in the development of Coastal Trail plans.

18. **Contingency Plans for Periods of Non-operation.** [Insert name of local government] will coordinate with [Insert name of transportation asset manager] and other relevant stakeholders to evaluate and identify strategies and/or to develop contingency plans to ensure that impacts to public access are minimized when transportation infrastructure is rendered periodically inoperable due to coastal flooding and/or erosion. Such options may include temporary road or lane closures and/or detour routes, along with appropriate signage or other notification systems to ensure information is provided to residents and visitors to coastal areas.

19. **Emergency Evacuation Routes**. Where transportation infrastructure functions as part of emergency evacuation routes, the [insert name of local government] should coordinate with [Insert name of transportation asset manager] to develop contingency plans and alternative routes to utilize when that infrastructure is inoperable due to coastal flooding and/or erosion, in coordination with relevant emergency response planners.

Hazard Analysis

20. **Best Available Science**. Use the current ‘best available science’ on sea level rise projections and impacts at the time of development application or plan development when reviewing new applications for transportation infrastructure and related adaptation planning. As of [insert date], the best available science can be found [insert applicable document title]. Use a range of sea level rise projections in sea level rise analysis for transportation infrastructure development and planning, and analyze how such infrastructure would be affected by higher risk aversion

scenarios (including the H++ scenario) described in current best available science or the equivalent in future updates. Note that while planning and project analyses should consider the H++ scenario, it may be appropriate for individual projects to be designed for lesser amounts of sea level rise as long as additional adaptation pathways are included to address higher sea level rise amounts.

21. **Planning Horizons for Transportation Infrastructure**. Sea level rise impacts shall be evaluated over a time period appropriate to the planning or project type. Adaptation planning and transportation system planning documents should consider the short-term transportation needs and priorities within a long-term context of potential SLR impacts (minimum 100 years). For example, system plans, which often have a 20 to 30-year horizon, should identify the necessary short-term projects such as repair and maintenance, temporary protection, or other phased adaptation measures that support possible long-term adaptation approaches. Planning horizons for individual projects should reflect the anticipated lifetime of the project, or the time period over which the project is expected to be usable for the purpose for which it is designed. The anticipated lifetime of major infrastructure projects such as new or realigned roads or rail lines, road expansion, new bridges or tunnels, culverts, or other major structures, is 100 or more years. Minor projects such as safety barriers, rumble strips, re-paving, lighting, or projects designed as phased adaptation measures have anticipated lifetimes of 20-50 years.

22. **Hazard Assessments**. Site- or region-specific sea level rise vulnerability assessments conducted by the [insert name of local government] to analyze the vulnerability of transportation infrastructure, and similar studies required by [insert name of local government] as part of permit applications, shall address the following topics at a level of detail appropriate for the project type (e.g., major versus minor projects) and for the stage of the planning or project development process:

    » Analyze the expected impacts of sea level rise upon the subject transportation infrastructure over the appropriate planning horizon and risk aversion scenario ***[See Example Policy 21]***;

    » Be based upon the current best available science, including as it guides the use of appropriate sea level rise projections ***[See Example Policy 20]***;

    » Analyze all relevant hazards including but not limited to wave run-up, tidal inundation, storm flooding, groundwater change, and short- and long-term erosion, all as influenced by sea level rise;

    » Examine hazard conditions with and without the effects of existing shoreline protective devices;

- » Evaluate the foreseeable effects that the transportation infrastructure will have on communities, vulnerable populations, and coastal resources over time (including in terms of impacts on public access for all types of coastal users, shoreline dynamics, natural landforms, natural shoreline processes, beach widths, wetlands, other shoreline habitats seaward and inland of the transportation infrastructure, public views, and cultural and historical resources) as project impacts continue and/or change over time, including in response to sea level rise;
- » Be conducted by a licensed engineer with expertise in coastal engineering and geomorphology or other suitably qualified professional; and
- » Be coordinated with relevant stakeholders and partners to the extent feasible.

In cases where a specific adaptation strategy is being proposed, the assessment shall include an analysis of the strategy's potential impacts to coastal resources, capacity to abate hazards over the applicable planning horizon, as well as an analysis of applicable alternatives, such as nature-based adaptation strategies, all evaluated at a similar level of detail.

Large-scale projects require more detailed analysis than minor projects. Minor projects may include those that are small in scale and have limited potential consequences to development or coastal resources; projects with short anticipated lifetimes; and/or projects with a high adaptive capacity. Major projects include those with converse characteristics, such as capacity-increasing construction, realignment projects, proposals for shoreline protective devices, and bridge and/or causeway designs or replacements. Generally, analyses for minor projects may utilize information from existing sea level rise models and/or vulnerability assessments. Site-specific sea level rise studies for major projects may also pull information from existing resources, but shall include all necessary additional, detailed analyses of relevant coastal hazards and potential impacts of project alternatives to communities, environmental justice communities, and coastal resources, as well as implications for vehicle miles traveled.

New Infrastructure

23. New or Expanded Transportation Infrastructure. New transportation infrastructure – and transportation infrastructure projects that would widen or otherwise increase the capacity of the infrastructure – shall be sited and designed to avoid becoming vulnerable to sea level rise over the appropriate planning horizon(s) ***[See Example Policy 21]***. New transportation infrastructure shall, consistent with Section 30253 of the Coastal Act, do all of the following:

- » Minimize risks to life and property in areas of high geologic, flood, and fire hazard;
- » 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;

- Be consistent with requirements imposed by an air pollution control district or the State Air Resources Board as to each particular development;
- Minimize energy consumption and vehicle miles traveled; and,
- Where appropriate, protect special communities and neighborhoods.

New transportation infrastructure shall also be designed to avoid or minimize impacts to coastal resources, including public access, recreational resources, marine resources, sensitive habitats, agricultural lands, and scenic and visual resources, consistent with the LCP. Additional considerations, such as reducing VMT and enhancing multimodal and Complete Streets opportunities, shall be assessed when planning new transportation infrastructure.

Assumption of Risk Policy Note:

An important consideration for jurisdictions planning for sea level rise is that the public trust boundary will migrate inland in some locations as sea levels rise. As this occurs, infrastructure might come to be located on public trust property during its lifespan. LCP policies should recognize that development that comes to encroach on public trust land will likely cause new coastal resource and public trust impacts and will no longer be within the local jurisdiction's Coastal Act permitting authority. The development should therefore be conditioned to clarify that it does not allow encroachment onto public trust lands and that any such encroachment must be removed unless the owner of the structure obtains necessary authorization for it to remain from the Coastal Commission and the State Lands Commission or other tidelands trustee agency. In order to permit such structures to remain on public trust land, the Coastal Commission would need to find that they are consistent with Chapter 3 policies of the Coastal Act, and the State Lands Commission or other trustee agency would need to find, among other things, that they do not substantially impair public trust resources. Policy language may need to be modified based on whether infrastructure is located on public, private, or leased land.

24. **Assumption of Risk, Waiver of Liability, and Indemnity Agreement**. As a condition of coastal permit approval for transportation-related development in potentially vulnerable areas, applicants shall be required to acknowledge and agree: 1) that the development is located in an area with current or potential future coastal-related hazards and may be subject to erosion, landslides, bluff retreat, flooding, wave run-up, tsunamis, and sea level rise; 2) to assume the risks of injury and damage from such coastal hazards in connection with the permitted development; 3) to unconditionally waive any claim of damage or liability against the [insert local government name, and Coastal Commission, if permit is appealed], its officers, agents, and employees for injury or damage from such hazards; 4) to indemnify and hold harmless the [insert local government name, and Coastal Commission, if permit is appealed], its officers, agents, and employees with respect to approval of the project against any and all liability, claims, demands, damages, costs (including costs and fees incurred in defense of such claims),

expenses, and amounts paid in settlement arising from any injury or damage due to such hazards; 5) that the boundary between public trust land (tidelands) and uplands may shift with rising seas, the structure may eventually be located on public trust lands, and the development approval may not permit encroachment onto public trust land; and 6) any future encroachment must be removed unless the Coastal Commission determines that the encroachment is legally permissible pursuant to the Coastal Act and authorizes it to remain, and any future encroachment would also be subject to the State Lands Commission's (or other trustee agency's) leasing approval.

25. **Coastal Hazards Monitoring Plan.** When approving transportation infrastructure development in an area subject to current or expected future coastal hazards, require a Coastal Hazards Monitoring Plan to establish the framework and parameters for (1) regularly monitoring flood and other coastal hazards at the site, and managing responses to those hazards both on and off-site; (2) identifying how those hazards are affecting or will soon affect the operations of the transportation infrastructure; (3) identifying changes necessary to allow continued safe functioning of the transportation infrastructure; and (4) identifying hazard 'triggers' to establish when actions (such as retrofits, upgrades, and including infrastructure relocation) need to be pursued. At a minimum, the Monitoring Plan shall include metrics for assessing site conditions and potential responses related to flooding, groundwater rise, and erosion as these may be influenced by coastal flooding and sea level rise during both typical and extreme storm events. Monitoring Plans shall account for increased frequency of inspection as coastal hazards threaten the integrity of the infrastructure.

Policies that Implement Various Adaptation Options

26. **Nature-Based Adaptation Strategies.** Nature-based adaptation strategies with measurable environmental benefits shall be prioritized over strategies with additional coastal resource impacts, such as those associated with hard shoreline protective devices. Soft strategies (e.g., dune and wetland restoration, sand replenishment, and other options that do not fix the shoreline) shall be prioritized over hybrid armoring (e.g., strategies that fix the shoreline combined with natural features), and hybrid armoring shall be prioritized over hard shoreline protection. Hybrid armoring shall only be allowed if it complies with all of the requirements of **Policy 27**, except for the near-term danger requirement as specified in **Policy 27.a**. Instead of the near-term danger requirement, hybrid armoring may be allowed to protect infrastructure that is expected to be threatened by hazards in [insert appropriate planning horizon, consistent with relevant planning and funding cycles; e.g., 20-30 years], and shall be constructed with enough lead time for vegetation cover to establish or for other steps to be completed so the project can provide the benefits for which it was designed. In all cases, the least environmentally damaging feasibly alternative shall be selected.

27. Hard Shoreline Protective Devices and Long-Term Planning. Permits for new hard or hybrid shoreline protection to protect transportation infrastructure shall include conditions requiring long-term sea level rise adaptation planning that protects public safety and coastal resources, and ensures structural stability of that infrastructure, in a manner that, if feasible, does not require the long-term retention of the protective device. Subject to specific criteria, and notwithstanding any other policy in the LCP, hard or hybrid shoreline protective devices may be permitted to protect existing, critical transportation infrastructure at near-term risk from erosion or flooding when there is no less environmentally damaging feasible alternative, when designed to eliminate or mitigate adverse impacts on local shoreline sand supply, and provided that (a) special conditions state that the permit will expire in [insert appropriate timeframe considering long-term planning needs], and (b) a sea level rise adaptation plan must be submitted for review and approval by [list agency] prior to the end of the permit term. Prior to the end of the permit term, the applicant shall also submit a permit amendment application to implement the measures identified in the approved sea level rise adaptation plan. If a sea level rise adaptation plan is not approved, the permitted shoreline protective device may be required to be removed.

- **a. Hard shoreline protective devices shall be permitted when**: (1) needed to protect transportation infrastructure that is in near-term danger from coastal hazards; (2) there is no less environmentally damaging feasible alternative to the proposed shoreline protective device; (3) sited and designed to eliminate or mitigate adverse impacts on local shoreline sand supply; (4) sited and designed to avoid or minimize coastal resource impacts to the maximum extent feasible; and (5) all of the following standards are met:

  - **i. Mitigation required**. Mitigation for impacts on all coastal resources shall be required. For temporary shoreline protective devices on or adjacent to beaches, mitigation shall be required for all impacts, including impacts to public access and recreation, environmentally sensitive habitats, and shoreline sand supply that result from the footprint of the proposed shoreline protective device as well as from halted erosion that would have occurred over the life of the shoreline protective device. Mitigation shall minimize impacts to the extent feasible and fully compensate impacts that remain; mitigation shall address impacts that will occur over the full life of the structure, but may be assessed in appropriate increments, rather than being required entirely up front. For temporary shoreline protective devices on or adjacent to other coastal habitats (e.g., wetlands), appropriate mitigation shall be required. In-kind mitigation shall be prioritized, although in-lieu fee mitigation may be appropriate, such as when used for programs developed to advance community-wide public access goals and environmentally protective adaptation strategies. Mitigation shall be designed such that the benefits derived from mitigation are equitably distributed and/or increase benefits to communities that have traditionally lacked public access opportunities and the benefits associated with other coastal resources.

ii. **Maintenance and monitoring.** Shoreline protective devices constructed to protect transportation infrastructure shall be monitored and maintained in their permitted configuration to prevent impacts to public access, recreation, environmentally sensitive habitats, and other coastal resources.

iii. **Long-term planning required.** Approvals of shoreline protective devices shall include a special condition requiring planning for a long-term solution. This condition shall require the Permittee to acknowledge that the Coastal Development Permit only authorizes the development for an initial, temporary period, during which time the Permittee must develop a longer-term Sea Level Rise Adaptation Plan that, if feasible and consistent with other applicable LCP policies, does not rely on armoring. Permit applications shall include a plan and timeline for the development of the Sea Level Rise Adaptation Plan. The Plan shall be based on best available science and include, at minimum, possible options to explore as long-term solutions, including phased adaptation strategies as appropriate, a mechanism and process to choose the preferred long-term adaptation approach, and a reporting cycle with deadlines for action. The Sea Level Rise Adaptation Plan shall also consider and prioritize feasible nature-based adaptation strategies, as well as measures to minimize greenhouse gas emissions and to ensure the benefits and impacts to all communities, including environmental justice populations, are equitably distributed. The date by which Sea Level Rise Adaptation Plans shall be completed shall depend on the vulnerability of the transportation segment and its potential to cause coastal resource impacts. If the segment is expected to be vulnerable in the near-term, adaptation planning shall be required in the near-term, and the permit shall specify a completion date that allows an appropriate amount of lead time for permit review and implementation before impacts are expected to become significant.

iv. **Assumption of risk**. As a condition of coastal permit approval for temporary shoreline protective devices, applicants shall be required to acknowledge and agree to assume risks as required in **Policy 24**.

v. **Maximize environmental benefits.** Any permitted shoreline protective device shall be designed and constructed in a manner that maximizes environmental benefits. Such benefits shall not be considered the creation of habitats that require protection; when appropriate, such shoreline protective devices shall be removed as planned.

28. Transportation Infrastructure Realignment.

a. Siting of Realigned Transportation Infrastructure. Any new transportation infrastructure footprint shall be set back or otherwise designed to be safe from the impacts of sea level rise over at least 100 years from the estimated date of construction, including but not limited to projected inundation, erosion, and storm flooding. If complete avoidance of impacts is infeasible, the new transportation infrastructure footprint shall be set back as far as possible and phased adaptation strategies shall be planned to minimize hazards, assure structural stability, and protect coastal resources in the future. The precise siting of the realigned transportation infrastructure shall minimize impacts to coastal resources and vulnerable communities.

b. Design of Realigned Transportation Infrastructure. Relocated transportation infrastructure shall incorporate design features that maintain and enhance public access, public safety, water quality, scenic resources, archaeological resources, agricultural lands, and habitats. Relocated transportation infrastructure shall also maintain and enhance, where feasible, multi-modal transportation (e.g., bike lanes, sidewalks, the California Coastal Trail) and public transit (e.g., bus and transit stops and stations, parking lots and public access areas associated with the former highway footprint, necessary turn pockets for ingress and egress to access facilities, park and ride lots to promote car and van pools, bike parking, and safe pedestrian crossings). In addition, relocated transportation infrastructure shall incorporate best management practices for water quality protection; use drought-tolerant native landscaping; and protect scenic and visual qualities, including coastal and ridgeline viewsheds. Where the California Coastal Trail, or other significant public access element, parallels the existing transportation infrastructure, realignment projects should include any necessary relocation of the Trail and its related features (e.g., parking areas, signs, bridges, boardwalks, and benches) in order to maintain its function as an off-highway and/or integrated trail system.

c. Removal of Former Infrastructure and Restoration of Right-of-Way. Removal of all infrastructure associated with the original segment and restoration of the right-of-way to its pre-development state shall be required, including any necessary public access or habitat restoration. Any shoreline armoring that is present but no longer needed to protect other existing or coastal-dependent structures in danger of erosion shall be removed and the site restored to a pre-development condition, unless maintaining it would be most protective of coastal resources. The [insert name of local government] may exempt portions of infrastructure from these requirements if they are identified for reuse for trail or other public access and recreational purposes and if otherwise consistent with LCP policies.

d. Assumption of risk. As a condition of coastal permit approval for a temporary shoreline protective device, applicants shall be required to acknowledge and agree to assume risks as required by **Policy 24**.

29. Causeways and Bridges

a. Causeway and bridge elevation. Incorporate sea level rise projections into the elevation of causeways and bridges as adaptive strategies.

i. Require elevation to account for full sea level rise projection: Determine minimum bridge soffit elevation by adding the sea level rise scenario ***[See example policy 20]*** and anticipated hydrological changes such as increases in storm and flooding intensities and occurrences for the appropriate planning horizon ***[See example policy 21]*** to the existing storm flow elevation predictions typically used by Caltrans and relevant transportation authorities. The analysis shall also include wave setup and crest heights if the project may be subject to wave action. Any additional freeboard necessary to allow for recreational boating passage during high tides, or any additional freeboard required by FEMA, should also be added; or

ii. Allowances for elevation to less than the full sea level rise projection, plus other adaptation measures: Elevation of bridges/causeways to less than the recommended highest sea level rise scenario ***[See example policy 20]*** for the appropriate planning horizon ***[See example policy 21]*** may be allowed, but in such instances shall incorporate additional adaptation measures in order to ensure that the structure will minimize risks to life and property and assure stability and structural integrity over its lifetime. Additional adaptation measures may include: designs that allow for incremental increases in elevation in the future, planned reconstruction when impacts occur, or temporary closures/detours during extreme events. This strategy may be appropriate when further elevation is not feasible or impacts to coastal resources (e.g., visual resources, habitats, agricultural lands, etc.) from further elevation outweigh the benefit derived by designing to the full sea level rise scenario. Extreme event monitoring shall be required as part of the operation and maintenance of the facilities.

b. Causeway and bridge design. Incorporate sea level rise into the design of causeway and bridge touchdowns.

i. Where the bridge/causeway crosses channels that provide flood conveyance, project design shall provide for channel widths that provide the optimum tidal and fluvial flows to support fish passage, wetland and habitat restoration, and other beneficial environmental outcomes. Causeway and bridge touchdowns shall be located to provide for this optimum channel width and to be safe from hazards influenced by sea level rise, including flooding, scour, erosion, and sedimentation.

ii. Causeway and bridge design shall also avoid or minimize adverse impacts upon sensitive species, tidal circulation, flood flows and associated scour, river mouth migration, sediment transport, wildlife connectivity, and associated impacts on wildlife habitats and federal or state jurisdictional waters/wetlands.

c. **Assumption of risk**. As a condition of coastal permit approval for temporary shoreline protective devices associated with causeways and bridges, applicants shall be required to acknowledge and agree to assume risks as required by **Policy 24**.

30. **Development Inland of Lateral Transportation Infrastructure**. Low-lying development that would otherwise be affected by rising seas if not for intervening transportation infrastructure shall be sited and designed assuming that the intervening infrastructure will not provide long-term protection (i.e., assuming the infrastructure will be relocated inland or elevated on a causeway) unless a long-term adaptation plan for the intervening infrastructure has been approved by the Coastal Commission or certified as part of this LCP that indicates otherwise.

MODEL POLICIES FOR WATER INFRASTRUCTURE

There is no single approach for adapting water infrastructure for sea level rise. Most options for adapting wastewater and stormwater systems will include a range of approaches that are likely appropriate at different times. However, every community should consider the following principles in their LCP:

- Use the best available science and higher sea level rise projections (medium-high and extreme risk aversion scenarios) to evaluate critical infrastructure in vulnerability assessments.
- Conduct long-term planning to assess life expectancy, potential impacts of hazards, the feasibility and social/environmental/economic costs of adaptation strategy alternatives over time, and the logical triggers for phased adaptation.
- Prioritize hazard avoidance, and where hazard avoidance is not feasible, consider nature-based adaptation before considering hard armoring options.
- Avoid and minimize hazards by reducing the amount of wastewater and stormwater runoff being generated and directed into municipal conveyance systems, and invest in alternatives to siting infrastructure in hazardous locations, including alternatives to discharging treated wastewater and stormwater through outfalls to coastal waters. (Note that some ocean outfalls may need to be maintained, where feasible, to facilitate discharges associated with water supply sustainability and resiliency projects.)
- Coordinate regionally on phased solutions.
- Monitor for hazardous conditions and develop triggers to phase planning approaches.
- Prioritize multiple benefits from projects, such as reducing greenhouse gases (GHG), recycling water where possible, restoring natural processes, and minimizing flood risk.

