California Regional Water Quality Control Board
San Francisco Bay Region

Proposed Basin Plan Amendment on Climate Change and Aquatic Habitat Protection, Management, and Restoration

Draft Staff Report

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

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1 Introduction

Globally and in the San Francisco Bay region, climate change is manifesting as higher temperatures; rising sea and groundwater levels; changes in the timing, frequency, intensity, and duration of precipitation and runoff; more frequent and severe storm surges, floods, and droughts; drowning and downshifting of wetlands; and landscape aridity that increases the risk of catastrophic wildfires. These changes are impacting the health, integrity, and resilience of the region's built and natural communities in complex and interconnected ways, and they pose a special threat to the region's waters, including wetlands. The threats are especially acute in and near the San Francisco Baylands and low-lying areas of the Pacific coast, where climate change impacts to watersheds are compounded by impacts from rising sea and groundwater levels. Efforts to respond to and prepare for climate change through the construction of traditional infrastructure and armoring, such as levees, seawalls, engineered flood control channels, and rock revetments, can exacerbate harm to aquatic ecosystems and vulnerable shoreline communities.

Recognizing the threat that climate change poses to the region, multiple efforts are underway to assess the vulnerability of the region's coastal, shoreline, estuarine, and nearshore assets, and to develop adaptation plans to improve the long-term resilience of these assets. The San Francisco Bay Regional Water Quality Control Board (Water Board) participates in many of these efforts, due to its broad authority to regulate activities and factors that may affect water quality. For example, the Water Board can regulate how dredging and filling of waters, flood management, beneficial reuse of sediment and treated wastewater, shoreline development, and related activities can impact water quality and the beneficial uses of the region's waters, including wetlands. This broad regulatory authority enables the Water Board to play a key role in facilitating projects and programs that improve the beneficial uses of the region's waters.

The Water Board helped lead the 2015 update of the Baylands Ecosystem Habitat Goals (Goals Project 2015), which articulated a vision for accelerated habitat restoration in the San Francisco Baylands to prepare for rapidly rising seas in the latter half of the 21st century. More recently, the Water Board is funding the development of the San Francisco Bay Shoreline Adaptation Atlas (SFEI and SPUR 2019), which proposes a science-based framework for identifying opportunities to deploy nature-based infrastructure along the Bay's shoreline. Water Board staff also help lead the development of a Wetland Regional Monitoring Program that, if implemented, will assess where and how tidal wetlands, including restoration projects, are responding to climate change.

In 2016, Bay Area voters approved Measure AA, which is providing $500 million over 20 years to fund tidal wetland restoration and related activities in the Bay through the newly formed San Francisco Bay Restoration Authority (SFBRA). In anticipation of the need to efficiently permit SFBRA projects, state and federal regulatory agencies[1] have initiated a collaborative effort called

[1] BRRIT participants include the Water Board, U.S. Army Corps of Engineers, Bay Conservation and Development Commission, National Marine Fisheries Service, U.S. Fish and Wildlife Service, and the California Department of Fish and Wildlife.

the Bay Restoration Regulatory Integration Team, or BRRIT. The BRRIT will coordinate permitting efforts between regulatory agencies and consult on relevant policy and procedural changes to facilitate restoration project planning and implementation. SFBRA funding and BRRIT permit coordination are expected to increase the number of tidal wetland restoration and sea level rise adaptation projects in the region, as well as the pace at which they move through planning, design, permitting, and implementation. The locations and designs of these projects will likely result in temporary and/or permanent impacts to coastal and nearshore waters of the state, and therefore these projects require Water Board involvement.

To help inform the planning, permitting, and implementation of projects that will protect and restore the beneficial uses of the region's coastal waters, and to help prevent projects that will have long-term and/or cumulative negative impacts to these systems, it is important that the Water Board update the Basin Plan to provide information related to climate change and share the knowledge the Water Board has acquired to protect the beneficial uses of waters in the face of climate change. The Basin Plan currently lacks any description of climate change and its relevance to the Water Board's regulatory programs, particularly dredge or fill activities in and near the region's shorelines. The Water Board therefore identified a climate change amendment to the Water Quality Control Plan for the San Francisco Basin (Basin Plan) as a high priority in its 2015, 2018, and 2020 Triennial Reviews of the Basin Plan. This Staff Report describes the proposed Basin Plan amendment, its technical support, and its components, all of which are informational and non-regulatory.

2 Project Terminology and Description

This section defines the terms used to describe the waters of the San Francisco Bay region. It also describes the project, which forms the basis of the assessment required by the California Environmental Quality Act (CEQA), and explains why the proposed Basin Plan amendment project is needed.

2.1 Terminology

This report uses several terms to describe the waters of the San Francisco Bay Region. These terms are, in most cases, based on definitions in the Baylands Ecosystem Habitat Goals reports, the Bay Area Aquatic Resource Inventory, and the San Francisco Bay Shoreline Adaptation Atlas.

- *San Francisco Bay*: The body of tidally influenced water bounded by the Golden Gate in the west and Broad Slough in the east, including the portions of tributaries that drain to the Bay below the head of tide.
- *San Francisco Estuary*: The body of tidally influenced water bounded by the Golden Gate in the west, and the head of tide in the Sacramento-San Joaquin Delta to the east, including the portions of tributaries that drain to the Estuary below the head of tide.
- *Baylands*: The lands and shallow waters along San Francisco Bay that are or formerly were between the minimum and maximum boundaries of the Bay's tides. The baylands include multiple habitat types including but not limited to tidal and diked (non-tidal and muted tidal) wetlands, mudflats, ponds, pannes, channels, and beaches. For purposes of this report, the

baylands include adjacent estuarine-terrestrial transition zones (including levees, hillslopes, and floodplains) that are likely to be within the range of future (with sea level rise) tidal influence.

- *Estuarine wetlands*: Any wetland in the region formed or otherwise influenced by both terrestrial and marine processes, at or near the confluence of freshwater (from surface water or groundwater) and marine water. Estuarine wetlands encompass wetland and associated habitats within the San Francisco Baylands, as well as wetland and lagoon (bar-built estuary) habitats along the coastline of the Pacific Ocean and its embayments, such as Tomales and Half Moon Bays.
- *Coastal waters*: Coastal, shoreline, estuarine and nearshore waters and their associated habitats (including baylands, wetlands, mudflats, and beaches) within the San Francisco Bay Region, including within and along San Francisco Bay, the Pacific Ocean, their embayments, and their tributaries.