- Address any disproportionate burdens and benefits to environmental justice communities and incorporate meaningful engagement practices and equitable public participation processes throughout the entire planning process.

The model policies are divided into subcategories for planning, stormwater, wastewater, groundwater, and general adaptation. Planning process (Policies 31-35) for best available science, advanced planning (vulnerability assessments), siting and design for new water infrastructure, coordination with other planning documents such as PWPs, and environmental justice reflect fundamental policies for adapting water infrastructure for resiliency. The stormwater section (Policies 36-39) describes options for use of long-term planning, prioritizing nature-based adaptation strategies, and reducing runoff to mitigate hazard risk. The wastewater section (Policies 40-45) offers policy language for life expectancy analysis, long-term planning, prioritizing nature-based adaptation strategies, promoting water reuse, and protecting water quality at vulnerable outfalls and from septic systems as sea levels rise. Because the potential impacts of sea level rise and saltwater intrusion on groundwater is a significant issue in many coastal areas, and the Coastal Commission encourages LCP updates to address these issues where relevant. The groundwater management (Policies 46-50) emphasize potential approaches for agency coordination, as well as possible restrictions on infrastructure such as vulnerable wells and the development that depends on them for water supply. Lastly, the adaptation section (Policies 51-59) offers model language for protecting assets, regional coordination, water reuse, financial planning options for water infrastructure projects, and requirements for assumption of risk.

Planning Process

31. **Best Available Science.** Use the current ‘best available science’ on sea level rise projections and impacts at the time of development application or plan development when reviewing new applications for water infrastructure and related adaptation planning. Currently, as of [insert date], the best available science can be found [insert applicable document title].[40] Use a range of sea level rise projections in sea level rise analysis for water infrastructure development and planning, and analyze how such infrastructure would be affected by higher risk aversion scenarios (including the H++ scenario) described in current best available science or the equivalent in future updates.

32. **Advance Planning for Water Infrastructure**. By [insert date], [City/County] shall complete the following:

40 As of August 2021, the best available science can be found in both the *State of California Sea-Level Rise Guidance* (Ocean Protection Council, 2018 Update) and the *California Coastal Commission Sea Level Rise Policy Guidance* (2018 Update).

- » Identify components of water infrastructure systems that are vulnerable or that are expected to become vulnerable to coastal hazards, so that [insert name of City/County] will have sufficient time to plan, fund, and implement adaptation projects before significant impacts to coastal resources and public safety occur. [Insert name of local government] shall work with the Regional Water Quality Control Board/State Water Board and asset managers to conduct such advance vulnerability assessment and complete comprehensive planning and implementation processes in order to protect coastal resources and avoid the need for emergency shoreline protective devices.
- » Identify local information needs and develop a strategy, including monitoring, research, or phased implementation of pilot studies to increase understanding of sea level rise vulnerability and the feasibility of potential adaptation strategies.
- » Consider a full suite of potential adaptation strategies, including nature-based adaptation strategies, adaptive management strategies, relocation, elevation, and short-term use of shoreline protective devices.
- » Identify and reserve potential new sites for wastewater or other infrastructure that will need to be relocated.

33. Siting and Design of Water Infrastructure. New water infrastructure shall be sited outside of hazardous areas, including areas vulnerable to sea level rise, unless it is infeasible to do so. All new water infrastructure shall be consistent with Section 30253 of the Coastal Act, including that it shall:

- **a.** Minimize risks to life and property in areas of high geologic, flood, and fire hazard taking into account projected sea level rise over the anticipated life of the development; and
- **b.** Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area, or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.

34. Align Local Planning Documents. [Insert name of local government] shall ensure that LCPs and other relevant planning documents, including Public Works Plans, Capital Improvement Plans, Local Hazard Mitigation Plans, and Climate Action Plans, and other relevant plans provide a coordinated, cohesive, and mutually supportive approach to water infrastructure adaptation.

35. Environmental Justice Planning. [Insert name of local government] shall work with local stakeholders to identify vulnerable populations and environmental justice communities – including low-income communities, communities of color, California Native American Tribes, and other historically marginalized communities – that rely upon water infrastructure and/or live near existing storm and wastewater infrastructure or proposed sites for development. Meaningful engagement of such communities in the adaptation planning process shall be prioritized and started early to involve stakeholders in all stages of the planning process. Special efforts shall be made to reach disproportionately burdened communities, including scheduling meetings at times and locations most convenient to community members and providing translation and interpretation services at meetings if project will affect non-English speaking populations. [Insert name of local government] shall consider environmental justice impacts of proposed projects by evaluating cumulative environmental impacts to those populations from proposed infrastructure adaptation plans and projects and incorporating measures to address inequitable distribution of benefits and burdens.

Stormwater Management

36. **Update Stormwater Management Plans to Address Climate Change and Sea Level Rise**. Evaluate and update stormwater management plans to account for impacts to stormwater drainage systems and BMPs due to climate change and sea level rise, such as from rising groundwater, impaired stormwater drainage, and increased stormwater flooding, as applicable. Where appropriate, updates shall ensure the following:

    a. **Increase use of Low Impact Development (LID) stormwater strategies.** Incorporate LID stormwater infrastructure (e.g., retain stormwater on site to replicate the natural hydrologic balance, or maintain or enhance natural infiltration areas) to the maximum extent feasible to minimize the amount of stormwater that flows into the storm drain system and other stormwater conveyance systems, and to assist in infiltration and treatment of potential pollutants. These strategies include, but are not limited to, green roofs, permeable pavements, bioretention systems (e.g., bioretention basins, vegetated swales, rain gardens) and cisterns. Take sea level rise impacts and increased frequency of extreme storms into account in the design.

    b. **Retrofit existing development.** Identify and prioritize adaptation for development in low-lying or other at-risk areas with inadequate stormwater management, and take steps to retrofit the stormwater management system to minimize flooding and ensure protection of water quality as sea levels rise.

    c. **Plan for adaptation of stormwater infrastructure vulnerable to flooding, inundation, and rising groundwater**. Where low-lying or other at-risk areas will have inadequate stormwater infrastructure due to future sea level rise, evaluate and plan for adaptation strategies that will minimize flooding and ensure protection of water quality as sea level rises.

    d. **Provide incentives** for use of LID and other measures to reduce stormwater runoff.

37. **Bluff-top Stormwater and Dry Weather Flows.** Bluff-top development shall implement stormwater management practices that maximize on-site infiltration of runoff to the extent appropriate and feasible, and if it can be demonstrated that infiltration would not contribute to bluff instability. Bluff-top development shall also implement erosion control practices to convey site drainage in a non-erosive manner, including directing collected flows to inland areas and

not seaward off the blufftop edge, to protect water quality and minimize hazards resulting from increased runoff and accelerated erosion due to sea level rise. If on-site infiltration of runoff is not appropriate or feasible, runoff shall be directed inland to a storm drain system. If a storm drain system is not available, runoff shall be directed to an existing outfall, if feasible. Avoid uncontrolled sheet flow or channelized runoff from bluffs to the ocean and avoid new sources of runoff to the ocean. Avoid directing runoff from bluff-top development to the beach or the ocean.

38. **Use Natural Processes to Improve Flood Prevention.** Flood hazard prevention and mitigation shall prioritize restoration of low-lying flood-prone areas and natural drainageways. Native plants and nature-based, “soft” stabilization shall be prioritized over methods that rely on concrete channelization or other “hard armoring” stabilization methods.

39. **Design of Stormwater Outfalls.** Development shall be sited and designed to avoid the adverse impacts of discharging concentrated flows of stormwater or dry weather runoff through outfalls to coastal waters, intertidal areas, beaches, bluffs, or stream banks. If reliance on outfalls cannot feasibly be avoided, avoid construction of new stormwater outfalls, and direct stormwater to existing facilities with appropriate treatment and filtration, where feasible. Outfalls shall be sited and designed to protect and maximize public access, and to minimize visual impacts on the beach or at other coastal outfall locations and shall include energy dissipation to reduce erosion. Outfalls that are currently, or are likely to be, below sea level (due to sea level rise and/or high storm tides) should be retrofitted to prevent the entry of water and sediment, to the extent feasible. Where feasible, outfalls shall be reduced and consolidated as part of projects that affect stormwater systems in the area.

Wastewater Management

40. **Life Expectancy and Economic Analysis.** When applying for a coastal development permit for a major improvement or upgrade to wastewater infrastructure in a vulnerable area, or for any shoreline armoring to protect vulnerable wastewater infrastructure, the applicant shall conduct a life expectancy and economic analysis for wastewater infrastructure. The analysis shall help determine when the infrastructure cannot function without substantial investment and protective measures, serving to help define the future point when it might be appropriate to relocate the infrastructure, the length of time the infrastructure is expected to be in place, and the full cost of maintaining it in a vulnerable location. The analysis shall include the following:

    a. An evaluation of the annual and long-term costs of maintaining the existing infrastructure at its current location, including: repairing/maintaining and replacing existing components; upgrading existing components to meet regulatory (Regional Water Quality Control Board or other agencies) requirements/specifications; complying with habitat mitigation requirements for impacts from potential flood control projects; responding to coastal hazards risk (such as flood-proofing existing and new components over time, including in relation to offsite flood-proofing mechanisms such as lagoon management and expansion of shoreline protection devices); and addressing other non-coastal related climate change hazards and vulnerabilities (such as decreased influent quantity and quality associated with droughts and water conservation, increased influent quantity associated with peak storm events, temperature fluctuations and extremes, increased wildfires, and increased power outages). Cost evaluations should include benefits and impacts to habitat, access, recreation, and water quality, and should account for both market and non-market values.

b. Information on each component of the vulnerable infrastructure (e.g., for treatment facilities, this would include headworks, clarifiers, and digestors), the installation date of each component, upgraded component dates and the current condition of that equipment, major upgrade events, the expected lifespan, and repair/maintenance and replacement costs of each component (based on industry-accepted sources, manufacturers' information, and the reports of other municipalities with similarly sized facilities, and remaining years for each component and the overall facility).

c. Identification of the expected point in time when investments in infrastructure (including any continued flood protection measures) at the current location outweigh investing in relocation to an area that is safe from flooding and other coastal hazards.

d. Clear documentation and evidence to support all conclusions.

41. Long-Term Planning for Wastewater Infrastructure in Vulnerable Areas. No coastal development permit shall be issued for any major improvements or upgrades to wastewater infrastructure in vulnerable areas or for any shoreline armoring to protect vulnerable wastewater infrastructure, without the requirement for a long-term plan for adapting to sea level rise and coastal hazards. The long-term plan shall prevent impacts to water quality, protect coastal resources, and minimize use of shoreline armoring. In addition, consistent with Section 30412(d) of the Coastal Act, the plan shall identify and, where appropriate, reserve new sites for treatment plants or system components at locations that are safe from coastal hazards. The plan shall:

a. Consider a full suite of potential adaptation strategy alternatives, including relocation/retreat and nature-based adaptation strategies. In consideration of relocation alternatives, the plan shall provide details regarding the mechanisms, costs, funding options, and timing for potential relocation and for restoration of the existing vulnerable site. Relocation alternatives analyzed shall include alternative wastewater treatment options in-lieu of building a new inland treatment facility (including the construction of an inland package plant or plants, the possibility of combining services with other nearby existing plants, and similar alternatives). For outfalls, alternatives analyzed shall include land-based disposal, reuse of treated wastewater, and elimination of outfalls.

b. Prioritize strategies that avoid hazards related to sea level rise, such as relocation. After hazard avoidance, the next priority shall be nature-based adaptation strategies that reduce impacts to coastal resources and provide measurable environmental benefits.

c. Select strategies that maximize protection of coastal resources, including public access, recreation, marine and terrestrial resources, and visual resources; ensure safety and stability of infrastructure; and maintain wastewater service to communities that is responsive to shifting community needs over time.

d. If relocation is a selected adaptation strategy, provide a clear long-term strategy for providing necessary wastewater system functions at an inland location or locations that are not subject to the significant coastal hazards threatening the existing infrastructure, including reserving adequate property on which to construct treatment or collection (e.g., lift stations) facilities.

e. Consider phased and trigger-based adaptation measures including elevation, relocation, and/or periods of limited-duration shoreline protection if such protection is otherwise consistent with all LCP policies. Phases shall be designed to address expected amounts of sea level rise and associated impacts while avoiding or minimizing impacts to coastal resources, and specific triggers shall be identified after which each subsequent phase shall be implemented. The overall phased approach should be designed to minimize impacts to wastewater infrastructure, as well as to environmental, recreational, and public access resources over the planning horizon.

f. Incorporate appropriate periods of lead time that allow for planning, funding, and implementation. In addition, operational action such as efficiency improvements, monitoring, inspections, conservation, demand management, and flexible operations should be considered as part of adaptation strategies. Ensure that adaptation projects are planned, funded, and implemented before significant impacts to coastal resources and public safety occur.

g. Consider environmental justice impacts of proposed adaptation strategy and alternatives. The plan shall include a summary of low-income communities, communities of color, California Native American Tribes, and environmental justice communities affected by the proposal; develop actions to meaningfully engage them in the long-term planning process; and include an analysis of cumulative environmental impacts and measures to address burdens in these communities.

42. **Wastewater Infrastructure Planning and Land Use**. New wastewater infrastructure shall not be constructed, nor existing infrastructure expanded, in a manner that encourages or facilitates new development in vulnerable areas; rather, it shall encourage new development in areas safe from sea level rise and coastal hazards and be designed or limited to only accommodate new development and uses that are consistent with LCP provisions, including hazard provisions.

43. **Plan for Vulnerable Wastewater Outfalls.** By [insert date], a plan shall be required to repair, retrofit, relocate, or eliminate vulnerable wastewater outfalls, to prevent damage and impacts to water quality where sea level rise could affect the flow of wastewater from outfalls and lead to backup and inland flooding. Outfalls and pump stations for offshore outfalls that are below sea level, or are likely to be below sea level with sea level rise and/or high storm tides, shall be

eliminated, relocated, or retrofitted to prevent the entry of sea water and sand, to the extent practical. Evaluate whether or when the use of WWTP outfalls can be eliminated and the outfall removed, while accounting for current and potential future uses of the outfall to discharge brine or other lower salinity byproducts from recycled water or other advanced water treatment projects. Plan development shall include coordination with relevant stakeholders including but not limited to the California Department of Fish and Wildlife, California Fish and Game Commission, and the State Lands Commission, particularly for infrastructure within or adjacent to Marine Protected Areas.

44. **Recycled Water Management Plan.** A Recycled Water Management Plan shall be required when a wastewater treatment plant is constructed or redeveloped and prior to approval of increased use of an existing vulnerable outfall or development of a new outfall. The objective of the Plan shall be to ensure that the maximum amount of treated effluent is used for beneficial reuse purposes, with the ultimate goal of achieving 100% reuse. The Plan shall identify actions the operator will take within a five- and ten-year period to implement beneficial reuse, as well as specific milestones and projected timelines to implement the proposed actions. These actions may include developing programs and infrastructure for urban and agricultural reuse, groundwater replenishment, or other beneficial reuse that serves the community’s water needs and protects coastal resources. The Plan shall take into account the potential effects of sea level rise and potential aquifer seawater intrusion and shall specifically address replacing existing potable water use with recycled water use where feasible and appropriate. The asset operator shall submit updated Plans that describe progress made towards the goal of 100% reuse of treated effluent in subsequent five-year periods, and update actions and timelines for the upcoming five- and ten-year horizons.

45. **On-site Wastewater Treatment System (OWTS) Adaptation.** Avoid new septic systems in floodplains, sea level rise hazard areas, and tsunami run-up zones unless there is no feasible alternative way of serving the wastewater needs of existing structures. Analyze options for protecting health and water quality from septic systems that are failing or may fail in the foreseeable future due to sea level rise or coastal hazards in a manner that does not induce more development in areas subject to coastal hazards, including: removal of septic systems in hazardous areas, creating on-site wastewater management districts for identified problem areas, and retrofitting OWTSs. Where appropriate, encourage OWTS retrofits to include shutoff valves, which will make them resilient to saltwater intrusion in the near-term period. In the medium- to long-term period, allow for mounded septic systems or replacement of leach fields with holding tanks, where appropriate and feasible.

Groundwater Management

46. **Groundwater Basin Plan.** [Insert name of local government] shall 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, considering the impacts of sea level rise. Where relevant, work with groundwater sustainability agencies implementing groundwater sustainability plans to determine how and when sea level rise might raise groundwater levels or impair water quality.

47. **Limit Groundwater Extraction from Vulnerable Aquifers.** New development shall avoid extraction that, individually or cumulatively, causes or exacerbates overdraft of groundwater from aquifers that could increase susceptibility to saltwater intrusion. Approvals for new development shall consider the impacts that extraction could have on saltwater intrusion and avoid individual and cumulative impacts on fresh groundwater supplies.

48. **Relocate Vulnerable Well Facilities.** [The City/County] shall identify opportunities to relocate wells away from hazardous areas and/or areas where salinity is a problem or may become a problem with climate change and sea level rise.

49. **Restrict Development of New Wells in Sensitive Areas.** New well facilities shall not be sited in areas where saltwater intrusion could occur over the anticipated life of the development served by it, unless 1) there is no feasible alternative, 2) the well will not exacerbate the intrusion, and 3) treatment will render the water useful for its intended purpose.

50. **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 are suitable for the intended use of the development, considering potential impacts of sea level rise and saltwater intrusion upon groundwater supplies.

General Adaptation Planning

51. **Coastal Hazards Monitoring Plan.** When approving water infrastructure development in an area subject to current or expected future coastal hazards, require a Coastal Hazards Monitoring Plan to establish the framework and parameters for (1) regularly monitoring flood and other coastal hazards at the site, and managing responses to those hazards both on and off-site; (2) identifying how those hazards are affecting or will soon affect the operations of the water infrastructure; (3) identifying changes necessary to allow continued safe functioning of the water infrastructure; and (4) identifying flood, water quality, or hazard ‘triggers’ to establish when actions (such as retrofits, upgrades, and including infrastructure relocation) need to be pursued in response to specific hazard events, water quality concerns, or flood management activities. At a minimum, the Monitoring Plan shall include metrics for assessing site conditions and potential responses related to flooding, groundwater rise, and erosion as these may be influenced by coastal flooding and sea level rise during both typical and extreme storm events. Monitoring Plans shall account for increased frequency of inspection as coastal hazards threaten the integrity of the infrastructure.

52. **Nature-Based Adaptation Strategies.** Nature-based adaptation strategies with measurable environmental benefits shall be prioritized over strategies with additional coastal resource impacts, such as those associated with hard shoreline protective devices. Soft strategies (e.g., dune and wetland restoration, sand replenishment, and other options that do not fix the shoreline) shall be prioritized over hybrid armoring (e.g., strategies that fix the shoreline combined with natural features), and hybrid armoring shall be prioritized over hard shoreline protection. Hybrid armoring shall only be allowed if it complies with all of the requirements of the Shoreline Protection Devices **Policy 53**, except for the near-term danger requirement as specified in **Policy 53.a**. Instead of the near-term requirement, hybrid armoring may be allowed to protect infrastructure that is expected to be threatened by hazards in [insert appropriate planning horizon, consistent with relevant planning and funding cycles; e.g., 20-30 years], and shall be constructed with enough lead time for vegetation cover to establish or for other steps to be completed so the project can provide the benefits for which it was designed. In all cases, the least environmentally damaging feasibly alternative shall be selected.

53. **Shoreline Protection Devices and Long-Term Planning.** Permits for new hard or hybrid shoreline protection to protect water infrastructure shall include conditions requiring long-term sea level rise adaptation planning that protects public safety and coastal resources, and ensures structural stability of that infrastructure, in a manner that, if feasible, does not require the long-term retention of the protective device. Subject to specific criteria, and notwithstanding any other policy in the LCP, hard or hybrid shoreline protective devices may be permitted to protect existing, critical water infrastructure at near-term risk from erosion or flooding when there is no less environmentally-damaging feasible alternative, when designed to eliminate or mitigate adverse impacts on local shoreline sand supply, and provided that: (a) special conditions state that the permit will expire in [insert appropriate timeframe considering long-term planning needs], and that (b) a sea level rise adaptation plan must be submitted for review and approval by [list agency] prior to the end of the permit term. Prior to the end of the permit term, the applicant shall also submit a permit amendment application to implement the measures identified in the approved sea level rise adaptation plan. If a sea level rise adaptation plan is not approved, the permitted shoreline protective device may be required to be removed.

    a. **Hard shoreline protective devices shall be permitted when:** (1) needed to protect water infrastructure that is in near-term danger from coastal hazards; (2) there is no less environmentally damaging feasible alternative to the proposed shoreline protective device; (3) sited and designed to eliminate or mitigate adverse impacts on local shoreline sand supply; (4) sited and designed to avoid or minimize coastal resource impacts to the maximum feasible extent; and (5) all of the following standards are met:

        i. **Mitigation required.** Mitigation for impacts on all coastal resources shall be required. For shoreline protective devices on or adjacent to beaches, mitigation shall be required for all impacts, including impacts to public access and recreation, environmentally sensitive habitats, and shoreline sand supply that result from the footprint of the proposed shoreline protective device as well as from halted erosion that would have occurred over the life of the shoreline protective device. Mitigation shall minimize impacts to the extent feasible and fully compensate impacts that remain; and mitigation shall address impacts that will occur over the full life of the structure, but may be assessed in appropriate increments, rather than being required entirely up front. For shoreline protective devices on or adjacent to other coastal habitats (e.g., wetlands), appropriate mitigation shall be required to address impacts to wetlands and other coastal resources. In-kind mitigation shall be prioritized, although in-lieu fee mitigation may be appropriate, such as when used for programs developed to advance community-wide public access goals (for mitigating impacts to public access) and environmentally protective adaptation strategies. Mitigation shall be designed such that the benefits derived from mitigation are equitably distributed and/or increase benefits to communities that have traditionally lacked public access opportunities and the benefits associated with other coastal resources.

ii. **Maintenance and monitoring**. Shoreline protective devices constructed to protect water infrastructure shall be monitored and maintained in the permitted configuration to prevent increased impacts to public access, recreation, environmentally sensitive habitats, and other coastal resources.

iii. **Long-term planning**. Approvals of shoreline protective devices shall include a special condition requiring planning for a long-term solution. This condition shall require the Permittee to acknowledge that the CDP only authorizes the development for an initial, temporary period, during which time the Permittee must develop a longer-term Adaptation Plan that, if feasible and consistent with other applicable LCP policies, does not rely on armoring. Permit applications shall include a plan and timeline for the development of the Adaptation Plan. The Plan shall include, at minimum, possible options to explore as long-term solutions, including phased adaptation strategies as appropriate, a mechanism and process to choose the preferred long-term adaptation approach, and a reporting cycle with deadlines for action. The Adaptation Plan shall consider and prioritize retreat/avoidance strategies, followed by feasible nature-based adaptation strategies. The plan shall also consider measures to minimize greenhouse gas emissions and to ensure the benefits and impacts to environmental justice communities, disadvantaged communities, and economically depressed areas are equitable. The date by which adaptation plans shall be completed shall depend on the vulnerability of the water infrastructure and its potential to cause coastal resource impacts. If the segment or facility is expected to be vulnerable in the near-term, adaptation planning shall be required in the near-term, and the permit shall specify a completion date that allows an appropriate amount of lead time for permit review and implementation before impacts are expected to become significant.

iv. **Assumption of risk.** As a condition of temporary coastal permit approval for shoreline protective devices, applicants shall be required to acknowledge and agree to assume risks as required in **Policy 59** (Assumption of Risk, Waiver of Liability, and Indemnity Agreement).

v. **Maximize environmental benefits**. Any permitted shoreline protective device shall be constructed in a manner that maximizes environmental benefits. Such benefits shall not be considered the creation of habitats that require protection; when appropriate, such shoreline protective devices shall be removed as planned.

54. **Intergovernmental Coordination.** [The City/County] shall coordinate with regional partners on adaptation of vulnerable components of water collection and/or treatment infrastructure and shall develop related adaptation policies in accordance with other regional water planning efforts, such as Integrated Regional Water Plans, as well as relevant state water policies. For water infrastructure that crosses jurisdictional boundaries, coordination shall occur between local governments, utility managers, and state and federal agencies with jurisdiction over or interests in the service network.

55. **Support Recycled Water Use.** Development shall connect to reclaimed water lines when such lines are available and the substitution of reclaimed water for potable water uses is feasible.

56. **Innovative Funding Mechanisms.** Consider innovative funding mechanism such as Enhanced Infrastructure Finance Districts, water markets, risk reduction insurance, watershed assessments, and water surcharge fees to fund infrastructure projects and adaptation measures.

57. **Join or Create Joint Powers Authority.** Consider forming a joint powers agency or signing a joint powers agreement with other wastewater utilities or public works agency to allow regional public agencies to work together on managing and treating runoff and wastewater flows in adjacent jurisdictions. Consider these agreements to help finance regional public works projects, jointly purchase equipment, pursue grants to fund better services, start new programs, finance insurance pools, refinance member agencies' debts, or provide working capital by selling bonds.

58. **Environmental Justice Impacts.** [Insert name of local government] shall evaluate cumulative impacts to those populations from proposed water infrastructure plans and projects, including project alternatives, and evaluate whether adaptation proposals will result in inequitable distribution of benefits and burdens. [Insert name of local government] shall choose a final project plan or design that incorporates measures to avoid or mitigate project burdens in environmental justice communities to the maximum extent feasible.

Assumption of Risk Policy Note:

An important consideration for jurisdictions planning for sea level rise is that the public trust boundary will migrate inland in some locations as sea levels rise. As this occurs, infrastructure might come to be located on public trust property during its lifespan. LCP policies should recognize that development that comes to encroach on public trust land will likely cause new coastal resource and public trust impacts and will no longer be within the local jurisdiction's Coastal Act permitting authority. The development should therefore be conditioned to clarify that it does not allow encroachment onto public trust lands and that any such encroachment must be removed unless the owner of the structure obtains necessary authorization for it to remain from the Coastal Commission and the State Lands Commission or other tidelands trustee agency. In order to permit such structures to remain on public trust land, the Coastal Commission would need to find that they are consistent with Chapter 3 policies of the Coastal Act, and the State Lands Commission or other trustee agency would need to find, among other things, that they do not substantially impair public trust resources. Policy language may need to be modified based on whether infrastructure is located on public, private, or leased land.

59. **Assumption of Risk, Waiver of Liability, and Indemnity Agreement.** As a condition of coastal permit approval for water infrastructure in potentially vulnerable areas, applicants shall be required to acknowledge and agree: 1) that the development is located in an area with current or potential future coastal-related hazards, and may be subject to erosion, landslide, bluff retreat, flooding, waves, storm wave, tsunamis, and sea level rise; 2) to assume the risks of injury and damage from such coastal hazards in connection with the permitted development; 3) to unconditionally waive any claim of damage or liability against the [insert local government name, and Coastal Commission, if permit is appealed], its officers, agents, and employees for injury or damage from such hazards; 4) to indemnify and hold harmless the [insert local government name, and Coastal Commission, if permit is appealed], its officers, agents, and employees with respect to approval of the project against any and all liability, claims, demands, damages, costs (including costs and fees incurred in defense of such claims), expenses, and amounts paid in settlement arising from any injury or damage due to such hazards; 5) that the boundary between public trust land (tidelands) and uplands may shift with rising seas, the infrastructure may eventually be located on public trust lands, and the development approval does not permit encroachment onto public trust land; and 6) that any future encroachment must be removed unless the Coastal Commission determines that the encroachment is legally permissible pursuant to the Coastal Act and authorizes it to remain, and any future encroachment would also be subject to the State Lands Commission's (or other trustee agency's) leasing approval.

APPENDIX C.

Steps for Sea Level Rise Adaptation Planning

The Commission recommends six steps to address sea level rise as part of the development of an LCP, LCP Amendment, or other plan.

1. Choose a range of sea level rise projections
2. Identify potential sea level rise impacts
3. Assess risks to coastal resources and development
4. Identify adaptation measures
5. Draft updated or new LCP policies
6. Implement LCP, monitor, and revise as needed

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. Steps 1-3 are often referred to as a "sea level rise vulnerability assessment." As recommended in the Coastal Commission's *Sea Level Rise Guidance*, agencies should assess the vulnerability of Critical Infrastructure by using a range of sea level rise projections that are higher and longer than for many other types of coastal development. These vulnerability assessments should also consider impacts on people and property that rely on that infrastructure and potential impacts on broader community recovery from a hazard event. Step 4 refers to adaptation planning which, for infrastructure, may be able to build upon plans for other types of development. Steps 5 and 6 refer to implementation of adaptation policies.

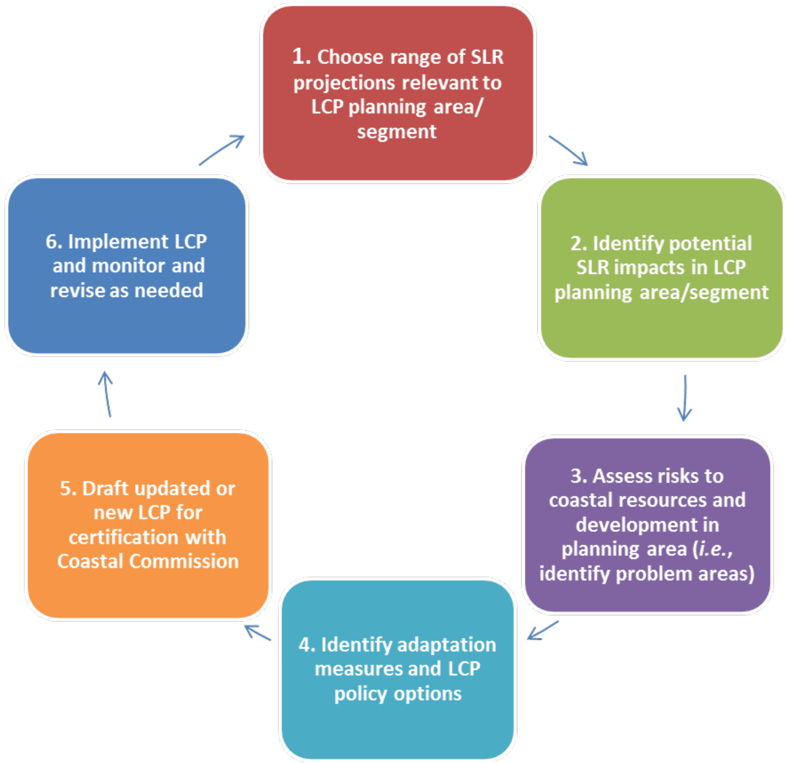


Figure C-1. Sea level rise adaptation planning process for new and updated Local Coastal Programs.

VULNERABILITY ASSESSMENT

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of coastal hazards intensified by climate change, including climate variability and extremes. A vulnerability assessment is a science-based effort to identify how and why resources are likely to be affected by future climate conditions and coastal hazards.

There are three main factors for understanding vulnerability: (1) exposure; (2) sensitivity; and (3) adaptive capacity. Exposure refers to the degree of hazard the resource will experience. Sensitivity is a measure of whether and to what extent a resource will be affected by a hazard. Lastly, adaptive capacity is the ability of the resource to accommodate the hazard impacts with minimal disruption. More exposure or higher sensitivity increases vulnerability, while more adaptive capacity reduces vulnerability. Many vulnerability studies use this approach to quantify the vulnerability of assets to future hazards (see Appendix D).

Vulnerability

Degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change.

Scientific literature, government reports, and other local data sources provide information about sea level rise vulnerabilities by sector for each of California's coastal counties (See Table D-1 in Appendix D). Coastal Commission staff conducted a statewide assessment of coastal infrastructure vulnerability and documented data sources in Appendix D. A notable finding from the statewide assessment is that transportation infrastructure is vulnerable in every coastal California county. In addition, every county has at least some elements of water infrastructure that are vulnerable to sea level rise impacts, whether wastewater treatment, stormwater drainage, or water supply-related. However, as discussed, it will be important to evaluate not only the extent of vulnerable facilities and service areas, but also their sensitivity and adaptative capacity.

Figure C-2 shows level of exposure by county as measured by the area of infrastructure vulnerable to inundation by 5 feet of sea level rise along California's coast (Heady *et al.,* 2018). Transportation infrastructure encompasses highways, major and minor roads, and railways. Other infrastructure corresponds to area of wastewater treatment plants, levees, and artificial shore. While Sonoma, Marin, San Francisco, and San Mateo Counties have a considerable amount of vulnerable infrastructure (non-transportation infrastructure in particular), much of that infrastructure is along San Francisco Bay, outside of the Coastal Commission's jurisdiction. What is most notable is the high level of vulnerability for transportation-related infrastructure.

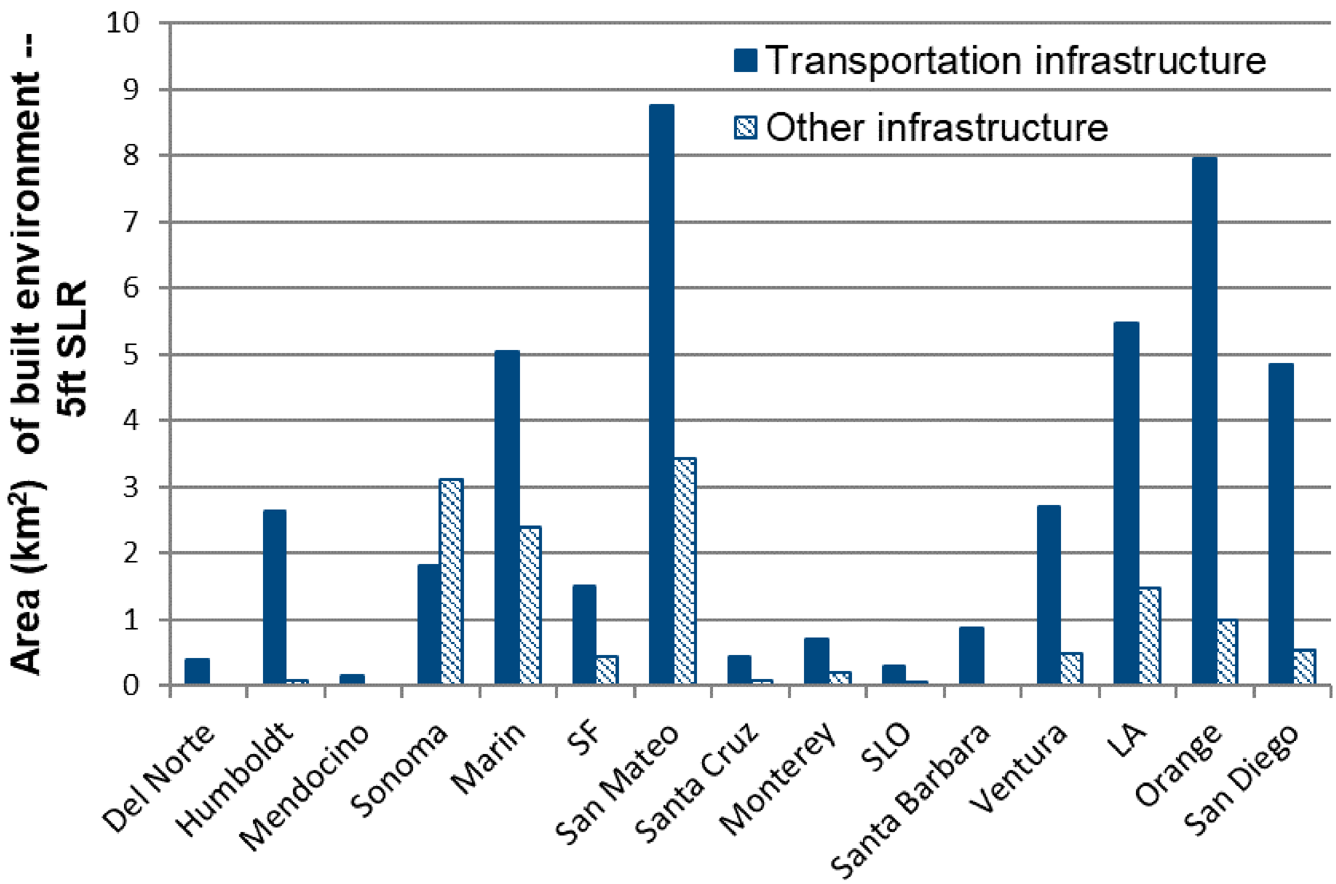


Figure C-2. Area (km^2) of built environment within 5ft of SLR analytic zone according to county (Source: Heady *et al*. 2018). Marin, Sonoma, and San Mateo counties include the Bay side as well as the Pacific coast.

Although transportation infrastructure generally has a larger area of exposure to sea level rise, in the near-term, it tends to have less sensitivity and more adaptive capacity than other types of infrastructure. For example, transportation sensitivity can be lower because a flooded road or train tracks can often be returned to service once cleared of water and debris. Furthermore, transportation may have more adaptive capacity than other types of infrastructure because traffic can often be rerouted along less hazardous corridors. However, with more sea level rise, flooding may become too frequent to make vulnerable corridors usable. In addition, there are some stretches of coastline where transportation infrastructure has limited adaptive capacity. For example, when the southern access to Big Sur via Highway 1 collapsed in a deep-seated landslide in 2017, a 30-mile stretch of Big Sur was isolated from the rest of California and became accessible only by helicopter.

In contrast to roadways, wastewater treatment plants tend to have a smaller footprint that is exposed to flooding, but significantly higher sensitivity and less adaptive capacity. Flooding at a wastewater treatment plant can create more long-lasting, public health-related, or costly damage than a flooded road. In addition, wastewater plants typically have no redundancy because they are not connected to other plants; rather, they operate as a single collection system that does not have a back-up if something goes wrong.

RISK EVALUATION

Risk is a term that accounts for the likelihood and consequences of damage; risk is frequently examined in vulnerability assessments. When examining risk for infrastructure, it is important to look at both the risks to the infrastructure itself as well as the impacts to the people and development that rely upon the infrastructure.

Risk aversion, or the inclination to avoid taking risks in the face of uncertainty, influences how decision makers and communities take action. State and local governments should consider the risks associated with various sea level rise projections and determine their tolerance for, or aversion to, those risks. Similar to the recommendation in the *State of California Sea-Level Rise Guidance* from OPC (2011 and 2018), the Commission does not recommend using sea level rise projections solely from the lower end of the ranges, as this does not give a full picture of the potential risks. Looking instead at a range of projections provides a fuller understanding of the overall risk that sea level rise poses to a region or site now and in the future. In general, as recommended in the Commission's *Sea Level Rise Guidance*, major infrastructure should assume a long life expectancy and evaluate impacts related to medium high and extreme sea level rise projections due to the community-scale importance of these facilities and the potential effects of their failure.

Risk Considerations

Risks are evaluated relative to sea level rise projections.

A range of sea level rise projections provide a better understanding of the overall risks.

The *State of California Sea-Level Rise Guidance (OPC 2018)* specifies that assessing risk requires evaluating two dimensions: 1) uncertainty, which can be analyzed and assessed using a range of sea-level rise projections, and 2) impacts or consequences, which may require a combination of quantitative and qualitative assessments. Consequences for critical infrastructure should encompass potential damage, as well as service disruption and cost. Economic costs of service disruption and repairing or replacing assets can be estimated quantitatively, but qualitative assessments are also necessary to describe non-monetary impacts, such as damage to natural environments when infrastructure fails, or understanding whether there is an inequitable distribution of burdens among different populations served by the infrastructure.

Risks are reduced through adaptation planning. By planning ahead, communities can mitigate or avoid 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.

ADAPTATION PLANNING

Adaptation strategies generally fall into three main categories – protect, accommodate, and retreat. Although strategies continue to evolve or be developed, many have long been used to address coastal hazards like flooding and erosion.

- **Protect:** Protection options include those strategies in which a physical barrier is constructed to essentially keep water (either from flooding or from short and long-term erosion) away from a structure. This includes both hard shoreline protective devices – such as seawalls, rock revetments, bluff retaining devices, groins, levees, and so on – as well as “soft” or “green” strategies – those features that rely on natural components and processes to provide protection, such as constructed or restored dunes, beach nourishment, vegetation, oyster beds, and the like.
- **Accommodate:** Accommodation strategies are those in which the asset itself is designed to better withstand the impacts from coastal hazards. This could include engineering structures to be physically stronger, such as building with stronger materials (cement, steel, etc.), or using caissons or foundations that ensure stability. It also includes options that allow structures to work with changing water conditions. For example, roads, bridges, various components of wastewater treatment plants,

Adaptation Planning

Adaptation measures are strategies, such as physical alterations or planned triggers for future changes, that effectively address coastal hazard risks to development or habitats over time. Adaptation strategies must also protect coastal resources consistent with Coastal Act requirements.

and other infrastructure can be elevated above a certain flood level, generally to protect against storm conditions or extreme tides, while piers and docks can be designed to float up and down as the tide changes throughout the day. Note that some accommodation strategies, including use of stronger materials or deep caissons, may result in the asset itself acting like shoreline protection, resulting in coastal squeeze.