2.2 Project Description

The project proposes to amend portions of Chapters 1, 2, and 4 of the Basin Plan to update descriptions in the Basin Plan related to water quality challenges posed by climate change, update references, make non-substantive edits and corrections, and provide questions and information related to climate change and adaption that may be relevant to Water Board permitting of dredge or fill activities affecting the region's coastal, shoreline, estuarine and nearshore waters of the state (collectively referred to in this report as "coastal waters" or "coastal waters of the state"). As the Water Board's master planning document for water quality, the Basin Plan establishes beneficial uses of waters, water quality objectives to protect those beneficial uses, and implementation programs for achieving the water quality objectives. The following changes to the Basin Plan are proposed, by chapter:

Chapter 1

- Revision 1(1). In Section 1.1, remove text comparing the size of the region to the size of the state of Connecticut and insert text indicating that the changing climate is altering estuaries.
- Revision 1(2). Insert a new Section 1.7 describing the effects of a changing climate on water quality and the need to address these effects on a landscape scale.

Chapter 2

- Revision 2(1). In Section 2.2.3, update the name of the California Department of Fish and Game to the California Department of Fish and Wildlife. Update references to the Baylands Ecosystem Habitat Goals Report and EcoAtlas.

Chapter 4

- Revision 4(1). Update references to planning documents related to wetland restoration and mitigation in Sections 4.23, 4.23.1, and 4.23.4.

- Revision 4(2). In Section 4.23.2, correct an erroneous reference to Table 2-3; the correct reference is Table 2-4. In the same section, update the reference sources that can help determine the beneficial uses for coastal waters in the region, including wetlands. Revision 4(3). Change the name of Section 4.23.4 to "Wetland Dredge or Fill" from "Wetland" to more accurately describe the section. Make minor edits to the description of how waters of the state are affected by dredging, diking, and filling in the same section. Add information on the State Water Resources Control Board's (State Water Board) "Wetland Definition and Procedures for Discharges of Dredged or Fill Material to Waters of the State" (Dredge and Fill Procedures) to reflect the current regulatory landscape. Delete an obsolete reference to the Wetland Ecological Assessment.
- Revision 4(4). Insert a new Section 4.27 entitled "Climate Change and Aquatic Habitat Protection, Management, and Restoration," which:
    - Acknowledges and describes how climate change can adversely impact aquatic habitats and their beneficial uses. Describes how certain climate adaptation projects can exacerbate impacts to aquatic systems. Describes efforts made to support the long-term resilience of aquatic habitats in the region.
    - Provides questions and information related to climate change and adaption that may be relevant to Water Board permitting of dredge or fill activities in or near coastal waters. When permitting such activities, under existing laws and regulations, the Water Board is required to ensure that adverse impacts to waters of the state have been appropriately avoided, minimized, and compensated. Understanding the reasonably foreseeable influence of climate change is important to adequately assess the impacts of these activities to waters of the state. In addition, the Water Board has increased its knowledge with respect to climate change adaption projects and their potential for adverse impacts to waters of the state and the questions and information incorporate this knowledge. The questions and information cover the following:
        1. **Is the proposed project design, as well as assessment of its near-term and long-term impacts at site- and landscape-scales, based on the best available science describing climate change and its influence on the environment?** Projects should be based on the best available science on the anticipated future conditions over the life of the project, including but not limited to any reasonably foreseeable changes in (1) sea levels and nearshore groundwater levels; (2) the timing, frequency, intensity, and duration of seasonal precipitation, watershed runoff, Delta outflow, and wave events; and (3) the supply of sediment available to maintain healthy coastal habitats. Projects should be designed to avoid/minimize direct, indirect, and cumulative impacts by accommodating existing and likely future physical and ecological drivers and conditions at the project site. Sometimes, future conditions are presented in probabilistic risk aversion categories. In such cases, a project should be based on the appropriately protective risk aversion approach to ensure that water quality impacts from project performance are avoided and minimized where practicable.

2. **Is the proposed project designed as part of a phased adaptation strategy that anticipates potential future projects and accommodates these projects in a manner that protects future beneficial uses of the site and its landscape?** Phased adaptation strategies are actions to provide flood protection at different climate change thresholds over time. Initial actions are designed to provide flood protection in the near-term while allowing for a range of future actions to address uncertainty and allow flexibility over the long term. Preferable actions will maintain long-term lines of flood defense along San Francisco Bay and the Pacific Ocean as far landward as practicable to minimize the isolation of wetlands and waters behind flood management infrastructure, reduce the risk of flooding of low-lying areas by surface water or groundwater, and create space for the restoration of complete estuarine wetland systems and other nature-based adaptation measures.
3. **Is the proposed project designed within a landscape-scale, cross-jurisdictional framework, such as an operational landscape unit?** Climate change operates on a landscape-scale. Therefore, strategies to address climate change are more likely to be successful in the long-term if they are planned, designed, permitted, and implemented on a landscape-scale, and not limited by political boundaries. Projects designed to consider current and anticipated future conditions not just at the project site, but also the broader landscape within which it is embedded are likely to have fewer long-term direct, indirect, and cumulative impacts than projects that only address near-term, site-specific conditions. In some cases, the least impacting project may be one that spans multiple jurisdictions, such as parcel or municipal boundaries. Projects that avoid or minimize direct impacts at the project site only to trigger indirect and/or cumulative impacts off-site are not preferable.
4. **Does the proposed project utilize practicable natural and/or nature-based design features, or a combination of traditional and nature-based features?** Properly designed and sited, projects that facilitate and/or leverage natural physical and ecological forms and processes in the long-term, and on a landscape-scale, are more likely to support beneficial uses presently and in the future than designs that impede those processes. Preferred nature-based design features include, but are not limited, to the following:
    - Living shorelines, such as oyster reefs and submerged aquatic vegetation beds
    - Beaches of sand, shell, gravel, cobble, or combinations thereof
    - Estuarine wetland protection, enhancement, and restoration, especially in locations with connectivity between supratidal, intertidal, and subtidal habitats
    - Reconnection of estuarine habitats with rivers, creeks, and flood control channels
    - Strategic placement of sediment in estuarine wetlands and mudflats

- Gradually sloped (“ecotone”) and treated wastewater (“horizontal”) levees adjacent to estuarine wetlands
- Making space for the sea level rise-driven migration of estuarine wetlands into adjacent uplands.

5. **For a proposed dredge or fill activity, what are the near- and long-term direct, indirect, and cumulative impacts to the acreage, functions, and values of waters of the state when considering the reasonably foreseeable conditions from climate change?** Some dredge or fill activities, such as the construction of rip-rap or other similar grey infrastructure, can avoid near-term impacts to the acreage, functions, and values of waters of the state only to cause long-term impacts within the context of climate change. Other dredge or fill activities, such as the construction of natural and nature-based features described above under (4), can generate near-term impacts to the acreage, functions, and values of waters of the state, but over the long term have less impacts within the context of climate change. In fact, these projects can have long-term benefits. Thus, understanding both the near- and long-term impacts of dredge or fill activities when considering the reasonably foreseeable conditions from climate change is important to assess the totality of impacts. Assessing long-term impacts under climate change conditions can be difficult, especially considering uncertainties about future rates of sea level rise, the influence of extreme events, local and regional planning decisions, and how landscapes could change in response to these and other factors. To reduce uncertainties and help identify the circumstances under which proposed dredge or fill discharges appropriately avoid, minimize, or compensate for impacts to waters of the state, the following questions may be helpful:
   - Environmental drivers:
     - What are the primary hydrologic, geomorphic, and ecological drivers of beneficial uses and habitat resilience at the site- and landscape-scale, and how are they likely to influence the landscape in the near- and long-term?
     - Where and how are processes such as upland migration (transgression), erosion, progradation, accretion, and/or drowning likely to impact the condition, location, and distribution of different habitat types?
     - How might the proposed dredge or fill activities influence these drivers?
   - Impacts of no action:
     - How would the affected landscapes be likely to evolve in the absence of the proposed dredge or fill activities?
     - Given the likely range of anticipated environmental drivers, would the absence of the proposed activities likely result in less diverse, resilient, and/or complete habitats in the long-term?

- Coherent landscapes:
    - Are the proposed dredge or fill activities geographically and geomorphically situated and designed to work with both site-scale and landscape-scale natural processes, such as the movement of water and sediment, shifts in plant communities, and the movement of fish and wildlife between different habitats?
    - Will the proposed activities enhance or impede the ability of these natural processes to exert work on the landscape?
- Type conversions: Some dredge or fill activities may convert one type of water of the state to another (e.g., salt pond to tidal flat/tidal wetland), or convert one component of the estuarine wetland ecosystem to another (e.g., tidal wetland to estuarine-terrestrial zone, tidal wetland to high tide refugia, or tidal wetland to tidal channel). The overall impacts of proposed wetland type conversions can be assessed using technical guidance such as the Aquatic Resource Type Conversion Evaluation Framework.
    - Does the landscape setting, including but not limited to local climate, hydrology, sediment supply, degree of urbanization, habitat connectivity, and geomorphic setting, support the intended habitat type?
    - Does the intended habitat type require intensive management that will have to be funded and implemented in the long-term?
    - What ecosystem functions will be gained or lost through type conversion, and what is the potential timing and magnitude of these changes? How are these changes likely to influence ecosystem functions within the broader landscape?
    - Is the proposed type conversion consistent with strategies developed by collaborations of stakeholders to achieve regional goals such as recovering rare and/or historic habitat types, improving landscape connectivity/complexity, and/or supporting long-term habitat resilience?

2.3 Project Purpose

The purpose of this proposed amendment is to include information about climate change and how it threatens the health, integrity, resilience, and beneficial uses of waters of the state into the Basin Plan. The amendment provides informative resources related to climate change, natural and nature-based project approaches, and questions and information that may be relevant to Water Board staff permitting dredge or fill activities in or near coastal waters.

3 Project Background

There is scientific consensus that since the Industrial Revolution, human activities have increased and continue to increase concentrations of greenhouse gases such as carbon dioxide and methane in the earth’s atmosphere, causing rapid and accelerating changes in the Earth’s climate and global water cycle. This consensus is reflected in a broad range of international and national technical and policy documents, including reports and recommendations from the International Panel on Climate Change and the United States Global Change Research Program. Recognizing the threat that climate changes poses to the health, safety, and well-being of Californians and the landscapes on which they depend, the State of California has since 2006 developed four comprehensive climate change assessments. These assessments focus on the impacts and risks from climate change in California and inform State policies, plans, programs, and guidance to support effective climate change mitigation and adaptation[2]. California's Fourth Climate Assessment, completed in 2018, describes in detail how climate change is already impacting California through higher temperatures, rising sea levels, declining snowpack, and increasing frequencies and severities of drought and extreme precipitation events, and it describes how these troubling trends are expected to intensify in the future (Bedsworth et al. 2018).

3.1 Sea Level Rise

Sea level rise is among the most apparent impacts of climate change in California (Griggs et al. 2017). In the San Francisco Bay region, the tide gage at the Golden Gate has recorded almost 8 inches (0.2 m) of sea level rise over the past century (OEHHA and CalEPA 2018), as shown in Figure 1.

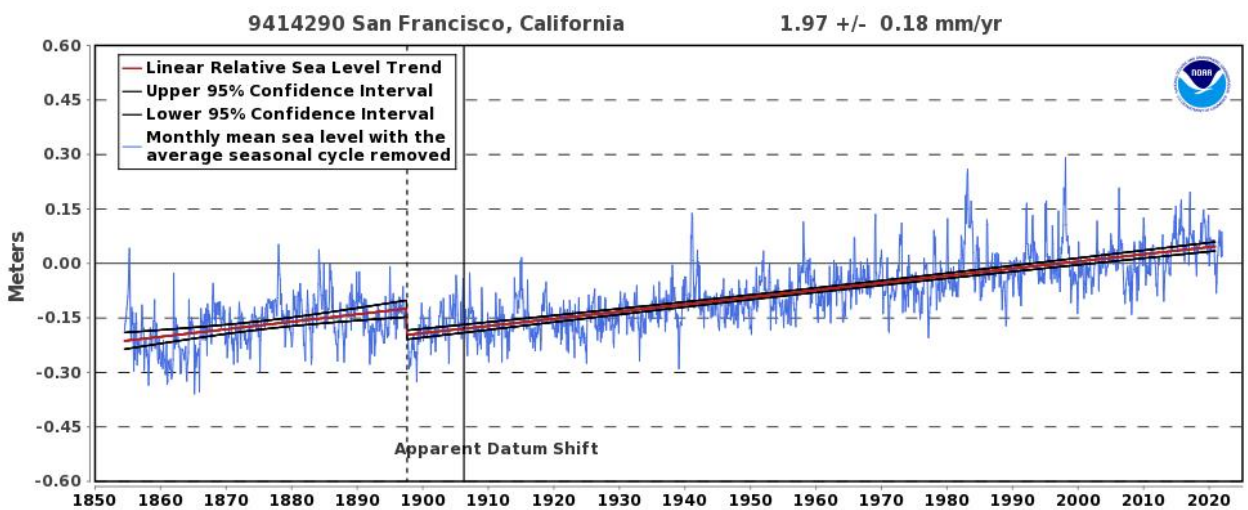

Figure 1. Sea level rise at the Golden Gate has risen almost 8 inches in the past 100 years. (Image: NOAA CO-OPS)

[2] *Mitigation* actions reduce emissions of greenhouse gases into the atmosphere, to reduce the future impacts of climate change. *Adaptation* actions reduce harm to communities and landscapes from the impacts of climate change.