- **Retreat:** Retreat strategies are those in which assets are moved out of harm's way. This includes both removing or relocating existing structures that are in danger from hazards, as well as siting new development to avoid hazardous areas so that it will be safe over its anticipated lifetime without requiring additional adaptation measures. Due to the connectivity and linkages of most infrastructure systems, retreat strategies may need to address not just the portions that will be at-risk, but also adjacent segments so that the whole system can continue to function.

In practice, hybrid approaches may be taken in which strategies from each category are used together on a single site to address different levels of risk, or different strategies may be phased and implemented over time to address changing conditions. Examples of such hybrid approaches to address coastal hazard risks to critical infrastructure are common throughout California (see Appendix E for several case studies, and Appendix F for an overview of nature-based adaptation strategies). For example, Highway 1 and coastal wastewater treatment plants are protected in many places by seawalls or rock revetments to guard against erosion impacts, as well as elevated to protect against daily tidal inundation or occasional storm flooding. The recently completed Cardiff Beach Living Shoreline Project is an example of hybrid armoring that combines a soft strategy (restored dunes) with a hard shoreline protective device (buried revetment) to provide protection against day-to-day conditions as well as extreme storm events for Highway 101 (see Appendix E Case Study 1). Other examples highlight the need for adaptation strategies to be phased over time. For example, portions of Highway 1 near Piedras Blancas were protected by temporary armoring as planning for realignment occurred. Similar phased strategies are currently being planned for other portions of Highway 1 as well as several wastewater treatment plants.

Importantly, each adaptation strategy carries with it its own benefits and costs. A fundamental challenge of sea level rise adaptation planning is that resource needs are often in direct competition, and adaptation planning choices can approach a zero-sum scenario. The most direct example of this is the choice between protecting built structures and allowing for the continuation of natural processes. On undeveloped shorelines, natural habitats like beaches and wetlands can migrate upwards and inland as sea levels rise (assuming the local geology and sediment dynamics allow for it). However, development, including structures like houses, infrastructure, and the armoring necessary to protect development, forms a barrier to this natural migration. On shorelines where the back of the beach is "fixed" by development, beaches and wetlands will eventually drown and be completely lost as sea levels rise. Strategies, including nature-based adaptation, allow for protection of development and continuation of natural habitats for a period of time, but as sea levels rise, eventually one of these resource types will lose out.

This balancing act between competing resource needs is not a simple exercise, as it involves consideration of technical, legal, economic, and political feasibility, as well as both social and environmental needs. There are no easy answers, and the inherent characteristics of critical infrastructure make the questions even more complex. But the goal of LCP planning processes must be to identify an appropriate, feasible, fair, and equitable approach that balances all these factors both now and into the future. Critically, adaptation planning needs to evaluate all costs and benefits of various options being considered, including non-market and other values that can sometimes be more difficult to quantify (e.g., the inherent value of a beach). Adaptation planning works best when all such options are evaluated at a similar level of analytic detail.

APPENDIX D.
Vulnerability Information

Table D-1. Vulnerabilities to future sea level rise identified by county. Sources include Coastal Commission Statewide Vulnerability Synthesis (2016) and Heberger et al. 2009.

County	Communications	Energy Facilities	Gas Lines	Power Lines	Transportation	Stormwater	Wastewater Treatment	Water Supply
Del Norte				Y	Y		Y	
Humboldt	Y	Y	Y	Y	Y	Y	Y	Y
Mendocino					Y			**
Sonoma					Y			
Marin					Y	Y	*	**
San Francisco					Y	Y	Y	
San Mateo					Y	Y	Y	
Santa Cruz		Y	Y	Y	Y		Y	
Monterey		Y	Y	Y	Y	Y	Y	Y
San Luis Obispo			Y	Y	Y		Y	Y
Santa Barbara		Y	Y	Y	Y	Y	Y*	Y
Ventura		Y	Y	Y	Y		Y	
Los Angeles	Y	Y	Y	Y	Y	Y	Y	Y
Orange		Y	Y	Y	Y	Y	Y	
San Diego		Y	Y	Y	Y	Y		

* Vulnerable OWTS   ** Vulnerable Wells

Table D-2. Data sources and stakeholder agencies for vulnerability information by infrastructure type.

Infrastructure Type	Data Source	Citations
Communications	Internet infrastructure from Internet Atlas project	Durairajan, Barford, and Barford. 2018. Lights Out: Climate Change Risk to Internet Infrastructure.
Critical Facilities (fire, police, medical, etc.)	Facilities, Modeled for Pacific Institute	Heberger, *et al*. 2009. *The Impacts of Sea-Level Rise on the California Coast*. Prepared by the Pacific Institute for the California Climate Change Center.
Energy Facilities	Coastal Energy Facilities, Modeled for Pacific Institute	CEC GIS Unit, QFer, WRPS, REAT, Siting Office, Compliance Office and GeoScience; Pacific Gas and Electric Company, 2016, Climate Change Vulnerability Assessment and Resilience Strategies.
Energy/Gas pipelines Energy/ Transmission lines	California Energy Commission, 2012. CEC GIS Unit, Energy Assessments Division, PennWell, NPMS, PG&E, SoCalGas, SDG&E; REAT, Caliso, PG&E, SCE, SDG&E, LADWP, WAPA, IID, SMUD, MID, MWD, GE, Platts, ANZA Electric Cooperative, Bear Valley, City of Anaheim PUD, City of Colton, City of Vernon, Plumas Sierram PUC, Riverside Public Utilities, and Silicon Valley Power	Radke, J. D., *et al*. (University of California, Berkeley). 2016. *Assessment of Bay Area Natural Gas Pipeline Vulnerability to Climate Change*. California Energy Commission. Publication number: CEC-500-2017-008 Sathaye, J., Dale, L., Fitts, G., Larsen, P., Koy, K., Lewis, S., & Lucena, A. (2011). *Estimating Risk to California Energy Infrastructure from Projected Climate Change* (No. CEC-500-2011-XXX). California Energy Commission. California Coastal Commission. 2016. *Statewide Sea Level Rise Vulnerability Synthesis.*

Table D-2 Continued.

Infrastructure Type	Data Source	Citations
Ports, Airports, Ground Transportation (Road, Rail)	Modeled for Pacific Institute USGS Hazard Exposure Reporting and Analytics (HERA) application Caltrans	Heberger, *et al*. 2009. *The Impacts of Sea-Level Rise on the California Coast*. Prepared by the Pacific Institute for the California Climate Change Center. Roads and rails – Jones, J.M., Wood, N., Ng, P., Henry, K., Jones, J.L., Peters, J., Jamieson, M., 2016, *Community Exposure in California to Coastal Flooding Hazards Enhanced by Climate Change*, reference year 2010: U.S. Geological Survey data release, http://dx.doi.org/10.5066/F7PZ56ZD Caltrans vulnerability assessments and adaptation priorities reports and the draft 2021 Draft State Highway System Management Plan (SHSMP): https://dot.ca.gov/programs/asset-management/state-highway-system-plan California Coastal Commission. 2016. *Statewide Sea Level Rise Vulnerability Synthesis.*
Wastewater Infrastructure/ Stormwater Infrastructure	Wastewater Treatment Facilities, Modeled for Pacific Institute; list from State Water Resources Control Board; US Environmental Protection Agency	Heberger *et* al. 2009. *The Impacts of Sea-Level Rise on the California Coast*. Prepared by the Pacific Institute for the California Climate Change Center. California Coastal Commission. 2016. *Statewide Sea Level Rise Vulnerability Synthesis*. State Water Resources Control Board List of NPDES dischargers (Pers. Comm, June 22, 2017)

Table D-2 Continued.

Infrastructure Type	Data Source	Citations
Water Infrastructure	California State Water Resources Control Board	California Drinking Water Watch website. https://sdwis.waterboards.ca.gov/PDWW/ Water Boards Data and Databases. (Page last updated 4/27/20). https://www.waterboards.ca.gov/resources/data_databases/drinking_water.html Department of Homeland Security (DHS). 2015 Water and Wastewater Sector-Specific Plan. https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf California Coastal Commission. 2016. *Statewide Sea Level Rise Vulnerability Synthesis*.

Table D-3. California wastewater treatment facilities (excluding San Francisco Bay) and infrastructure components at risk from sea level rise-related impacts**. Data sources for Table D-3 include State Water Board staff, Coastal Commission staff, Heberger et al. (2009), and a variety of vulnerability assessments and coastal development permits. Note that these descriptions are not comprehensive assessments of all potential vulnerabilities.

County	Treatment facilities	Potential vulnerability to sea level rise
Del Norte	Crescent City Wastewater Treatment Facility*	The City's wastewater treatment plant and discharge, originally constructed in the late 1950's, underwent a major Wastewater Treatment and Disposal System upgrade in 2010 (Municipal Service Review 2011). The plant is located adjacent to the ocean (on a section of the coast where offshore bathymetry concentrates wave energy) and is vulnerable to sea level rise. According to its current NPDES permit, the facility is preparing a Climate Change Readiness Study Plan (to be done by 2021). While this WWTP is the only large-scale plant in Del Norte County, there are other community systems that are vulnerable, such as a community leach field system located on the Klamath River.
Humbolt	McKinleyville CSD WWTF	The McKinleyville CSD Wastewater Treatment Facility is located in Humboldt County and discharges treated wastewater year-round to the mouth of the Mad River and to a percolation basin adjacent to the Mad River at its mouth. Recycled wastewater is also beneficially used for irrigation of low-lying agricultural areas near the Mad River. Higher tides associated with sea level rise will further impair the drainage of the Mad River, thereby increasing backwater flooding and expanding the floodplain over time.
	Arcata Municipal Wastewater Treatment Facility*	The most critical and vulnerable asset in the City of Arcata is its wastewater treatment facility, which is located on Humboldt Bay and discharges to the bay. The WWTP is vulnerable to flooding at the current sea level. The treatment system is separated from the bay by a system of barrier levees, 1.1 miles of which would be overtopped by three feet of sea level rise (or a combination of two feet of sea level rise and King Tides). The WWTP is also increasingly vulnerable from backwater flooding. (City of Arcata Vulnerability Assessment, 2018)

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
Humbolt	Greater Eureka Area/ Elk River Wastewater Treatment Facility [PI]	Commissioned in 1984, the Elk River Wastewater Treatment Plant serves the City of Eureka and surrounding unincorporated areas. The plant is located on Humboldt Bay near the mouth of the Elk River and discharges to the bay. Increased coastal erosion has already required emergency armoring to protect the City's Crosstown Interceptor (a major sewer main that runs along the bayfront) and the bay outfall pipe. In addition, the collection system serves some of the most low-lying developed areas around Humboldt Bay and due to significant inflow and infiltration into the collection system during storm and high-tide events, Eureka's treatment plant often approaches the peak wet weather design flows during storm and high-tide events and is under a cease-and-desist order in part from blending primary and secondary treated wastewater when flows are high. Additional infiltration is predicted to occur from increased tidal and stormwater flooding and elevated groundwater levels under sea level rise scenarios.
	Loleta Wastewater Treatment Facility	The Loleta Wastewater Treatment Facility is located in Humboldt County and discharges treated wastewater year-round to a wetland tributary of the Eel River. Higher tides associated with sea level rise will further impair the drainage of the Eel River, as well as the tributaries and stormwater runoff that discharge to the river, thereby increasing backwater flooding and expanding the floodplain over time (CDP Application No. 1-17-0200). In Humboldt County there are smaller community systems that are also at increased vulnerability due to sea level rise, such as a number of systems in the Eel River basin.

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
San Francisco	Oceanside Water Pollution Control Plant*	Built in 1993, the Oceanside Waster Pollution Control Plant is the one San Francisco treatment facility on the outer coast, and treats 20% of the City’s wastewater. While this facility is relatively new and sited inland of the Great Highway that runs along the western shore, coastal erosion could damage the Lake Merced Tunnel that collects sewage and stormwater for the Oceanside Treatment Plant. Under high SLR projections (55 inches by 2100), the seven westside combined sewer discharge (CSD) weirs will still be above the estimated sea level rise by 2100, but the shoreline will be subject to more erosion if not protected (SF Sewer Master Plan 2010). Consequences of erosion of the Lake Merced Tunnel include potential sewage spills, disrupted treatment operations, and a decrease in storage for the plant (Coastal Protection Measures & Management Strategy for South Ocean Beach, 2015).
San Mateo	Mid-Coastside Sewer Authority[*,PI]	The Sewer Authority Mid-Coastside Wastewater Treatment Plant is presently subject to groundwater intrusion, and can be vulnerable to creek backup caused by heavy rainfall that coincides with high tides (San Mateo County SLR Vulnerability Assessment Asset Vulnerability Profile). The San Mateo County Vulnerability Assessment also found that the plant is vulnerable to storm flooding (100-year storm) with 6.6 feet of SLR. Additionally, 22% of storm drains, 63% of stormwater pump stations, and 49% of outfalls could be exposed to flooding under storm flooding (100-year storm) with 3.3 feet of SLR.

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
Santa Cruz	Santa Cruz Wastewater Treatment Plant [PI]	Santa Cruz Wastewater Treatment Plant operators face two natural hazards: flooding from Neary Lagoon and high groundwater levels, which push against the underground tanks and cause cracking (City of Santa Cruz Climate Adaptation Plan Update 2017-2022). The plant deals with high groundwater levels on a regular basis (City of Santa Cruz City Climate Change Vulnerability Assessment, 2011).
	Watsonville Wastewater Treatment Facility [PI]	The Watsonville/Pajaro Valley area faces groundwater contamination by saltwater intrusion. The Watsonville Wastewater Treatment Facility is vulnerable by 2100 to storm flooding under high SLR scenarios of 58 inches as well (Coastal Resilience, California). In 2010, the City of Watsonville completed its upgrade of the wastewater treatment plant to include tertiary treatment for water reuse, to reduce effluent discharge in the Monterey Bay and to protect against seawater intrusion. The wastewater is treated to the advanced secondary treatment level for ocean discharge, and advanced tertiary treatment for direct food crop irrigation.
Monterey	Carmel Area Wastewater District Wastewater Treatment Plant [*,PI]	The Carmel Area Wastewater District owns and operates a wastewater plant and collection system located in a low-lying area adjacent to the Carmel River Lagoon in Carmel-by-the-Sea. The Carmel Area Wastewater District Wastewater Treatment Plant is potentially threatened by Carmel River flooding, closed lagoon inundation with moderate storms, backwatered lagoon inundation, groundwater intrusion, and ocean inundation/erosion. A 2018 Carmel Area Wastewater District Sea Level Rise Study assessed force mains, gravity mains, and structures such as the pump stations, in addition to the treatment plant. The study indicated that storm flooding threatens the plant in 2050 with 2 feet SLR and inundation, as well as storm flooding by 2100 (with 6 ft. SLR). Erosion under these scenarios threatens force mains and gravity sewers in the collection system.

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
San Luis Obispo	San Simeon WWTP *	The San Simeon WWTP is located in a low-lying area that is just above the beach and sea level on a low bluff that is also located just above and adjacent to Arroyo del Padre Juan Creek. This area is subject to coastal hazards related to ocean and creek flooding, and has a history of unpermitted revetments to protect against flooding. In addition, more recent repairs to the outfall indicate that as recently as 2010 the outfall had failed in one section and released treated sewage (disinfected secondary effluent) onto the beach and into the surf zone. A recent CDP (see CDP Application No. 3-15-2214) included special conditions requiring development of a long-term plan to address coastal hazards.
	Morro Bay – Cayucos Wastewater Treatment Plant*	Morro Bay's existing wastewater treatment plant is located within a flood hazard zone and in the expected sea level rise inundation zone. While the plant is not expected to be permanently underwater, occasional flooding and inundation may be damaging. The Coastal Commission approved a new treatment facility in a new location to replace the current plant (CDP Application No. 3-19-0463).
	City of Pismo Beach WWTP	State Water Boards staff noted the City of Pismo Beach WWTP may meet vulnerability criteria. The WWTP is located near Pismo Creek and partially situated within the FEMA regulatory floodway. Distribution pipelines and facilities extend throughout the city, and some key facilities like sewer pump stations have recently necessitated the armoring of bluffs for their protection. (Draft City of Pismo Beach Sea Level Rise Vulnerability Assessment)
	Avila Beach Community Service District WWTP	State Water Boards staff noted the Avila Beach Community Service District WWTP may meet vulnerability criteria. There is no existing treatment redundancy at the site as existing biological treatment system cannot be taken out of service, it is an aging facility, and future needs are projected to be beyond existing capacity.
	South San Luis Obispo County Sanitary District WWTP *	The WWTP site and several of the existing buildings and critical facilities are currently at elevations where they may be subject to rare flooding currently, and flooding is expected to increase in frequency with sea level rise. The existing access to the WWTP is at a low elevation and it is likely to be regularly impacted by 2050 (CDP Application No. 3-16-0233).

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
Santa Barbara	Santa Barbara (El Estero) Wastewater Treatment Facility *,PI	A Santa Barbara vulnerability assessment updated in 2020 shows the El Estero Wastewater Treatment Plant partially in the tidal inundation and storm flooding hazard zones by 2100, and the Charles E. Meyer Desalination Plant at least partially exposed to the tidal inundation and storm flooding hazard zones by 2100. However, due to tidal inundation of the infrastructure associated with these plants, as well as portions of the plants themselves, both the El Estero Wastewater Treatment Plant and the Desalination Plant will be permanently inoperable by 2100 if no action is taken. Tidal inundation of some of the wastewater piping system flowing into the plant will occur by 2060 if no action is taken. Additional analysis is needed to determine how much this will interrupt operations of the plant.
	Montecito Sanitary District WWTP	State Water Boards staff from Region 3 noted the Montecito Sanitary District (MSD) WWTP may meet vulnerability criteria. Maintaining groundwater supply and saltwater intrusion are concerns in the area.
Ventura	Oxnard Wastewater Treatment Plant *	The City of Oxnard owns and operates its own wastewater collection and treatment system, including the Oxnard Wastewater Treatment Plant (OWTP). Final effluent is routed to the City's Advanced Water Purification Facility (AWPF) to recycle water or is conveyed to the Pacific Ocean and discharged offshore. The OWTP is vulnerable to tidal inundation and storm flooding by 2100 under high sea level rise scenarios of 58 inches (Coastal Resilience Ventura 2013 Technical Report). The existing storm drain system also lacks sufficient capacity to convey the 100-year design storm runoff while meeting the flooding criteria.

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
Los Angeles	Hyperion Wastewater Treatment Plant (outfall pipes)*	The Hyperion Wastewater Treatment Plant (HTP) is located next to Dockweiler State Beach at ~32 feet above sea level. HTP is sensitive to storm-related flooding which could cause equipment and operations failures due to damage of electrical pumps and panels from exposure to water. Significant increases in sea level could reduce the plant's efficiency in the discharge of effluent because the pumped flow would be met with more water pressure. While erosion could result in some loss of the beach in front of the plant, the plant itself is not very sensitive to erosion or interaction with the groundwater because it is built on top of a large cement catacomb. However, localized flooding and damage to equipment and the structure of the facility is possible during extreme wet weather, if there are failures to critical individual unit processes, failure of effluent pumping, or failure of influent bypass pumping of influent sewer flow. Damage to process control operations (secondary treatment) is possible from extreme wet weather washout. (City of LA SLR Vulnerability Assessment, pg. 21.)
Orange	Orange County Sanitation District Plant 2 [PI]	According to a 2014 Vulnerability Assessment, there is potential for widespread inundation across large portions of northern Huntington Beach in the vicinity of Huntington Harbour and Bolsa Chica by 2100 (under 5.5 ft. SLR). Critical facilities such as the Orange County Sanitation District (OCSD) wastewater treatment facility in south Huntington Beach are vulnerable to tidal inundation, extreme wave events, and stormwater runoff. The primary risk to wastewater infrastructure in this planning area is from inundation of City-owned and Sunset Beach Sanitary District lift stations, and high groundwater levels causing increased inflow and infiltration into the collection system which may potentially reduce capacity at lift stations or treatment facilities. Stormwater infrastructure is also likely to be vulnerable under this 5.5 ft. SLR scenario, so more study of the following is recommended: Performance impact on pumps due to higher tail water elevation; potential for flow-reversals due to higher tail water elevation; and buoyancy effects on underground vaults due to higher groundwater levels. (City of Huntington Beach Sea Level Rise Vulnerability Assessment, 2014)

Table D-3 Continued.