Climate change contributes to global sea level rise and relative sea levels[3] through a variety of global, regional, and/or episodic mechanisms. Global contributions to sea level rise include long-term changes in geophysical, atmospheric, and hydrologic conditions and processes across the globe, such as the thermal expansion of warming oceans and the melting of land-based ice in glaciers, ice caps, and ice sheets. Regional contributions to relative sea levels include vertical land motion due to plate tectonics, subsidence and compaction, the effects of melting ice on Earth's rotation and gravitational fields, and periodic changes in Pacific Ocean winds, circulation, and temperatures. Episodic contributions to Bay relative sea levels include short-term impacts on local sea levels from storms, waves, "king" (perigean spring) tides, and Delta outflow. These drivers are discussed in Appendix A of Toms et al. (2019).

As of 2021, the best available science describing potential future sea level rise scenarios in California is the April 2017 report *Rising Seas in California: An Update on Sea Level Rise Science* (Griggs et al. 2017), published by the California Ocean Protection Council Science Advisory Team. This report incorporates the findings of a broad range of climate change research. Among its important findings is that the rate of ice loss from the Greenland and West Antarctic ice sheets is increasing and that this loss will soon become the largest component of sea level rise globally and in California.

To help planners and decision-makers contextualize the risk associated with planning for different levels of sea level rise, the *Rising Seas* report assigns statistical probabilities to a range of potential sea level rise scenarios based on low and high emissions[4] scenarios. Under a low emissions scenario, there is a 66 percent probability that by 2100, sea levels at the Golden Gate will have risen by 1.0 to 2.4 feet (ft), and a 0.5 percent probability that sea levels will have risen 5.7 ft. Under a high emissions scenario, there is a 66 percent probability of 1.6 to 3.4 ft of sea level rise by 2100, and an 0.5 percent probability of 6.9 ft of sea level rise. Note that since the probabilities presented in the *Rising Seas* report are based on two precise emissions scenarios, they may not reflect the actual emissions of the future, and therefore do not represent the actual probability that a given amount of sea level rise will occur.

The *Rising Seas* report also describes an extreme long-term sea level rise scenario, called H++, which was previously defined in the *Fourth National Climate Assessment* (USGCRP 2017) and supporting scientific literature. This scenario accounts for potentially catastrophic West Antarctic

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[3] Global sea level rise is the worldwide average rise in mean sea level. Relative sea level is the elevation of the sea relative to a reference land elevation at a given location. In some areas where land is rising faster than the pace of SLR due to tectonic action (for example, much of the southern coast of Alaska), relative mean sea levels are *falling* even though global mean sea levels are *rising*. See Appendix A and https://tidesandcurrents.noaa.gov/sltrends/ for more information.

[4] Greenhouse gas emissions govern global rates of SLR. In the *Rising Seas* report and the *State of California Sea-Level Rise Guidance*, "low emissions" refers to Representative Concentration Pathway (RCP) 2.6, which requires substantial reductions in global greenhouse gas reductions. "High emissions" refers to RCP 8.5, a "business as usual" scenario that assumes that global greenhouse gas emissions will continue to increase over time. Modeling indicates that the differences in SLR and other climate change impacts between these two scenarios will be especially stark in the latter half of this century. A reader-friendly guide to the RCPs and their utilization in global climate modeling is available at https://skepticalscience.com/rcp.php.

ice sheet loss, but due to the level of scientific uncertainty associated with its occurrence, the *Rising Seas* report does not assign it a probability.

The 2017 Rising Seas report formed the technical basis for the Ocean Protection Council's *State of California Sea-Level Rise Guidance* (OPC 2018), which at the time of publication is the State's official sea level rise guidance for State and local governments. The guidance proposes a methodology for decision-makers to analyze and assess the risks posed by sea level rise based on the best available science (Griggs et al. 2017), a framework for incorporating sea level rise into planning, permitting, and investing decisions, and descriptions of preferred multi-benefit coastal adaptation approaches and strategies.

3.2 Extreme Storm Events

California has more variable annual precipitation than any State in the contiguous U.S., due in large part to variability in the frequency, timing, duration, and intensity of large winter storms which provide most of the State's precipitation (snowfall and rainfall). Many of these storms are called "atmospheric rivers" due to the way they transport tremendous amounts of water vapor from the Pacific Ocean to California in long (approximately 1000 miles long), narrow (less than 100 miles wide) ribbons, which can drive significant regional gradients in precipitation totals. The spatial and temporal variability of these storms in California tends to drive hydrologic extremes (including the extent and severity of droughts and floods) as well as Statewide water resources (due to their influence on snowpack). In the San Francisco Bay region, atmospheric rivers encounter the steep topography of the Coast and Diablo Ranges and become capable of dropping tremendous amounts of rain in short periods of time. These extreme events can drive local flooding, especially where rivers and streams are influenced by tides, waves, and storm surge in San Francisco Bay and the Pacific Ocean.

The best available science indicates that climate change is driving and will continue to drive more extreme storm events in the region, primarily due to stronger atmospheric rivers that can deliver more intense rainfall. This consensus is reflected in California's Fourth Climate Assessment (Bedsworth et al. 2018), the California Department of Water Resources' annual hydroclimate reports (DWR 2015 – 2019), the *Indicators of Climate Change in California* report (OEHHA 2018), and other State climate change guidance documents. However, due to the complexity of modeling climate change impacts on regional hydrology, the State has not yet developed quantitative projections for future extreme precipitation events the way it has for sea level rise. Nonetheless, local flood management agencies such as Sonoma Water and Valley Water are moving forward with the development of their own climate change action and adaptation plans to address anticipated increases in precipitation, flows, and flood risks (Bijoor et al. 2021, Sonoma Water 2021).

3.3 Effects of Colonization and Climate Change on the Health, Diversity, and Resilience of Coastal Waters

Colonization and climate change impact the health, diversity, and resilience of the region's coastal waters by altering the physical and ecological conditions and processes on which these systems depend. These impacts are well-documented in regional technical and planning documents, including the 1999 *Baylands Ecosystem Habitat Goals Report* and its 2015 follow-up, *The Baylands and Climate Change: What We Can Do* (referred to in this report as the 1999 and 2015 Goals Reports, respectively). The 1999 Goals Report was a regional, interdisciplinary effort that synthesized the best available science on Bay estuarine hydrology, geomorphology, and ecology to propose strategies for the long-term conservation and restoration of bayland habitats, including tidal wetlands and mudflats. The 2015 Goals Report updated the 1999 Goals Report by incorporating the science detailing how climate change and sea level rise could lead to the loss of baylands, and by revising the proposed conservation and restoration strategies to reduce these losses. Both reports were developed by teams of scientists and engineers from public agencies, including the Water Board, as well as non-governmental organizations, academia, and private industry. This chapter summarizes the major findings of these reports and related scientific literature with regards to the impacts of European colonization on bayland habitats and beneficial uses, and how climate change is compounding these impacts.

3.3.1 Effects of Colonization on San Francisco Estuary Bayland Habitats

European colonization of the San Francisco Bay region has had a profound influence on local landscapes, and nowhere is this more readily apparent than in the region's baylands and shorelines. This sections below describe the characteristics of the historic San Francisco Estuary (including San Francisco Bay, San Pablo Bay, and Suisun Marsh) bayland habitats and how colonization led to their reclamation, fragmentation, and disconnection.

3.3.1.1 Characteristics of Historic San Francisco Estuary Bayland Habitats

Prior to European colonization in the 18^{th} century, the San Francisco Estuary supported a spatially and temporally variable mosaic of bayland habitats that included over 190,000 acres of tidal wetlands, 51,000 acres of tidal mudflats, 2,000 acres of natural salt ponds, and 23 miles of beaches (Goals Report 1999). These habitats formed roughly 2,000 to 6,000 years ago, as formerly rapid sea level rise due to the melting of Ice Age glaciers and ice caps leveled off (from rates of near 20 mm/year to 1-2 mm/year), allowing tidal flows and river/stream deltas to deposit broad plains of sediment in the baylands (Atwater et al. 1979). Bayland habitats were connected to subtidal Bay habitats, to watersheds, and to each other through complex, dendritic networks of tidal sloughs and stream channels whose flows of freshwater and sediment would shift across the landscape in response to floods and storms (Figure 2). Bayland habitats were also connected to terrestrial habitats through numerous types of estuarine-terrestrial transition zones that reflected the region's varied geomorphic settings (Figure 3).

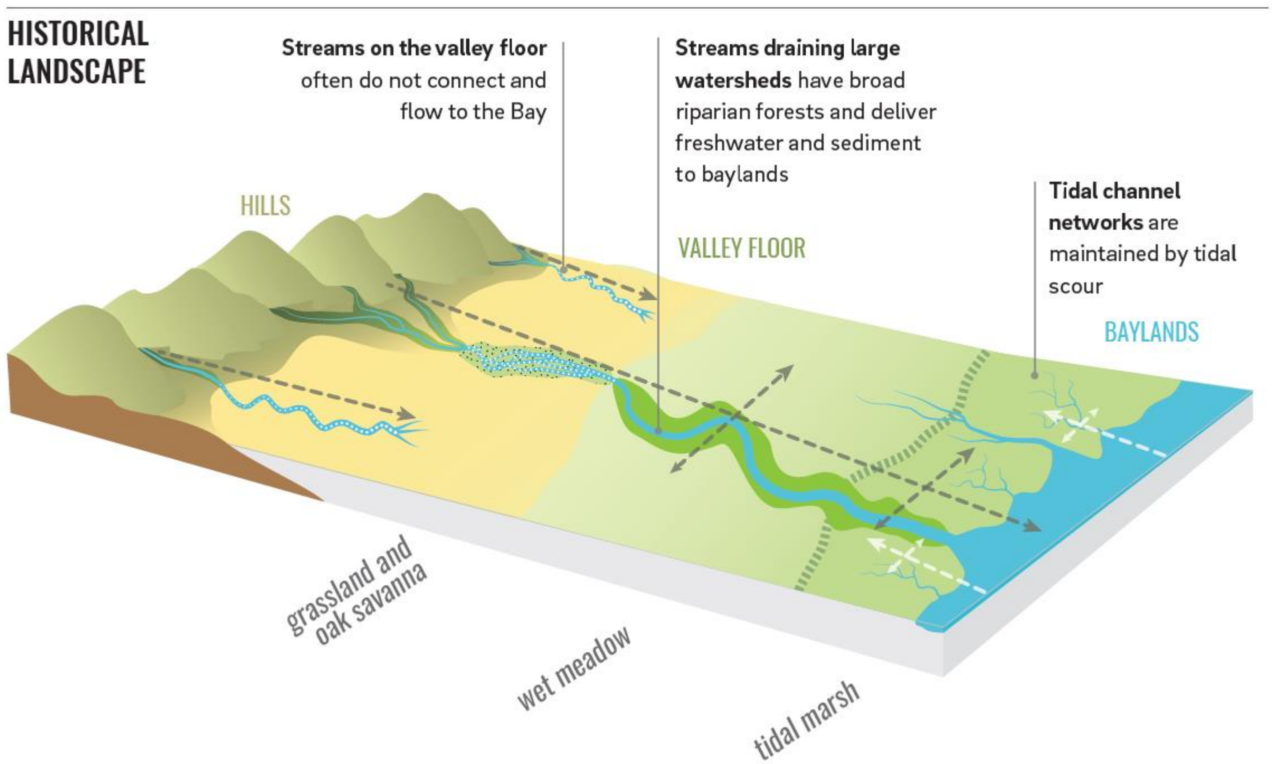

Figure 2. This graphic from the SFEI report Changing Channels: Regional Information for Developing Multi-Benefit Flood Control Channels at the Bay Interface (Dusterhoff et al. 2017) illustrates some of the dominant fluvial-tidal transition zones that historically existed within the baylands, prior to colonization.