County	Treatment facilities	Potential vulnerability to sea level rise
San Diego	Point Loma Treatment Facility [β]	The 2018 San Diego Summary Report for California's Fourth Climate Change Assessment found wastewater infrastructure is also vulnerable to coastal flooding with SLR and can be particularly impactful when also associated with a large storm. Sanitary sewers in low-lying locations will be vulnerable to floodwater inflow, which could exceed their capacity, potentially resulting in discharge of wastewater to the Bay. Note, in all scenarios, storm sewers are highly vulnerable to flooding and inundation in the Bay due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas. The 2019 City of San Diego State Lands Sea Level Rise Vulnerability Assessment found up to 90 stormwater outfalls, 2 stormwater drain pump stations, 17 of 23 wastewater pumps, 361 of 436 wastewater pipes, and 205 of 226 water pipe segments will be vulnerable to flooding from sea level rise and storm surge by 2100. No water pipe or wastewater pipe segments face exposure to cliff erosion and 23 to 24 water pipe segments and 16 wastewater pipe segments face exposure to shoreline erosion, depending on whether adaptive actions are taken.

* California Coastal Commission. 2016. *Statewide Sea Level Rise Vulnerability Synthesis*.

[PI] Vulnerability according to Pacific Institute's study (Heberger *et al*. 2009).

[β] Coastal plants (such as Point Loma) are designed for coastal impacts, so all equipment is marine rated (e.g., units are housed to prevent corrosion) (City of San Diego Sea Level Rise Vulnerability Assessment – Draft, 2019). The Point Loma Treatment Facility is not vulnerable to SLR flooding.

** Note: the descriptions of vulnerabilities reflect recent sea level rise assessments and staff knowledge, but are not comprehensive assessments of all vulnerable wastewater infrastructure or of potential issues at a facility level.

APPENDIX E.
Case Studies

CASE STUDY 1. CARDIFF STATE BEACH LIVING SHORELINE PROJECT

Transportation Adaptation Example	
Infrastructure at Risk: Coastal erosion and flooding along Highway 1 in Encinitas, San Diego County	**Adaptation Method**: Nature-based adaptation strategy consisting of engineered dune system over buried revetment
Term of Strategy: Interim Adaptation Strategy completed in 2019 with a projected life of approximately 30 years to allow time to plan for longer-term adaptation	**Implementing Entities**: State Coastal Conservancy, the City of Encinitas, California State Parks, and the Nature Collective
This is an example of a nature-based adaptation strategy that included years of coordination by City of Encinitas with State Parks, Caltrans, other state and local agencies, stakeholders, science advisors, and the community that resulted in a project consisting of a native dune system over a buried revetment on State Parks property. Grant funding was obtained to support this project.	

Summary

The Cardiff State Beach Living Shoreline Project, constructed in the winter of 2018-2019, is an example of how a nature-based adaptation strategy can be used to address coastal hazards exacerbated by sea level rise for a stretch of highway. The project consists of an engineered dune system and cobble toe on top of a buried revetment. The project is intended to accrete and erode with the seasons and provide a natural buffer for Highway 101 while preserving coastal views, improving access, and creating habitat. Existing, degraded rip rap was reconfigured and supplemented with 9,000 cubic yards of rock, in a manner consistent with Sections 30235 and 30253 of the Coastal Act. The armoring is intended to act as a last line of defense for the existing development, Highway 101, which is a critical component of the region's transportation network, until approximately 2050. Beyond 2050, it is anticipated that implementation of a long-term solution will be needed.

The project was proposed and implemented by the City of Encinitas (the City) in partnership with the State Coastal Conservancy, California State Parks, and the Nature Collective (formerly San Elijo Lagoon Conservancy) on Cardiff State Beach in San Diego County to protect a city-owned stretch of Highway 101. The State Coastal Conservancy led project development, including obtaining funding, coordinating a regional science advisory committee, helping prepare final design and plans for grading, and finalizing all required environmental permits.

The project serves as an important pilot of nature-based adaptation strategies for the region and state. The Cardiff Living Shoreline provides many co-benefits, including aesthetics, habitat enhancement and recreational opportunities, while longer-term adaptation strategies are developed to address the hazards posed by sea level rise.

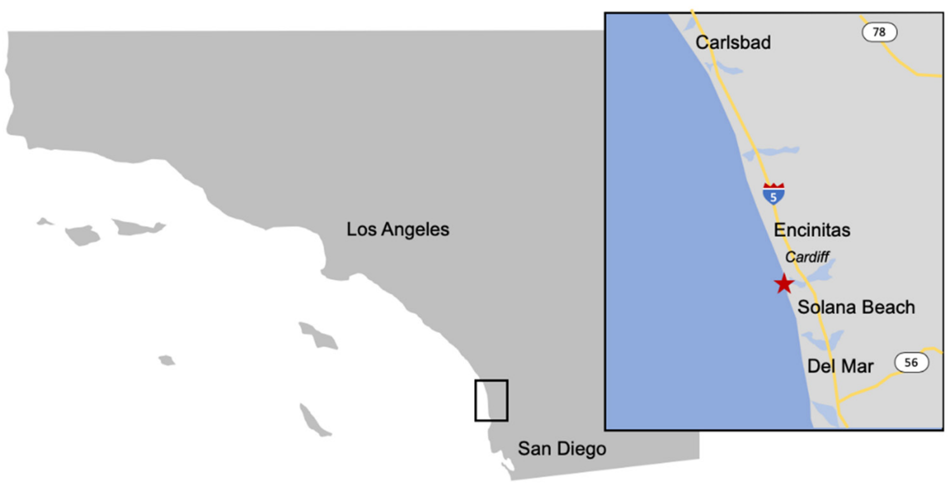


Figure E-1. Cardiff Living Shoreline Project Location.

Background

Undermining and flooding of Highway 101 caused by large waves during high tides led to several closures and substantial maintenance needs for the City of Encinitas. This project was designed to address those coastal hazards while restoring dune habitat and improving beach access along the highway. The project is a pilot study for the region and the state and builds off similar engineered dune-cobble systems in Ventura, CA (see Surfer's Point Case Study).

Previous feasibility studies in the late 1990s for this stretch of coast suggested using a traditional rock revetment; however, concerns over the cost (~$20 million) and impacts to coastal resources (such as beach ecology and coastal access) led the City to abandon the approach for armoring the shoreline and continue the strategy of closing the roadway during high wave events and doing emergency maintenance after roadway damage. In the early 2010s, the State Coastal Conservancy funded a study to look at the efficacy of a dune system to address the hazards to the coastal highway.

Figure E-2. Flooding of Highway 101 along Cardiff State Beach (Cardiff Beach Living Shoreline Project Final Feasibility Study, 2016).

Coordination

Early on, staff from the State Coastal Conservancy, City of Encinitas, California State Parks, and the California Coastal Commission (CCC) as well as the non-profit Nature Collective, the City's consultants and researchers from UCLA and Scripps Institute of Oceanography discussed each agency's goals for the project, outlining potential concerns and addressing questions before much of the design was even started. For example, these discussions resolved CCC concerns about the extent and sizing of the proposed armoring to be buried, resulting in an agreement to minimize the amount of additional rock added while maintaining a backstop to address the concerns of the City if the project were to fail unexpectedly. Partner discussions also led to an expansion of the initial goals to include enhancing access through pedestrian and bike paths. Partners were also able to come to consensus that this project was a pilot for the region and the state and that it would also be an interim solution to a longer-term adaptation strategy.

Design

The Cardiff site posed several constraints to the construction of a typical dune system that was historically found in Southern California. For the development of alternatives, the design team drew upon existing California dune areas and, to the extent possible, guidance from the design of East Coast dune systems. The East Coast dune systems can be significantly different from the native dunes found on the West Coast due to different native dune vegetation, wave climates, and beach conditions; this makes applying technical guidance developed for East Coast dunes difficult for California. Because of these limitations, the design team used a numerical model, XBeach, to assess the performance of design alternatives. The alternative selected was found sufficient to protect the road during 100-year sea conditions (large waves during high tides) at 2016 sea levels and during approximately 50-year sea conditions with two feet of sea level rise.[41] Some of the design constraints of the dune-system were the backshore position of the parking area and newly constructed pedestrian/bike path, maximum dune crest elevations to protect scenic viewsheds along the highway, and the need to maintain sufficient 'towel space' of dry sandy beach for recreation seaward of the dunes.

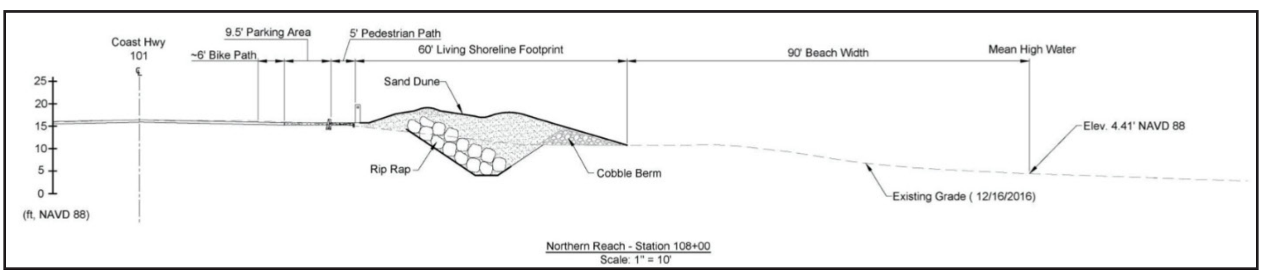


Figure E-3. Cardiff living shoreline design section drawing (Moffatt & Nichol, 2017)

41 While the projections of SLR used in this project are lower than the projections currently recommended by the Coastal Commission to be used when designing and planning for critical infrastructure, this project serves an important interim solution.

The selected project alternative is a 60-foot-wide dune system along 2,900 feet of the coastal highway with naturally occurring cobble organized into a berm at the toe of the dunes to reduce erosion during large wave events. Existing rip rap which, prior to the project, had been spread across the back beach, was reorganized into a revetment at the base of the highway and buried beneath the dune system. The rip rap serves as a final line of defense to protect the highway in the case that the beach, cobble, and dune were to fully erode.

An important component of the project was the creation of vegetated dune habitat. The project's ecological component similarly included performance goals of restoring two acres of stable, vegetated dune habitat with native plant cover. These goals were defined by measurable performance standards with trigger points for maintenance activities. Additional experiments are also being conducted to assess different methods of biomimicry design features that aim to imitate the natural process of sand retention by dune vegetation while the planted species are establishing.

Beyond the goal of addressing present-day hazards, the project was designed to withstand sea level rise over approximately the next 30 years. The chosen design was shown, through the numerical modeling, to be able to withstand approximately two feet of sea level rise (plus approximately 50-year sea conditions), after which, the project is expected to require significant and recurring maintenance and will likely need to be succeeded by an alternative approach.

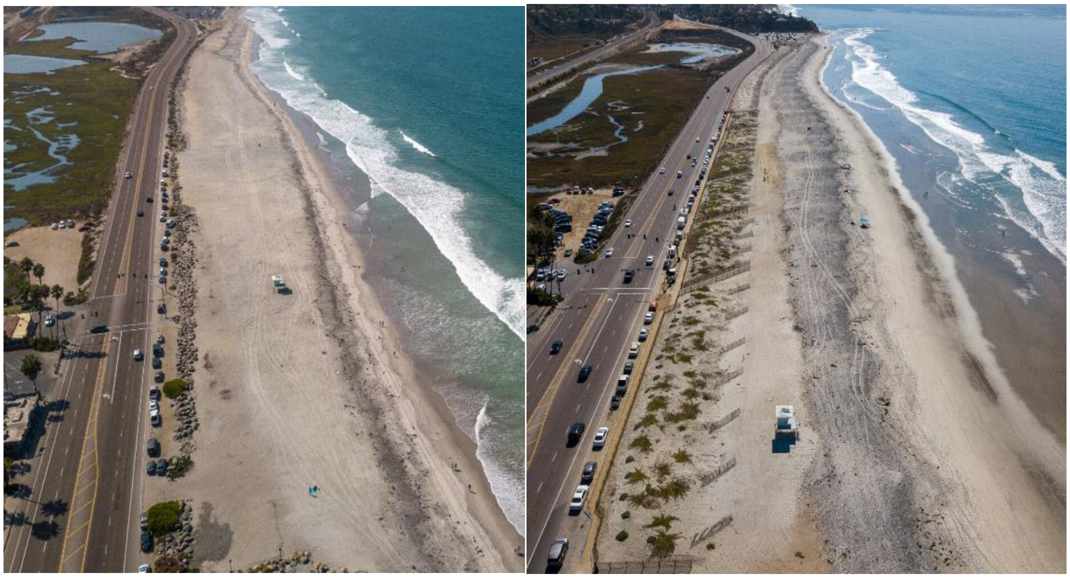


Figure E-4. Aerial views of part of the project location before (left) and after (right) construction (Army Corps of Engineers Feasibility Study, 2016).

Status, Monitoring, and Management

The restored dune habitat performed well in the year following initial construction. It has been a focal point for community engagement including volunteer work on native planting, invasive vegetation removal, and public outreach and education. The system did not experience a very large wave event in its first year, but researchers on the monitoring team are actively monitoring wave and water levels to help answer questions around its performance as flood protection, including as sea levels rise.

The Coastal Development Permit approved by the CCC for this project required a robust monitoring and adaptive management program. The monitoring has several goals, including performance assessments of both protection of the highway and ecological criteria. In partnership with UCLA and Scripps, the City is monitoring the wave and climatic conditions year-round as well as taking surveys of topography and bathymetry quarterly and after large storms to assess the performance of the dune system as flood protection and providing reports on the monitoring results. The Nature Collective (a non-profit partner of the project) is similarly monitoring the ecological performance of the constructed dune habitat. These partnerships are an important part of the project, which aims to advance technical understanding and engagement with the community.

Another goal of the monitoring program is to inform the maintenance and adaptive management of the dune system while the City works on longer-term adaptation strategies. The Adaptive Management and Monitoring program lays out five phases of adaptive management:

- **Develop** long-term strategy for Highway 101 before the dune system becomes obsolete with sea level rise
- **Continue** to pursue beach nourishment projects, including scheduled maintenance dredging of the nearby San Eligo Lagoon Mouth
- **Maintain** dune system based on defined maintenance triggers
- **Adapt** the dune system based on performance
- **Abandon** the dune system and accelerate long-term strategy.

San Elijo Lagoon is regularly dredged to maintain tidal function, and sand from this dredging will be a key component for maintenance of the dune system. However, realizing that the current project may lose its protective function with modest sea level rise (>2 feet), the Adaptive Management Plan includes clear and well-defined triggers for maintenance and possible adjustments to the dune system. The Adaptive Management Plan also describes the City's efforts to pursue funding opportunities and regional partnerships to develop longer-term adaptation strategies. In this way, the project ensures that the issues presented by increasing coastal hazards to both the highway and coastal resources (e.g. sandy beach for recreation, access, and habitat) are addressed. Some of these triggers include the following:

1. Erosion of a 15-foot-wide sacrificial erosion zone from an area 25 feet greater in length would trigger maintenance (i.e. placement of sand);
2. Exposure of the rip rap or loss of a full dune section, (defined as 30 feet of erosion from the seaward edge of the dune or a vertical loss of 18 feet from the initial dune crest) would trigger maintenance (placement of sand);
3. Wave overtopping of the dune which causes dune breaching (i.e., major sand loss and subsequent pedestrian pathway flooding) at a specific area or along the entire Project reach would trigger planning for dune heightening.
4. Should significant dune system overtopping or erosion be realized prior to the design event (i.e., 2 feet of sea level rise and an approximately 50-year return period wave event), the dune system would no longer be anticipated to be effectively designed for existing oceanographic conditions. This would trigger the City to begin planning a capital improvement project such as lane reduction to Highway 101 and a landward migration of the dune.
5. Should more than 5% of total vegetative cover be non-native, additional non-native vegetation removal would be enacted by the Nature Collective.

Key Points

A goal for this pilot project was to help inform similar nature-based adaptation strategies across the state. Two years post-construction, there are several key lessons to share about the planning, design, and construction of similar nature-based adaptation strategies to coastal hazards.

- **Early partnerships are key to success.** Meaningful partnerships made early in the process can spark consideration of nature-based adaptation strategies in place of armoring and address concerns of important stakeholders early in the design process.
- **Coordinate on opportunities for beneficial use of dredged material.** The partnership between the City of Encinitas, CA State Parks, and the Nature Collective (formerly San Elijo Lagoon Conservancy) was critical to a productive coordination between the dredging of the San Elijo Lagoon mouth (and associated beach nourishment on Cardiff State Beach) and the living shoreline project, which used some of the sand from the dredging project.
- **Phased responses are a critical tool for climate adaptation**. The City of Encinitas illustrated the importance of proactive planning by identifying the road as a critical stretch of at-risk infrastructure and seeking funding for a nature-based adaptation strategy to provide necessary flood protection while creating habitat and access for the short-term, and improving visual resources, while buying time to plan for a longer-term solution.

- **Models and coastal engineering experience can be used to evaluate efficacy of innovative designs.** The design process shows how numerical models can be used to test the relative efficacy of nature-based adaptation strategies when there are limited examples of comparable projects in the state. The project's engineers have also learned lessons about the importance of understanding the quantities of available native cobble, suggesting preliminary sub-surface investigations and use of historic photos may be important for informing the design of cobble berms.
- **Adaptive management is critical for addressing unanticipated outcomes.** Less than two years after completion, the project has experienced two main challenges: (1) the erosion of sand into un-filled air voids in the buried rip rap and (2) the focusing of wave runup into beach accessways. The first challenge has to do with construction management and highlights the importance of filling air voids in buried revetments which can occur when burying revetments with relatively dry sand (through dump trucks). The second challenge was discovered during construction where relatively high waves caused runup to occur through the accessways from the pedestrian path to the beach. Runup was not high enough to flood the road, but proved to be a potential point of failure for the system. The solution decided upon during construction was to place temporary relatively low-elevation sand berms towards the beach side of the accessways that maintain access on the paths while preventing runup. The berms will likely be placed yearly before each winter season.

Benefits

The Cardiff Living Shoreline Project was implemented as an interim solution to address flooding of Highway 101 while allowing time to develop long-term adaptation strategies. The project also created two acres of vegetated dune habitat and improved public access opportunities to Cardiff State Beach. In addition to these benefits, the Cardiff Living Shoreline Project included the construction of a new pedestrian and bike path, beach accessways, and aesthetic improvements (compared to degraded revetment and scattered rock) which improved the access to the beach and enhanced recreational use. Anecdotal reports suggest the dunes also act as a barrier against highway noise, resulting in a more enjoyable environment for recreators on the beach.

CASE STUDY 2. SURFER'S POINT SHORELINE MANAGEMENT PROJECT

Public Access Adaptation	
Infrastructure at Risk: Coastal erosion along a public bikeway and coastal access parking lot in City of Ventura, Ventura County	**Adaptation Method**: Managed retreat of a portion of a bike path and public parking lot and nature-based adaptation using an engineered dune system over buried cobble berm
Term of Strategy: Phase 1 of the project completed in 2010 with a second phase planned to relocate the remaining parking lot and bike path and expand the dune and cobble berm system	**Implementing Party**: City of Ventura

This project provides a combination of managed retreat and nature-based adaptation strategies to protect public access development threatened by coastal erosion, located downcoast of the mouth of the Ventura River. This is an example of how nature-based adaptation strategies can use local circumstances to inform successful design, function, and performance. The use of a cobble berm with an associated dune system, in this case, mimics natural cobble berm/platform nearby and has now demonstrated a decade of performance.

Figure E-5. Oblique aerial photo of the Surfer's Point Managed Shoreline Retreat Project in August 2019, looking Northeast (Google Earth).

Background

Surfer's Point is a popular beach in the City of Buenaventura (Ventura) in Ventura County. It is especially favored by surfers, kite surfers, and those recreating along the coastal bike path. The Point is located just downcoast (southeast) of the mouth of the Ventura River and seaward (south) of the Ventura County Fairgrounds. In the 1990s and early 2000s, the upper beach consisted mainly of imported siltier material atop a natural platform of river cobble and sand. Siltier fill material erodes quickly when exposed to waves.