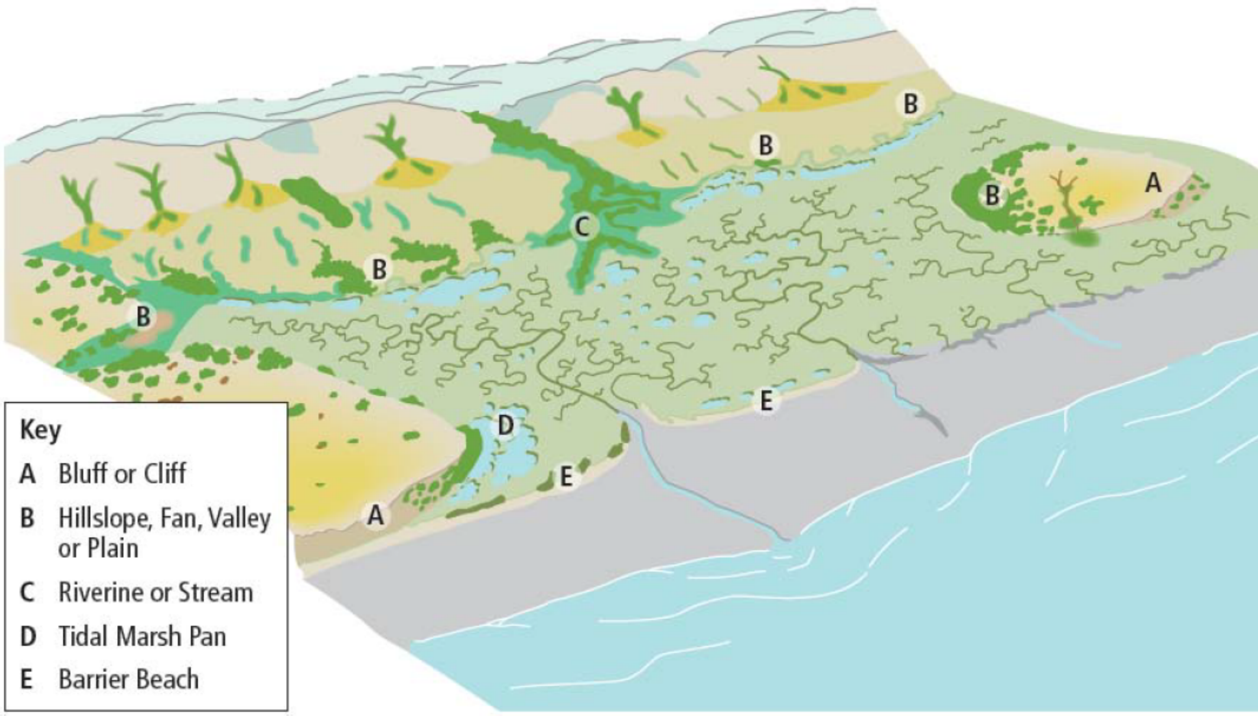

Figure 3. This graphic from the Baylands Ecosystem Habitat Goals Report: 2015 Science Update (Goals Project 2015) illustrates examples of the dominant estuarine-terrestrial transition zones that historically existed within the baylands, prior to colonization.

The 2015 Goals Report designated tidal wetlands with robust connections to subtidal, terrestrial, and fluvial habitats as “complete” tidal wetland systems that support different physical processes and ecological functions along their gradients. For example, subtidal connections allow sediment transported by the tides to move into tidal marshes and support accretion, while also allowing productivity from the marshes to be exported into open water ecosystems to support pelagic food webs. Intertidal channels weaving throughout marsh plains provide for the movement of water, sediment, and wildlife through the wetland. Supratidal areas within the interior of marsh plains (and near intertidal channels) provides high tide refugia for marsh wildlife when tides and storms inundate the marsh plain. The 2015 Goals Report places special emphasis on the importance of the estuarine-terrestrial transition zone. The report defines this zone as:

> *“...the area of existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems.”*

More than just an area of transition between estuarine and terrestrial vegetation, the transition zone is where physical and ecological processes, such as sediment delivery and wildlife movement, connect the baylands with contributing upland watersheds and vice versa. The extent of the transition zone is therefore spatially and temporally variable and depends on the ecosystem services being considered (Figure 4). The 2015 Goals Report includes an extensive list of the major ecosystem services provided by the transition zone, all of which directly or indirectly support the beneficial uses of the Estuary and its tributaries.

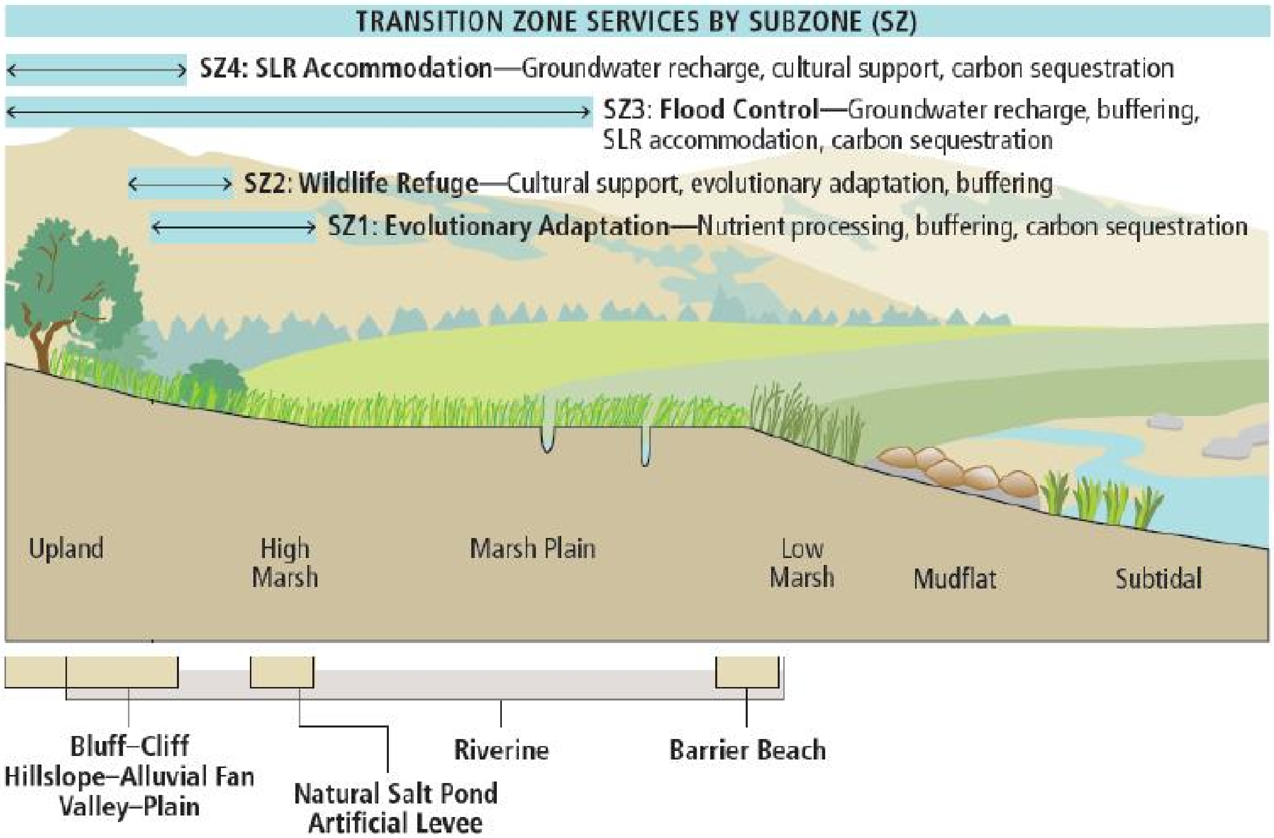

Figure 4. A conceptual diagram of a "complete" tidal wetland system from the 2015 Goals Report, showing how different portions of the estuarine-terrestrial transition zone provide different ecosystem services.