In 1991, a newly constructed bike path was quickly damaged by winter storms and presented significant issues to public safety and beach access. Local leaders recognized the need to restore the site to a more natural state in order to preserve and enhance public access, recreation, and ecology. The planning, design, and permitting process took place over several years starting in the mid-1990s and involved a wide array of stakeholders including state and local agencies.

Design

After being delayed by the Great Recession in 2008, construction began in 2010 on Phase 1 of the final project that relocated the western parking lot and bike path landward, removed the fill, imported nearby river cobble and beach quality sand, and constructed sand dunes on top of a cobble berm to mimic natural conditions near the site. The sand dunes were planted and restored with native dune vegetation and no irrigation – only rainfall. Phase 2 of the project will relocate the remaining parking lot and bike path and expand the restored dune-cobble system further downcoast.

The project aimed to restore as much of a natural dune system as possible while relocating parking further inland away from existing hazards. Restoring the ecology of a vegetated dune system was an important initial goal for the project. The project design considered only a modest amount of sea level rise (0.5 feet over the project's 50-year design life).[42] The longer-term viability of the dune-cobble system is dependent on several factors including the migration of the Ventura River mouth, sediment supply (including uncertainty about the fate of sediment currently trapped behind Matilija Dam), and sea level rise, which will contribute to shoreline recession and increased risk of wave overtopping. However, the project was designed to serve an important role in reducing damage from flooding, restoring habitat, and improving recreation.

42 While the projections of SLR used in this project are lower than the projections currently recommended by the CCC to be used when designing and planning for critical infrastructure, this project serves an important interim solution with many co-benefits.

Status, Monitoring, and Management

Planting efforts were largely conducted by volunteers, the City of Ventura, and community organizations, including the local Surfrider chapter. Volunteers planted native seeds with no installed irrigation during a multi-year drought from 2012-2016. Since planting, native dune vegetation has successfully established and the relative non-native vegetation cover remains very low through annual weeding. In addition, hummocky topography and accretion of sand has occurred as native vegetation has established (ESA, 2018).

The project has performed well during winter storms, including during the intense El Niño winter of 2015-2016. No damage or inland flooding occurred behind the dune-cobble system, in contrast with the damage and flooding experienced east of the project, including at the Ventura Pier; however, not all of the project site includes dunes or a cobble berm. The portion of the project managed as a flat beach and windsurfing recreation zone did experience inland flooding, and wave runup extents were not reduced. This underscores the value of dunes in combination with the cobble berm to reducing flooding here; the cobble berm stabilized the dunes during storms and the dunes provided the elevations needed to reduce wave overtopping. Since 2010, portions of the cobble berm have eroded (~20 feet) but the maintenance trigger of erosion of the cobble berm (to within 40 feet of the bike path, or deflation of the dune/berm crest to below +13 feet, MLLW) has not come close to being met (ESA, 2018; per. comm. B. Battalio, 2020). Even after the strong 2015-2016 winter, which saw some of the worst erosion of the sandy beach and cobble berm, the sandy beach fully recovered by the end of the summer due to natural seasonal dynamics in the system (ESA, 2017).

Figure E-6. Photo of eroded bike path and fill after storms in 1997 (Paul Jenkin, Surfrider Foundation).

Key Points

The Surfer's Beach project demonstrates that cobble berms can be an important part of nature-based adaptation strategies on the coast. Considering nearby natural references and the geomorphologic context of the site can help to design cobble berms in ways that restore the shore to more natural conditions. Cobble can effectively stabilize shorelines during extreme events. When combined with vegetated sand dunes, and sufficient cross-shore space, cobble berms can reduce flood risk and erosion of the shoreline while potentially facilitating natural recovery of the sandy beach.

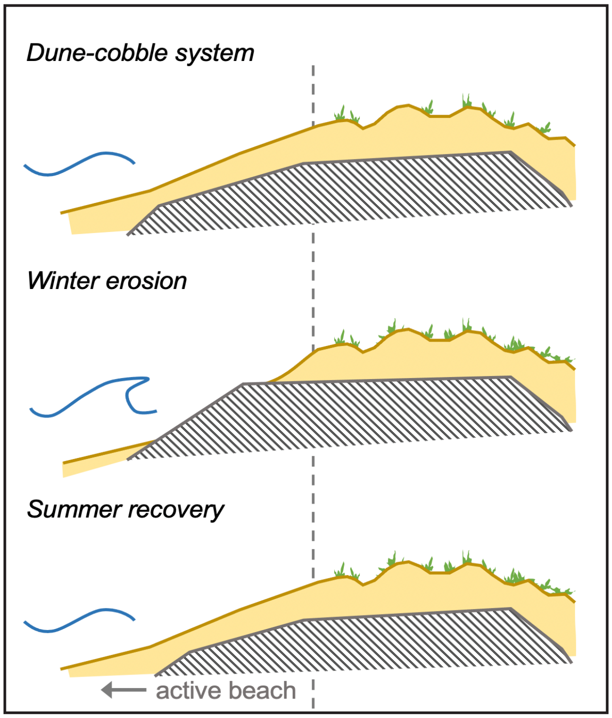


Figure E-7. Figure showing seasonal shoreline dynamics of a dune-cobble system (J. Smith).

A key component of nature-based adaptation strategies is to use reference sites to inform design, function, and performance of the proposed project. The Surfer's Point project used Emma Wood State Beach, where dunes sit on top of a natural cobble berm/platform, as its reference site. This type of coastal feature can occur where there is a high prevalence of cobble such as at the mouths of rivers. At beaches like Emma Wood State Beach, during winter storms, sand is carried offshore leaving mostly cobble on the beach. Large waves then build up the cobble into a berm, which dissipates (absorbs) wave energy and stabilizes the shoreline. Because of this wave dissipation, the portion of the beach that erodes and rebuilds with the change in seasons (called the active beach) is often narrower than those on beaches without cobble. In the summer months, when waves are generally smaller, the dissipative structure of the cobble can facilitate the recovery of the sandy beach (Newkirk *et al.*, 2018). Immovable barriers that limit space in the back beach can constrain the formation of cobble berms during storms, making the berms steeper than they would be with more space in the back beach, reducing dissipation and increasing reflection of wave energy. Increased wave reflection can prevent or slow the recovery of sandy beaches. At Surfer's Point, the retreat of the parking lot and bike path allowed for sufficient cross-shore space to mimic aspects of the natural geomorphology of the Emma Wood State Beach reference site, including a dune-cobble system and sandy summer beach.

Cobble berms and sand dunes can also reduce wave runup and overtopping. For this site, the cobble berm is "activated" during winter storms when waves erode the sandy beach. The cobble stabilizes the shoreline and dissipates waves as they runup the beach onto the foredunes. Most of the time, wave runup will not reach the dunes; however, during larger storms, waves are dissipated by both the cobble and foredunes. It is important to note that the cobble berm is dynamic and can be eroded in some cases, unlike traditional armoring approaches to shoreline stabilization.

Benefits

Figure E-8. Photo of restored back beach dune system and new trail (ESA, 2017).

In summary, the Surfer's Beach project demonstrates that cobble berms and sand dunes can be important parts of nature-based adaptation strategies on the coast. The dune-cobble system has been effective in attenuating flood and erosion threats to the relocated bike path and parking lot. Considering nearby natural references and the geomorphologic context of the site can help to design these in ways that restore the shore to more natural conditions. Cobble can effectively stabilize shorelines during extreme events, which, when combined with the space provided by retreating the parking lot and bike path, has allowed native dune vegetation to naturally accrete sand, effectively building up the constructed dunes to be more resilient to flooding. When combined with vegetated sand dunes, and sufficient cross-shore space, cobble berms can reduce flood risk and erosion of the shoreline while potentially facilitating natural recovery of the sandy beach. Surfer's Point is an example of how a nature-based adaptation strategy combined with retreat of infrastructure can reduce damage from coastal hazards, restore native habitat, and improve recreation.

CASE STUDY 3. RELOCATION OF THE MORRO BAY WATER RECLAMATION FACILITY

Wastewater Treatment Plant Adaptation	
Infrastructure at Risk: Coastal erosion and flooding anticipated during the life of a proposed redevelopment of a wastewater treatment facility, Morro Bay, San Luis Obispo County	**Adaptation Method**: Managed retreat consisting of relocation of the wastewater treatment and recycled water facility, associated pipelines, two new lift stations, and other associated facilities to inland area
Term of Strategy: Relocation of the facilities to an inland location to eliminate coastal erosion risks for the life of the facilities	**Implementing Entities**: City of Morro Bay and Cayucos Sanitary District
This is a managed retreat project, resulting in a long-term plan that protects the area’s wastewater and recycled water capabilities. As a result, this adaptation does not require future monitoring and management for coastal hazards risks.	

Background

The City of Morro Bay (the "City") and the Cayucos Sanitary District’s existing wastewater treatment plant was built in 1954 in a low-lying area near the confluence of Morro Creek and the Pacific Ocean. In 2011, the City proposed to construct a new plant on the original site as the aging infrastructure was failing to meet Clean Water Act standards. However, the City’s approval of the coastal development permit (CDP) for the project was appealed to the Coastal Commission by eleven different parties. In 2013, the Commission denied the City’s redevelopment-in-place proposal on the basis that the project was not consistent with the City's Local Coastal Program (LCP) policies on avoiding coastal hazards (flooding, sea level rise, tsunami), land use priorities, recycled water provisions, and public view protections. The project raised fundamental questions about whether critical wastewater infrastructure should continue to be located along the City’s public recreational shoreline, or whether it was time to relocate it inland and away from coastal hazards risk.

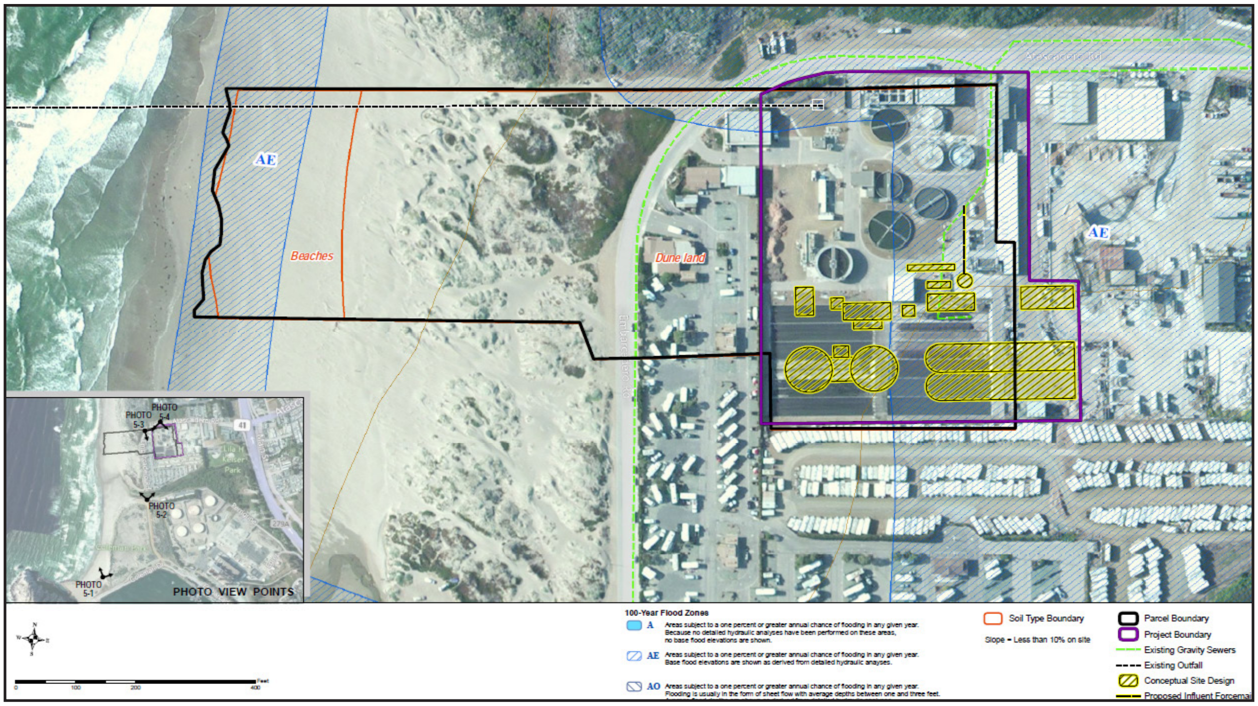


Figure E-9. Project plans for the denied Morro Bay Cayucos Wastewater Treatment Plant showing flooding hazards.

Coordination

The project included significant coordination among multiple planning partners, including the City of Morro Bay; Cayucos Sanitary District; Northern Chumash tribal representatives; Central Coast Regional Water Quality Control Board; California Department of Fish and Wildlife; San Luis Obispo County Department of Planning and Building.

Design

At the Commission's direction, the City proposed a redesigned project to site the project farther inland and at a higher elevation, away from coastal hazard threats, while still meeting the project goals of enhancing water quality protection and improving groundwater health and discharge quality. The proposed project includes construction of a new wastewater treatment and recycled water facility, associated pipelines, two new lift stations, underground recycled water injection wells and a modified existing ocean outfall. The City also worked with Northern Chumash tribal representatives on the alignment of the new pipelines to avoid known cultural sites. In July 2019, the Commission voted unanimously on the CDP to approve the new wastewater treatment and water reclamation facility, which is located more than 3 miles inland of the old site, and for the decommissioning, removal, and restoration of the existing site adjacent to the beach.

Figure E-10. Proposed relocation site.

Benefits

Relocating the City's wastewater infrastructure away from the shoreline eliminates coastal hazard threats, improves water quality, and avoids potential impacts to coastal resources. The resulting project will ensure that an expensive, sensitive, and critical public asset is safe from hazards for the expected life of the infrastructure. Moreover, the proposed recycled water component of the project is estimated to provide the City with some 825 acre-feet of water per year (or roughly 80 percent of its yearly water needs) through groundwater replenishment and improved aquifer health, thus providing community water security in the face of climate change and increasing water scarcity.

MORE INFORMATION:

The staff report for this item can be found at:

https://documents.coastal.ca.gov/reports/2019/7/Th13a/Th13a-7-2019-report.pdf

San Luis Obispo Tribune news article "After years of fighting, Morro Bay sewer gets final OK by Coastal Commission" (7/12/19)

https://www.sanluisobispo.com/news/local/article232572277.html

CASE STUDY 4. PIEDRAS BLANCAS (HIGHWAY 1) ROADWAY REALIGNMENT

Highway Adaptation	
Infrastructure at Risk: Severe coastal erosion along Highway 1 resulting in numerous locations of rock slope protection and minor realignments in San Luis Obispo County	**Adaptation Method**: Managed retreat consisting of relocation of 2.8 miles of highway further inland
Term of Strategy: Relocation of the highway up to 475 feet inland to reduce future coastal hazards risks	**Implementing Entity**: Caltrans
This is a managed retreat project, resulting in the realignment of a portion of Highway 1 further inland to minimize risks to facilities from coastal erosion. This allowed the removal of previously placed shoreline protection.	

Background

In the 1990s, Caltrans submitted a coastal development permit application to build a rock revetment to protect the highway from erosion. The Coastal Commission approved a temporary permit for the shoreline armoring structure; however, a condition of the permit required Caltrans to study the feasibility of relocating the highway inland and away from the eroding shoreline. This area of the coast contains many resources that the Coastal Commission is mandated to protect, such as coastal agriculture, public access, scenic views, and sensitive environmental resources. In addition, much of the area inland of the original highway alignment is private property, complicating Caltrans' ability to relocate the highway.

Coordination

Caltrans worked closely with the Coastal Commission and other state agencies including California State Parks, San Luis Obispo county government officials, stakeholders (including the Hearst Corporation which owned most of the inland property that would be affected), and the public throughout the planning process to forge a project that everyone could support. Ultimately, Caltrans returned to the Coastal Commission with a coastal development permit application to relocate this vulnerable stretch of highway inland of its original location.

The long-term planning for the highway also was incorporated into an agreement between the State and the Hearst Corporation, the American Land Conservancy, and the California Rangeland Trust to preserve 128 square miles of coastal prairie rangeland, including 18 miles of spectacular coastline along Highway 1.

Design

The Coastal Commission approved the relocation of a 2.8-mile vulnerable section of Highway 1 near Piedras Blancas in northern San Luis Obispo County (See Coastal Commission Staff Report for [Application No. 3-13-012]). This roadway had been experiencing severe coastal erosion (nearly 5 feet per year in some areas) resulting in numerous projects for rock slope protection and minor realignment over the previous 20 years. Caltrans determined that the temporary shore armoring was not sufficient to protect the road in the long-term, so the Commission worked closely with the Caltrans, California State Parks, and San Luis Obispo County officials to relocate nearly three miles of Highway 1 to safer ground. Through an agreement with private landowners and nongovernmental organizations, the area between the coast and the relocated highway added 73 acres to Hearst San Simeon State Park, opening new opportunities for beach access and affordable visitor facilities, such as a public campground and 3.5 new miles of the California Coastal Trail. This project took approximately 20 years from planning to completion.

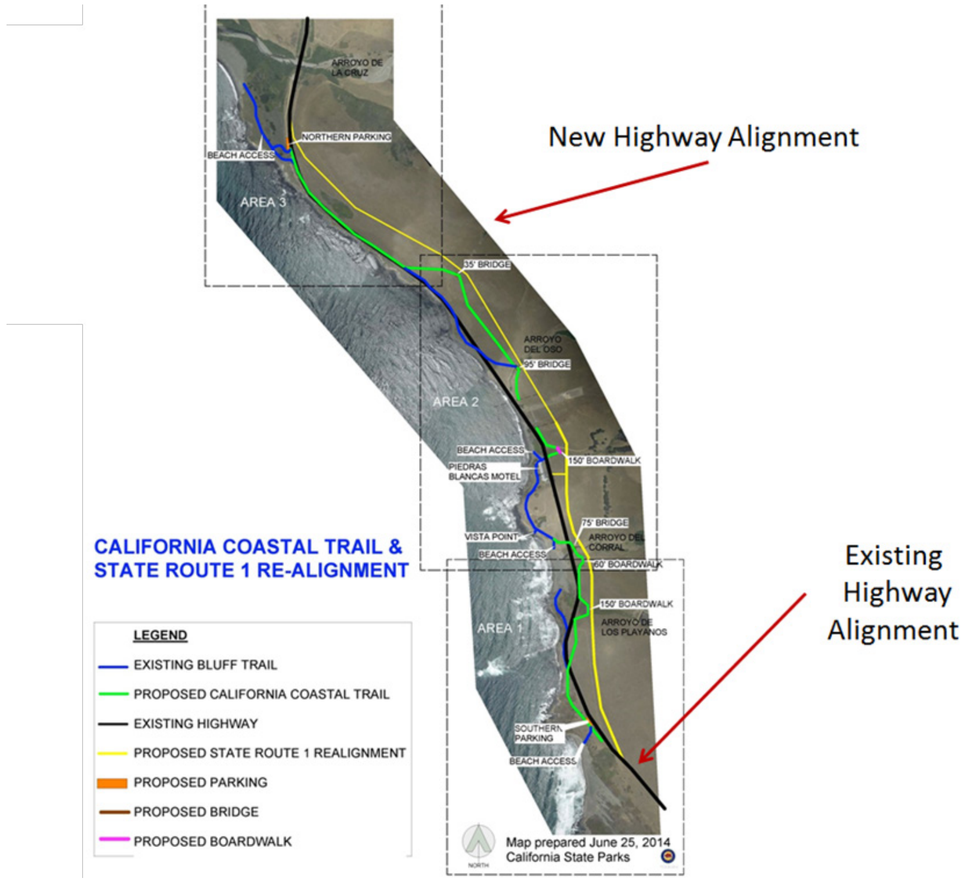


Figure E-11. Project plans showing realignment of Highway 1.

Figure E-12. Aerial view showing former alignment of Highway 1.

Key Points

While primarily intended to reduce risks from coastal hazards, this project illustrates how coastal zone management in California can achieve significant co-benefits, including ensuring environmental quality, fostering collaboration among governmental agencies and across disciplines, engaging and educating the public, providing equitable access, and encouraging responsible development and redevelopment.

Equitable Access

Although the realigned highway provides a mostly unobstructed view along the shoreline and will accommodate bicycle travel along its shoulder, it does reduce the public's ability to see and access the immediate shoreline due to its more landward position. To continue to provide and enhance shoreline access, Caltrans worked with State Parks to construct, operate, and maintain an off-road section of the California Coastal Trail seaward of the realigned highway. Caltrans also provided parking lots at the northern and southern project boundaries to facilitate use of the trail.

Visual Resources

Assurances in the form of permit conditions were built into the project so that the new section of roadway would not induce inappropriate development. For example, the new road must keep to two lanes. In addition, Caltrans purchased a Deed of Scenic Conservation Easement over 1,445 acres of land including 832 acres of agricultural land that has or will be transferred into public ownership. The scenic conservation easement applies over land to the west of the realigned highway right-of-way. The easement prohibits new development that would be most visible, while allowing the noted public access trails. Conditions of the permit also require a new access road and retention of an old parking lot from an abandoned motel site that State Parks plans to convert into a campground. Utility connections to this site were kept but undergrounded to improve the visual appearance.

Water Quality

Finally, since this project entailed constructing a new roadway in a parallel location inland of the existing highway, it posed potential impacts both in terms of adding impervious surface (with resultant runoff and pollutants) and disrupting hydrologic processes, including seasonal wetlands, groundwater, streams, and drainages flowing to the ocean. Thus, an extensive Water Quality Management Plan ensured that significant hydrologic impacts of the new highway alignment will be avoided, polluted runoff will be treated, and that drainage patterns will be preserved. Also, as part of the project, the existing culvert crossings that accommodate the three coastal streams in the project area were replaced by bridges, thus improving the ecological health of the streams.

Benefits

The shoreline armoring was removed after the highway realignment to reestablish natural shoreline processes along this stretch of coast. In addition, Caltrans and the Coastal Commission ensured that it also protected coastal resources. Paramount to the project's approval was the requirement for a Habitat Restoration Program for off-site restoration and enhancement at Arroyo de la Cruz, a significant coastal wetland that had degraded over time. Approximately 2.8 acres of wetlands were restored within the abandoned roadbed and adjacent areas that historically supported wetlands. These mitigations, along with the other benefits of the project, allowed the Commission to approve the project as consistent with the Coastal Act because, on balance, it is most protective of the environment.

CASE STUDY 5. NORTH COAST CORRIDOR PUBLIC WORKS PLAN/TRANSPORTATION AND RESOURCE ENHANCEMENT PROGRAM (NCC PWP/TREP)

Coordinated Approach to Infrastructure and Sea Level Rise Planning	
Infrastructure: Multimodal transportation (rail, highway, transit, bicycle, and pedestrian) projects and bridge design in the cities of San Diego, Encinitas, Carlsbad, and Oceanside	**Adaptation**: Taking a regional approach allows plans to include multiple types of infrastructure (e.g., highway and rail), which can improve efficiencies and cost and ensure adaptation to sea level rise is coordinated
Term: Proposed projects are scheduled for phased implementation over the next 30 - 40 years	**Implementing Entities**: Caltrans and SANDAG are responsible for implementation under the Public Works Plan; cities have responsibilities pursuant to their respective LCPs
This is an example of a coordinated and regional approach to infrastructure planning through a Public Works Plan certified by the Coastal Commission.	

SUMMARY

As discussed in Chapter 4, a Public Works Plans (PWP) is a land use planning tool that describes one or more public works projects across one or more local government jurisdictions, and is therefore particularly suited for planning for large scale, multi-jurisdictional, and phased infrastructure projects. This case study describes the North Coast Corridor (NCC) Public Works Plan/Transportation and Resource Enhancement Program (PWP/TREP). It discusses how the PWP addresses climate change and sea level rise, and how collaboration between local governments, stakeholders, and the PWP proponents – Caltrans and SANDAG – was instrumental in successfully developing the PWP itself and the associated Local Coastal Program (LCP) amendments.

Background

The North Coast Corridor Travel Shed (Figure E-13) is 27 miles long by 6 miles wide, and encompasses the cities of San Diego, Del Mar, Solana Beach, Encinitas, Carlsbad, and Oceanside. It includes Interstate 5, Coastal Highway 1, and the Los Angeles-San Diego-San Luis Obispo (LOSSAN) rail corridor. It also includes long open stretches of public beaches, six coastal lagoons, and five creeks and rivers, as well as associated open space and other coastal habitats.

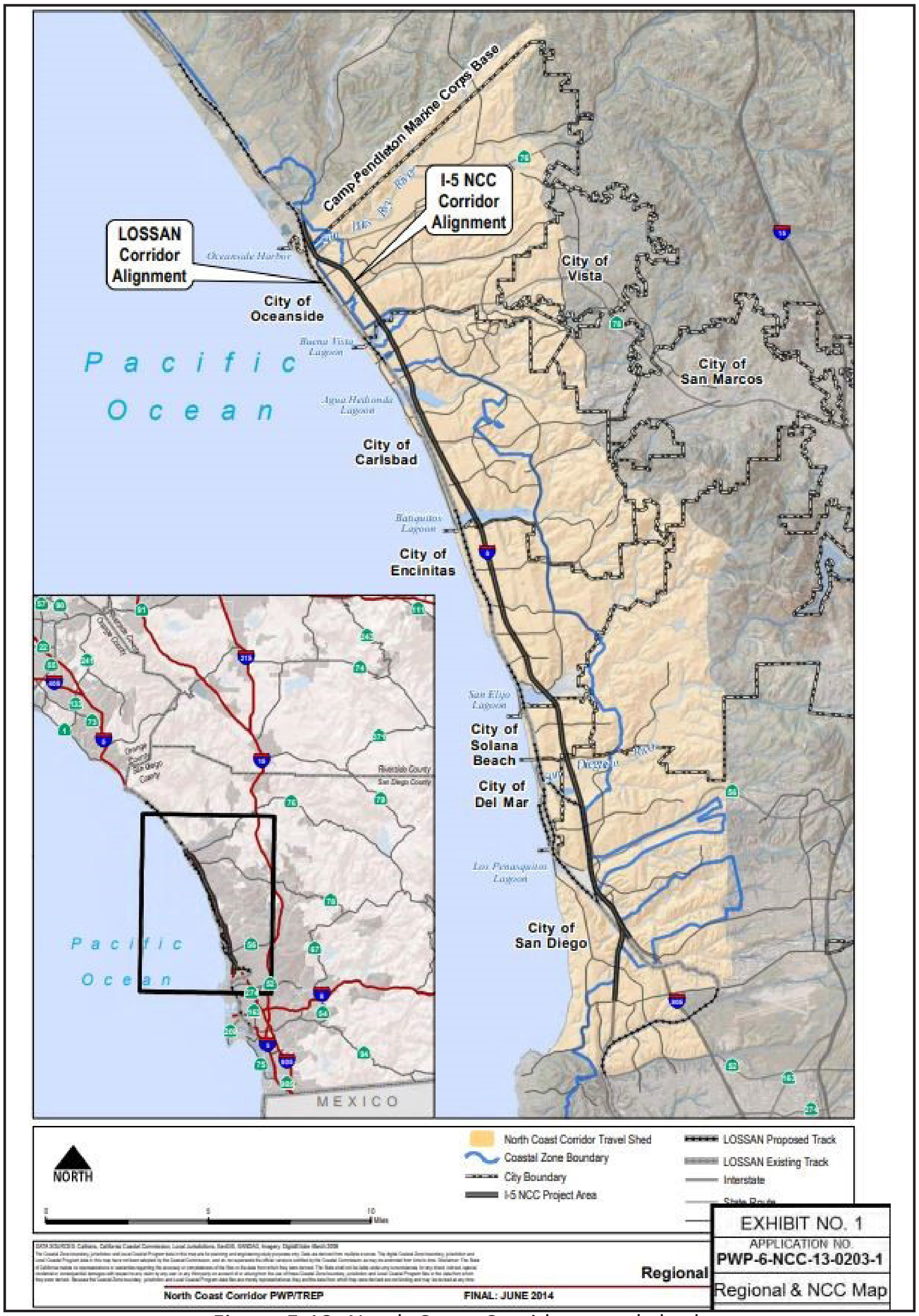


Figure E-13. North Coast Corridor travel shed.

The NCC PWP/TREP was developed in response to the need to expand Interstate 5 and address the associated impacts upon the adjacent lagoon watersheds and shoreline. The plan includes multiple highway, rail, community, and resource enhancement projects from La Jolla to Oceanside along the north San Diego County coastline. Specifically, it includes widening of Interstate 5 to accommodate four new Express Lanes, double tracking of LOSSAN rail corridor, Enhanced Coastal Bus and a Bus Rapid Transit service, a new 27-mile NCC Bikeway that would provide nonmotorized connectivity through the corridor, 7 miles of the Coastal Rail Trail, as well as other shorter connections to existing trail networks and transit stations – all of which are scheduled for phased implementation over the next 30 to 40 years. It also includes an Implementation and Phasing Plan that identifies phased project priorities while also providing some flexibility to accommodate opportunities and uncertainties that may occur over the 30 to 40-year implementation schedule.

Collaboration

In general, because PWPs often involve multiple jurisdictions and infrastructure owners, operators, and user groups, they typically require extensive coordination to develop. In the case of the NCC PWP/TREP, the development of the plan required an iterative and collaborative process between the applicants, all the affected local governments, federal and state resource and transit agencies, NGOs, public representatives, and Coastal Commission staff. This collaboration provided opportunities to achieve multiple objectives in the PWP. For example, the PWP proponents worked with federal and state resource agencies and NGOs such as the San Elijo Lagoon Foundation to identify and prioritize regional resource needs and align them with available restoration and enhancement opportunities throughout the NCC – an important opportunity to do so at a regional scale.

The NCC PWP/TREP also required significant coordination with the local governments with LCPs that overlapped the PWP's geographic scope, which served as the standards of review for the PWP. The NCC PWP/TREP required LCP amendments for the cities of San Diego, Encinitas, Carlsbad, and Oceanside, which are provided in Exhibits 21-25 of the Coastal Commission staff report and serve as good examples of how LCP amendments should dovetail with a PWP. These amendments were developed concurrently with the NCC PWP/TREP and include specific maps and project information related to the NCC PWP/TREP footprint as well as more general policy language to acknowledge the NCC PWP/TREP, but defer more specific project development standards to the language within the NCC PWP/TREP itself.

Together, the NCC PWP/TREP and associated LCP amendments provide an example of how PWPs can be developed to function similar to regulations in an LCP Implementation Plan or zoning ordinance; and Land Use Plan policies can also be modified to reflect and incorporate the specific provisions of the PWP as they relate to the transportation facilities in a corridor.

PWP Development and Approval Process

The procedures by which the NCC PWP/TREP and associated LCP amendments were developed provide a good example of how such processes can play out. An initial draft NCC PWP/TREP was released for public review in July 2010, followed by revised drafts released in March 2013 and November 2013. In December 2013, the Coastal Commission's Executive Director made a determination that authorized Caltrans and SANDAG to submit the LCP amendments on behalf of the cities of San Diego, Encinitas, Carlsbad, and Oceanside, as described in CCR Section 13666.2. The final PWP/TREP submitted to the Commission in June 2014 for Commission action in August 2014.

In general, PWPs can require multiple types of approvals from the Coastal Commission depending on the type of projects included in the PWP, including federal consistency certifications, LCP amendments, and the PWP approval itself. The NCC PWP/TREP required multiple and sequential approvals by the Commission all of which were combined into a single hearing item with one staff report. These sequential approvals included: a federal consistency certification for the TREP component of the plan; Local Coastal Program (LCP) amendments for the cities of San Diego, Encinitas, Carlsbad, and Oceanside; and then the proposed PWP.

The procedural advantage of first conducting the federal consistency review of the NCC PWP/TREP ahead of the LCP amendments gave the Commission the opportunity to determine the application of the NCC PWP/TREP on a regional and comprehensive basis under the Coastal Act. The LCP amendments were then crafted as overlays to reside within the City of San Diego, Encinitas, Carlsbad, and Oceanside LCPs and serve as the standard of review.

Climate change and sea level rise

The NCC PWP/TREP addresses climate change mitigation through a focus on greenhouse gas emissions associated with transportation. A primary goal of the NCC PWP/TREP is to move people more efficiently through a more coordinated and connected suite of transportation options that will encourage alternate modes of travel other than the single occupancy vehicle (SOV). The suite of projects in the PWP is expected to increase the transit mode share (percentage of travelers using transportation modes other than SOVs) from 2-3% at present to 10-15% at full implementation.

The NCC PWP/TREP also addresses sea level rise. To assist in planning and designing of the NCC lagoon bridge crossings, Caltrans and SANDAG prepared the San Diego Region Coastal Sea Level Rise Analysis, which assesses potential drainage, tidal inundation, and flooding impacts to transportation infrastructure crossing waterbodies within the NCC that are potentially subject to sea level rise. The results of the study were incorporated in the design of the NCC PWP/TREP infrastructure improvements. Most importantly, both rail and highway facility crossings were considered together to identify design options and, where necessary, adaptive strategies, that addressed the potential long-term impacts of sea level rise and related drainage, flooding, and shoreline erosion. As a result, the proposed bridge replacement projects are designed to accommodate the anticipated increase in sea level rise through the year 2100, both with and without fluvial floods (50-year and 100-year), through design and/or adaptive strategies. Furthermore, the NCC PWP/TREP requires that planned projects be analyzed against the most current sea level rise projections and best available science at the time they are implemented.

The coordination that occurred as part of the development of the NCC PWP/TREP also allowed Caltrans and SANDAG to study appropriate bridge designs using a lagoon-wide perspective rather than being limited to study of a precise project footprint. These analyses considered the existing infrastructure constraints in the context of the optimal lagoon environment in order to identify appropriate bridge dimensions that will enhance lagoon-wide function and services. The studies confirmed that existing rail and highway bridges at San Elijo, Batiquitos, and Buena Vista Lagoons were the primary opportunities where significant improvement could be realized through expanded bridge lengths. These optimized bridge designs represent another unique component realized through the NCC PWP/TREP that resulted in an opportunity to further minimize impacts on coastal wetlands and enhance habitat value, in light of sea level rise.

Conclusion

A discussed in this case study, a PWP can be an effective mechanism for incorporating a suite of adaptation planning strategies and specific public transportation improvements into an integrated plan for a specific transportation network or corridor. As such, PWPs must be developed through coordination with local governments and other federal, state, and regional agencies with jurisdiction in the corridor to align planning efforts toward a mutually agreeable plan. Local governments should fine tune any Land Use Plan policies to identify the specific improvements and facilities related to sea level rise adaptation strategies contemplated by the approved PWP for that specific LCP jurisdiction and transportation corridor. Ideally, as in the case of the NCC PWP/TREP, the LCP amendments are developed concurrent with the PWP and in cooperation with agency partners to achieve mutual objectives and shared goals related to adaptation planning.

REFERENCES: APPENDIX E

ESA. 2017. *Surfer's Point Shore Enhancement Project 2015-2016 Monitoring Report*.

ESA. 2018. *Surfer's Point Shore Enhancement Project 2016-17 Monitoring Report*.

Newkirk, Sarah, Sam Veloz, Maya Hayden, Walter Heady, Kelly Leo, Jenna Judge, Robert Battalio, Tiffany Cheng, Tara Ursell, Mary Small. (The Nature Conservancy and Point Blue Conservation Science). 2018. *Toward Natural Infrastructure to Manage Shoreline iv Change in California*. California's Fourth Climate Change Assessment, California Natural Resources Agency. Publication number: CCCA4-CNRA-2018-011.

APPENDIX F.

Nature-Based Adaptation Strategies for California

Critical infrastructure is found in a variety of coastal settings and can be exposed to distinct coastal hazards or site-specific challenges. When planning for and managing the impacts of sea level rise along the coast of California, the physical and ecological conditions of a location often determine the types of adaptation strategies that will be most effective for addressing the hazards of concern. Nature-based adaptation strategies can offer protection from coastal hazards while also contributing to the enhancement of natural resources and habitat areas by providing measurable environmental benefits. Nature-based adaptation strategies include options that are composed entirely of natural systems called “soft strategies,” or natural habitats restored or enhanced in combination with constructed features such as marsh sills, buried revetments, and cobble berms, called “hybrid armoring.”

Nature-based adaptation strategies typically work best when there is enough space (especially landward of the shoreline) for natural features like dunes or marshland to absorb wave energy and respond dynamically to waves, storms, and tides. In some cases, nature-based adaptation strategies may require time to establish and restore natural processes, and would need to be implemented before coastal hazard becomes an immediate threat. For these reasons, partial and phased relocation of infrastructure can be combined with nature-based adaptation strategies to optimize benefits and reduce risk. Likewise, structural or “hard” shoreline protective devices can be combined with nature-based adaptation strategies when site conditions or project needs make a solely natural approach infeasible.

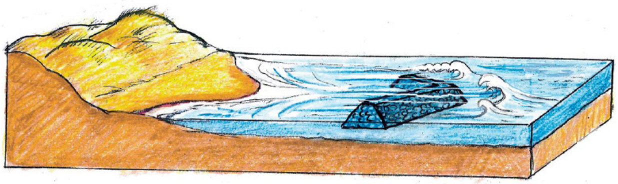
The unique geomorphology along California's coast may necessitate a different approach to nature-based adaptation strategies compared to the East and Gulf coasts of the United States, where nature-based adaptation strategies have been extensively implemented. The following information is adapted from the Federal Highway Administration's (FHWA) *Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide* and applied to the coastal settings in California. The tables in this appendix also highlight the range of potential nature-based adaptation strategies, organized by the hazard types listed below and geophysical context.

- **Erosion (sheltered coast):** erosion occurring in bays, estuaries, lagoons, harbors etc. (e.g. Humboldt Bay, Tomales Bay, San Diego Bay), often caused by small wind waves and/or tidal currents.
- **Erosion (beach):** erosion occurring on the open coast (exposed to ocean swell and Pacific storms) on or behind sandy beaches, often caused by wave runup or undermining.
- **Erosion (bluff):** erosion of bluffs (typically on the open coast), often caused by geologic instability and/or direct wave attack.
- **Flooding (static water level):** flooding from high water levels due to tides or storm surge where waves are not a significant contributor. This type of flooding mainly occurs in sheltered coastal areas that are of low-lying elevation (e.g. agricultural land around Humboldt Bay, Ports of Los Angeles and Long Beach, Newport Bay).
- **Flooding (wave overtopping and runup, sheltered coast):** flooding from waves in coastal areas in bays, estuaries, lagoons, etc., often strong wind events can cause larger-than-normal waves and are limited by the fetch (the stretch of water that wind blows over). Waves in sheltered areas are not nearly as big as the large swell seen on the open coast.
- **Flooding (wave overtopping and runup, open coast):** flooding from waves in coastal areas exposed to ocean swell and Pacific storms. The magnitude of wave needed to overtop a structure/beach depends on factors such as the water level as well as the height and slope of the structure/beach, but generally, strategies on the open coast need to consider the potential for very large waves, unlike sheltered areas.

Figure F-1. From left to right: Static water level flooding (Arcata), erosion on bluff (El Grenada), wave overtopping on open coast (Pacifica). (Source: California King Tides Project)

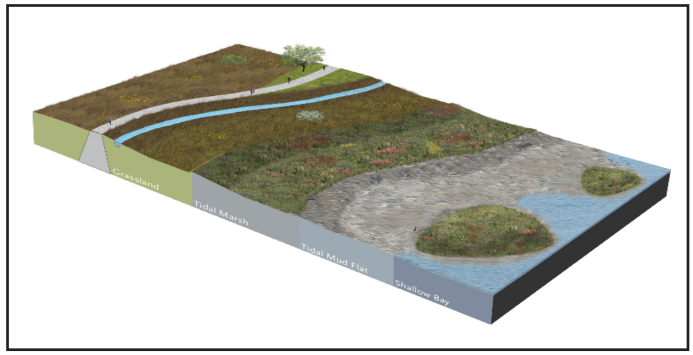
Table F-1 provides a brief description of different types of soft and hybrid strategies that can function as a nature-based adaptation strategy. Each strategy can be implemented alone, in conjunction with other strategies, or as part of a phased adaptation approach to address short-, mid-, and long-term sea level rise adaptation goals. As more nature-based adaptation strategies are implemented along the California coast, practitioners will be able to refine planning, installation, maintenance, and monitoring techniques and contribute to a growing repository of best practices.

Table F-1. A sample of nature-based adaptation strategies that can be implemented in California.