The dynamic, connected nature of bayland habitats drove their tremendous diversity and resilience, as plant and animal species could respond to environmental disturbances by dispersing across space and time to the microhabitats in the Estuary that met their precise life cycle needs. This highly productive landscape supported not only resident plants, fish, and wildlife, but was a vital refuge for migratory shorebirds and waterfowl along the Pacific Flyway, and a key nursery for Eastern Pacific populations of migratory fish, such as salmon and sturgeon.

Though many bayland habitats were managed in some way by local indigenous communities (e.g., enhancement of natural salt ponds to improve production, burning of coastal prairies and seasonal wetlands adjacent to tidal marshes), this management appears consistent with the physical and ecological processes that shaped the Estuary. These communities seem to have worked with the region's natural cycles to foster healthy bayland habitats and sustainable populations of estuarine food and fiber species, such as oysters, crabs, fish, waterfowl, tules, cattails, sedges, and rushes. This stewardship, honed through thousands of years of observation and generational instruction, was among the reasons the Bay Area became one of the most densely populated and linguistically diverse regions in pre-colonial California (Hykelma 2021).

3.3.1.2 Impacts of Colonization: Bayland Reclamation, Fragmentation, and Disconnection

When Europeans began to colonize what would become the San Francisco Bay region in the 1700s, the baylands' relatively flat topography stood in stark contrast to the steep slopes of the Coast Range that characterized much of the region. The flat, broad baylands – and the access to Bay shorelines and tributaries they provided – made them prime targets for reclamation to support development, agriculture, transportation, commerce, resource extraction, and other uses. Large-scale diking, draining, and filling of the region's tidal wetlands and mudflats began in the mid-1800s, and continued for well over 100 years. Bayland habitats were reclaimed or otherwise altered to support a variety of uses, especially urban development, agriculture, salt production, and duck hunting. Around much of the estuary, infrastructure, such as roads, railroads, and utilities, were concentrated along the landward edges of the baylands, just above the farthest reaches of the tides in the estuarine-terrestrial transition zone.

Mapping developed in support of the first Habitat Goals report indicated that by the late 1900s, the baylands supported only 40,000 acres of tidal wetlands (roughly 24,000 acres of which are much younger marshes formed by the accretion of Gold Rush sediments in the estuary) and 29,000 acres of tidal mudflats. Roughly 90,000 acres of tidal wetlands and flats had been converted into agricultural baylands (mostly around San Pablo Bay), 52,000 acres into diked wetlands (mostly within Suisun Marsh), and 38,000 acres into artificial salt ponds (concentrated in the Napa-Sonoma and South Bay regions) (see Habitat Goals 1999 and Figure 5).

The few patches of baylands that were spared reclamation in the 18th, 19th, and 20th centuries are embedded in a highly altered landscape, usually disconnected from the rivers and streams that would otherwise contribute pulses of freshwater and sediment to the baylands (Figure 6). In many locations, these connections to larger watersheds have been replaced by urban drains that discharge stormwater into baylands habitats. The relative absence of coarse sediment and abundance of nutrients favors pickleweed monocultures instead of diverse native tidal wetland plant communities. Most of the estuary's remaining tidal wetlands are cut off from their historic estuarine-terrestrial transition zones, and their landward edges are instead dominated by steep, often armored berms and levees that surround residential neighborhoods; industrial and/or commercial development, such as salt ponds and office parks; or infrastructure, such as highways and railroads (Figure 7). This landscape-scale disconnection limits ecological functions and beneficial uses in modern tidal baylands and habitat restoration projects and constrains their ability to shift and adjust in response to environmental disturbances.

Colonization of the region drove the loss of not only the region's tidal baylands, but of almost all its beaches, oyster reefs, and eelgrass beds as well. These losses are detailed in the 1999 and 2015 Habitat Goals reports as well as the 2010 Subtidal Habitat Goals report (SCC et al. 2010). Sand and oyster shell mining continues in portions of the Estuary to the present day.