Artificial/Constructed Reef An artificial or constructed reef is a submerged breakwater (meaning the reef is rarely exposed to the surface) that aims to dissipate waves and provide habitat for hard-substrate ecological communities in the surf zone.	 (ESPA/PWA 2012)
Cobble Berm Sometimes referred to as dynamic revetments, cobble berms are constructed out of smaller, typically rounded, rocks called cobble. The cobble can be moved by larger waves during storms to create berms that dissipate wave energy and stabilize the shoreline such as those that naturally occur around some river mouths.	 Surfer’s Point, January 2017 (ESA, 2018)

Ecotone Levee

Ecotone levees (also known as horizontal levees) are levees with a wide gently sloped footprint that extends from the subtidal zone to above mean higher high water (MHHW) to include the upland transition zone. They provide for extended zoning of ecological resources while simultaneously creating textured surfaces through the use of vegetation and substrates that dissipate wave energy. Ecotone levees are particularly well-suited to create more opportunity for the range of habitats that occur on sheltered shorelines. With sufficient vegetation, the heights of ecotone levees can be reduced to account for the dissipation of waves by the vegetation.



(City of San Jose)

Eelgrass Bed

Eelgrass beds are communities of eelgrass on soft bottom substrates at lower intertidal and subtidal areas that provide high levels of primary productivity, high biodiversity, and high species density. They are also important nursery habitat for many fisheries species. Eelgrass beds can provide protection by dissipating wave energy and slowing tidal currents at low tide. In addition, they can help mitigate for other climate impacts through carbon sequestration and buffering against ocean acidification.

(Morro Bay National Estuary Program)

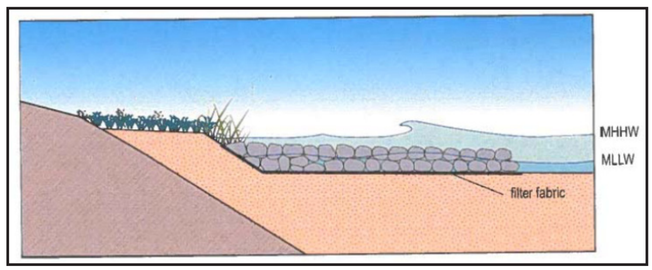
Living Seawall

While living seawalls do not restore natural processes and may have detrimental impacts to beaches comparable to traditional seawalls, living seawalls aim to enhance the ecological benefits of seawalls by creating habitat for hard-substrate and intertidal and subtidal communities where seawalls may be necessary.

Seattle Living Seawall (University of Washington, 2017)

Marsh Sill

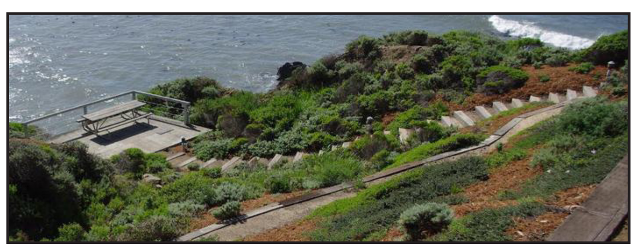
Marsh sills are shore parallel structures that combine a low-profile stone “sill” with wetland vegetation. The structural component provides protection to the marsh vegetation, allowing time for the plants to establish, as well as the upland environment by dissipating wave energy and reducing shoreline erosion.



Marsh Sill Diagram (Newkirk et al., 2018)

Native Vegetation Stabilization

Invasive bluff vegetation can increase bluff erosion, particularly iceplant (Carpobrotus edulis), which is commonly found on bluffs throughout California. Removal of invasive vegetation and planting of native vegetation that does not require irrigation can help stabilize the surface of the bluff face and reduce erosion.



Native Vegetation Garden, Central California (Bert Wilson)

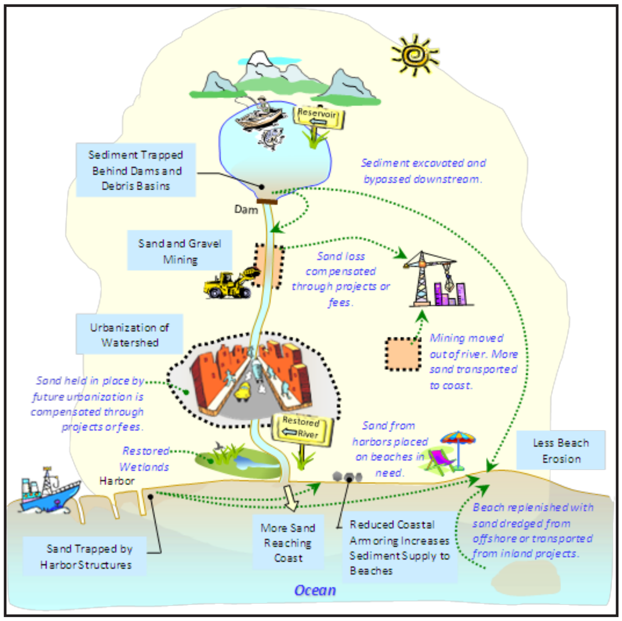
Oyster Bed

Oyster beds are low-relief structures that consist of native oyster aggregates located in intertidal and subtidal zones. Oyster beds act as an important breeding and foraging habitat for many species. They provide protection by buffering storm surges, attenuating waves, reducing shore erosion, and encouraging sediment accretion.

Native oyster shell used to encourage native oyster recruitment in Upper Newport Bay (Orange County Coastkeeper)

Regional Sediment Management (RSM)

Regional sediment management is the systematic approach to addressing sediment supply imbalances at a regional scale. RSM includes the restoration of natural processes as much as possible throughout the sediment system and encourages the use of clean sediment as a resource at sediment-starved locations. For more information, see the Coastal Sediment Management Working Group (CSMW).



Rock Platform + Vegetation

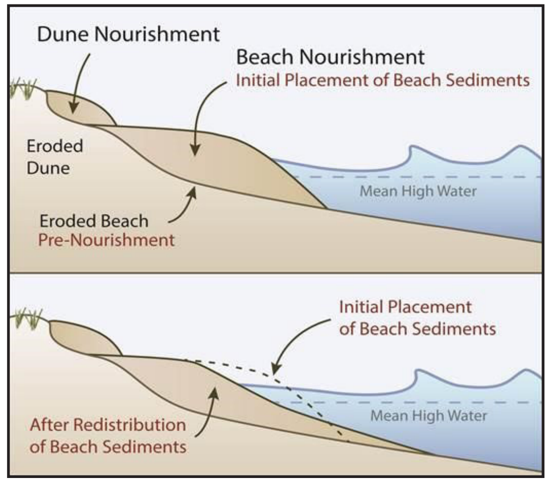
Rock platforms stabilize the toe of a bluff and provide a base for native vegetation to stabilize the bluff face.

(Mad River Bluff Riverbank Stabilization)

Sand Berm Sand berms are often constructed out of existing sand to create temporary flood protection. Sand berms create a high relief structure that reduces wave overtopping. Sand berms can be eroded during large storms or regraded into the beach. Sand can also be imported to create berms or “dune embankments” that may have vegetation.	 (Los Angeles County)
Sand Dunes Coastal dunes are mounds or hills of sand and native vegetation often situated landward of the wave runup zone of a beach. Native dune vegetation provides important habitat for many rare and uniquely adapted species, and helps trap wind-blown sediment, thereby building up or maintaining the general size of a coastal dune. Dunes can also act as a sand supply reservoir that helps re-nourish the beach when erosion from coastal storms and waves may deplete the sediment. Coastal dunes provide protection by reducing wave overtopping events and inhibiting saltwater surface intrusion into the backshore environment.	 Surfer’s Point, Ventura, California (ESA, 2017)

Sand Nourishment

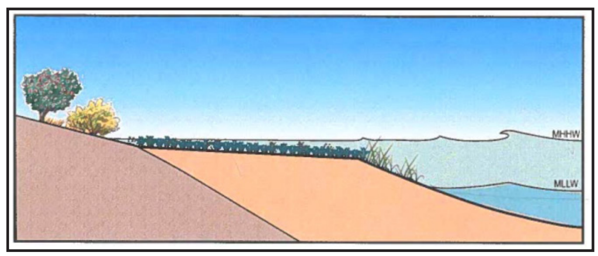
Sand nourishment, or beach nourishment, is the placement of sand onto a beach. The additional sediment gets redistributed either by waves and currents or through human manipulation until it reaches an equilibrium profile. Sand nourishment helps maintain the beach zone, acts as a buffer between upland areas to reduce the impacts of coastal hazards, and supports beach ecosystems.



(Massachusetts Wildlife Climate Action Tool)

Tidal Bench

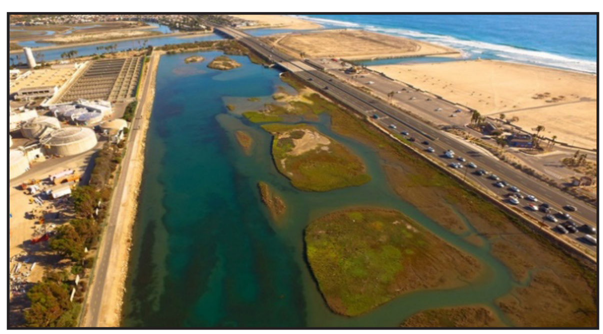
Similar to ecotone levees, tidal benches are gently-sloping benches that typically extend from the mean tide level (MTL) or lower towards the backshore (whereas ecotone levees extend into the dry upland transition zone). Tidal benches are constructed with fill material and vegetation. Tidal benches provide habitat and protection by dissipating wave energy and encouraging sediment accretion.



(Newkirk et al. 2018)

Wetland Restoration

Wetland restoration can help reduce erosion by restoring habitat through placement of imported sediment, removal of invasive vegetation and other foreign materials, and planting of native marshland vegetation that absorbs wave energy, stabilizes soils, increases sediment retention, and dampens incoming waves and coastal turbulence.


(Huntington Beach Wetlands Conservancy)

The nature-based adaptation strategies highlighted in Table F-2 are not fully comprehensive, but are meant to capture common or most likely approaches determined by the typical geophysical and engineering constraints for each hazard and geophysical context specific to California. The table is adapted from the FHWA's Implementation Guide on Nature-based Solutions for Coastal Highway Resilience, and not based on any quantifiable performance metrics. Projects requiring a Coastal Development Permit (CDP) will still be reviewed by Coastal Commission and/or local government for consistency with the Coastal Act and/or certified LCPs. Coastal managers and potential applicants are encouraged to reach out to staff early in the design process to discuss the potential for nature-based adaptation strategies.

Table F-2. This table provides examples of both softer strategies and hybrid armoring strategies that can be applied to different coastal settings in California.

Hazard/Issue	Softer Strategies	Hybrid Armoring Strategies
Erosion (sheltered coast)	• Oyster bed • Eelgrass bed • Tidal bench • Wetland restoration • Regional sediment management	• Cobble berm + sand dunes • Marsh sill • Marsh sill + breakwater • Tidal bench + breakwater • Cobble berm + marsh sill • Sand dunes + finger groins
Erosion (beach)	• Sand dunes • Sand nourishment • Regional sediment management	• Cobble berm • Buried revetment • Buried seawall • Artificial reef
Erosion (bluff)	• Native vegetation stabilization • Drainage improvements • Sand nourishment • Regional sediment management	• Cobble berm • Rock platform + vegetation
Flooding (static water level)	• Wetland restoration • Daylighting/widening/ naturalizing creek/ stream drainages • Adding tidegates, enlarging culverts, or replacing culverts with bridges	• Ecotone levee
Flooding (wave overtopping and runup, sheltered coast)	• Sand dunes • Eelgrass bed • Tidal bench • Oyster bed • Wetland restoration	• Cobble berm • Marsh sill • Ecotone levee • Sand dune + buried seawall • Artificial reef
Flooding (wave overtopping and runup, open coast)	• Sand dunes • Sand berm	• Cobble berm • Sand dunes + buried seawall • Artificial reef

APPENDIX G.

Cost Savings of Adaptation and Hazard Avoidance

Numerous state, local, and federal reports have concluded that the costs of sea level rise planning and adaptation are less than the costs of inaction. In other words, it is more cost effective to anticipate and avoid climate impacts than to wait for disasters to occur and clean up or rebuild afterward. These reports provide a compelling argument supporting proactive planning at all levels and sectors, and highlight the cost-saving nature of hazard avoidance.

FEDERAL STUDIES

The third National Climate Assessment states 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).

Additionally, a 2005 report from FEMA entitled "Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities," found that society saves roughly $4 for every $1 spent on mitigation through FEMA programs (Multihazard Mitigation Council, 2005). A 2017 update to this report aggregated more data and project examples, concluding that the average cost savings ratio is even higher, at 6:1 (Multihazard Mitigation Council, 2017). Figure G-1 shows the cost savings ratios associated with different hazard types.

National Benefit-Cost Ratio Per Peril *BCR numbers in this study have been rounded	Federally Funded	Beyond Code Requirements
Overall Hazard Benefit-Cost Ratio	6:1	4:1
Riverine Flood	7:1	5:1
Hurricane Surge	Too few grants	7:1
Wind	5:1	5:1
Earthquake	3:1	4:1
Wildland-Urban Interface Fire	3:1	4:1

Figure G-1. Benefit-cost ratio by hazard and mitigation measure. Source: Multihazard Mitigation Council, 2017.

An additional report dedicated to utilities and transportation provided case studies on the cost savings of proactive adaptation in those sectors. While not statistically valid because too few projects were included in the study, the case studies offer anecdotal evidence of the potential value of such types of mitigation. For example, four flood mitigation projects for roads and railroads had benefit-cost ratios ranging between 2.0 and 11.0, meaning that the benefits of avoiding damage and other impacts outweighed the implementations costs of the projects by 2-11 times. Flood mitigation for water and wastewater facilities produced benefit-cost ratios between 1.3 and 31.0 for four separate projects. Finally, one flood mitigation project for electric and telecommunications produced an estimated benefit-cost ratio of 9.4 (Multihazard Mitigation Council, 2018).

CALIFORNIA STUDIES AND REPORTS

California's Fourth Climate Change Assessment's technical report, *Adaptation Financing Challenges*, compiles a number of reports that demonstrate "there is general consensus that adaptation measures are cost-*effective*, given the far worse no-action alternative (Bjarnadottir *et al*. 2011, Chow *et al*. 2017, Hinkel et al. 2014, Hof *et al*. 2010, Kumar *et al*. 2016, Palanisami *et al*. 2015, Rodriguez-Labajos 2013, Rojas et al. 2013, Ryan and Stewart 2017, Stewart *et al*. 2014, Ward *et al*. 2010, and Wreford *et al*. 2015)" (Moser *et al.*, 2018). The report states, "Many adaptation-related costs are high (though not all), but available evidence suggests they may be widely underestimated and incomplete. At the same time, the limited available data suggest that adaptation is extremely cost-effective compared to inaction." In sum, while the costs of adaptation will probably be higher than expected, they are still less than the costs of inaction.

The 2018 report entitled *Paying it Forward*, which stemmed from the state Assembly Bill 2800 (Quirk, 2016), highlighted that "climate change can cause greater damages and higher costs to infrastructure if the impacts of climate change and related extreme events are not prevented or mitigated" (Climate-Safe Infrastructure Working Group, 2018). These costs can take the form of increased costs of operation, maintenance, and repair; delays to a community's return to full economic capacity after an extreme event; or increased research and development costs for innovations in engineering and design for infrastructure that can remain safe in place. It also highlights the fact that “the longer infrastructure is not maintained in a state of good repair, the more expensive the repair ultimately gets. […] In general, earlier maintenance keeps infrastructure in better condition and costs less than deferring maintenance to a later date.” Therefore, addressing the vulnerabilities of infrastructure to climate change in a proactive way, will ultimately lead to cost savings down the line.

These reports clearly call for adaptation planning and implementation to address climate vulnerabilities before disasters strike. In addition to these state reports, local studies have also demonstrated the value of adaptation, and in particular, have demonstrated that oftentimes the most cost-effective alternative in the long-term is to avoid the hazards of sea level rise altogether.

LOCAL STUDIES

The City of Pacifica’s *Sea Level Rise Adaptation Plan* included a cost/benefit analysis of three different sea level rise adaptation strategy options, including armoring, beach nourishment in combination with armoring, and managed retreat. The report states, “In a number of sub-areas, Alternative 3 [retreat] yielded the highest net-benefits (or lowest costs) because the cost of Alternative 1, which involves armoring, were higher than the benefits of protecting the property. Alternative 1 (armoring) may also reduce the width of beaches, which can lower recreational value” (ESA, 2018). The study looked at which of the three adaptation alternatives was most cost effective by 2050 and by 2100 for each of eight shoreline segments. For most segments and most timeframes, managed retreat was found to be the option with the highest net benefits.

The study included detailed analysis of each cost and each benefit, which provides valuable information on the distribution of costs and benefits across different populations and sectors. However, the report stated that managed retreat “is *less* aligned with the Council adopted goal to Preserve Existing Neighborhoods and Promote Environmental Justice and Local Economic Vitality. When considering policies to incorporate into the LCP Update, the City will need to consider costs/benefits on balance with community goals” (emphasis added). Therefore, while managed retreat is generally a cost-effective option, the city acknowledged the opposition to managed retreat among portions of its constituency and took that factor into account as it developed its sea level rise adaptation approach for the city.

Similar to the findings reported in Pacifica’s vulnerability assessment, the City of Imperial Beach’s *Sea Level Rise Vulnerability Assessment* reports that managed retreat has the highest long-term net benefits when compared to armoring, nourishment, green infrastructure, and groins (Revell Coastal, 2016). However, similar to Pacifica, the city’s constituency voiced strong opposition to managed retreat as an adaptation strategy, and the subsequent draft of its General Plan/Land Use Plan Update specifically excludes managed retreat as an adaptation strategy.

These anecdotes highlight the challenges associated with sea level rise adaptation planning: even if economic studies demonstrate which strategies are the most cost effective, other factors such as input from particular constituencies can push adaptation planning down different paths with different associated costs and benefits.

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APPENDIX H.

Transportation Planning Documents

The following appendix contains lists and descriptions of state, regional and local transportation planning efforts referenced in Chapter 5 on Tranportation Infrastructure in addition to several others not discussed in Chapter 5.

Adaptation Strategies Reports (2020-2021) These reports include a prioritized list of potentially exposed assets in each Caltrans District. The prioritization methodology in these reports considers, the timing of the climate impacts, their severity and extensiveness, the condition of each asset (a measure of the sensitivity of the asset to damage), the number of system users affected, and the level of network redundancy in the area.

Caltrans Strategic Management Plan (Draft, 2021) Caltrans' Strategic Plan.

California Transportation Plan 2050 (2020) The state's long-range transportation plan that establishes an aspirational vision that articulates strategic goals, policies, and recommendations to improve multimodal mobility and accessibility while reducing greenhouse gas emissions.

Climate Action Plan for Transportation Infrastructure (CAPTI) (Draft, 2021) A first of its kind document will be organized to align with Caltrans' Strategic Management Plan.

Climate Change Vulnerability Assessments (2017-2019) These assessments identify segments of the State Highway System vulnerable to climate change impacts including precipitation, temperature, wildfire, storm surge, and sea level rise. The results are used to guide analysis of at-risk assets and develop adaptation plans to reduce the likelihood of damage to the State Highway System.

Corridor Plans Define how a corridor is performing (and estimates for the future), why it is performing that way, and recommends projects and strategies that achieve corridor goals and objectives. The recommended strategies, opportunities, or projects may become candidates for funding programs. See Caltrans Corridor Planning Process Guide for more information. Note this Guide superseded the Transportation Concept Report (TCR) Guidelines, which are being phased out. There are many different types of corridor plans including Transportation Concept Reports, Corridor System Management Plans, and Comprehensive Multimodal Corridor Plans.

District System Management Plans Long range (20-year) strategic and policy planning documents created by Caltrans districts that present the long-range goals, policies, and programs the district intends to follow in maintaining, managing, and developing the transportation system. These serve as a resource for informing federal, state, regional and local agencies, and the public and private sector of the plans the district intends to follow in its partnership role with local and regional agencies. See this link for more information.

Interregional Transportation Strategic Plan (Draft, 2021) Provides guidance for the identification and prioritization of interregional transportation projects identified on the State's Interregional Transportation System, specifically, the 93 Interregional Road System routes and State-run intercity rail corridors. This plan is also used in the identification and selection of projects for Interregional Transportation Improvement Program funding.

Regional Transportation Plans Conducted by local regional transportation agencies, or metropolitan organizations, under Caltrans guidance, see 2017 Regional Transportation Plan Guidelines for Regional Transportation Planning Agencies.

State Highway System Management Plan (Draft, 2021) Presents a performance-driven and integrated management plan for the State Highway System (SHS) in California. SHS needs, investments, and resulting performance projects for the 10-year period spanning July 2019 to June 2029 are presented in the SHSMP. The SHSMP is organized to align with Caltrans' Strategic Management Plan.

State Rail Plan Update (2018) Provides a framework for California's rail network and sets the stage for new and improved rail and communities.