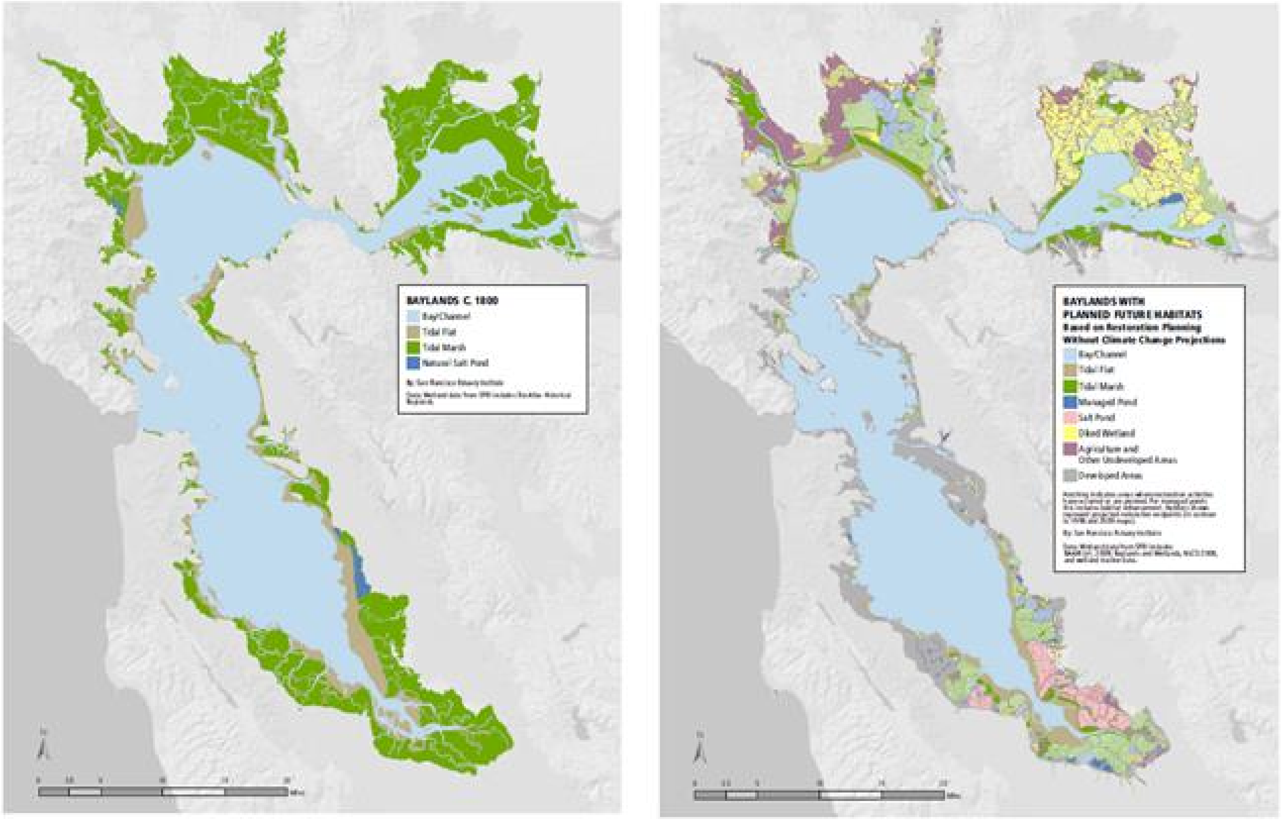

Figure 5. In the SF Bay region, the landscape-scale impacts of wetland loss have been deeply felt. By the mid-20th century, over 90 percent of the Bay's fringing marshes had been diked and drained for urban development, agriculture, and salt production. (Image: Goals Project 2015)

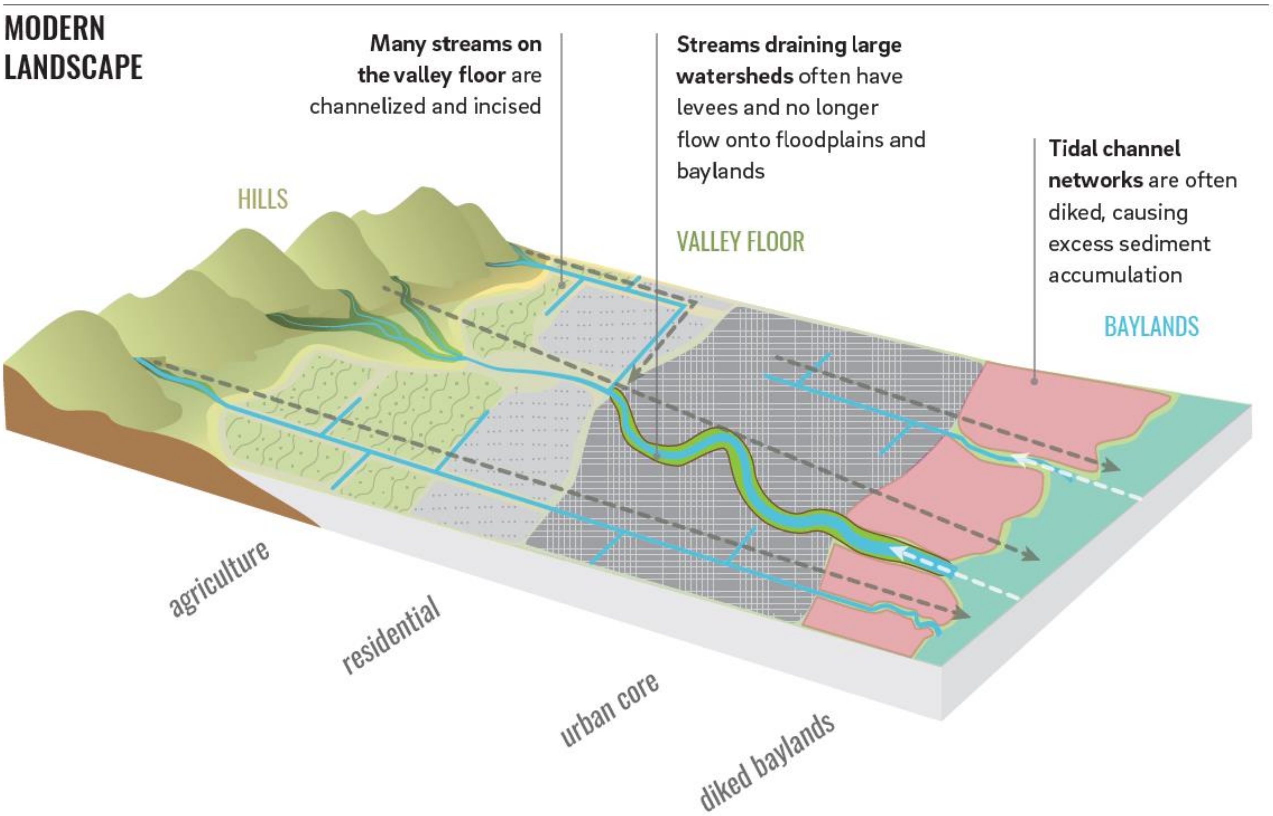

Figure 6. This graphic from Dusterhoff et al. 2017 illustrates how colonization and urbanization have disconnected intertidal bayland habitats from their subtidal, fluvial, and terrestrial components, resulting in a more simplified, less resilient estuarine landscape.

Figure 7. Tidal marshes within Faber Tract (left, Santa Clara County) and Point Edith (right, Contra Costa County) lack functional estuarine-terrestrial transition zones due to their proximity to developed baylands and uplands. (Images: Google Earth)

Colonists' physical reclamation of the estuarine landscape was compounded by their removal of indigenous traditions of land stewardship. Western settlers destroyed indigenous ways of life by limiting native people's access to the Estuary and its shoreline (Booker 2013). The cumulative results were highly destructive to the region's ecology and indigenous communities, turning an estuarine landscape of abundance, diversity, resilience, and connectivity into one of limitation, homogeneity, vulnerability, and isolation. These impacts have been well documented in many collaborative technical and policy documents, including the 1999 and 2015 *Baylands Ecosystem Habitat Goals* reports, the U.S. Fish and Wildlife Service's *Recovery Plan for Tidal Marsh Ecosystems of Central and Northern California* (2013), and elsewhere. These impacts include, but are not limited to:

- Significant reductions in foraging, breeding, and rearing habitat for a broad range of resident and migratory fish, wildlife, and invertebrates, including many now-rare and endangered aquatic and terrestrial species that are directly and/or indirectly dependent on bayland food webs
- Significant reductions in habitat for numerous native plant species, including now-rare and endangered species and ecotypes that are uniquely adapted to live in the baylands
- Significant reductions in the acreage of tidal wetlands that can sequester carbon from the atmosphere
- Ecological invasion by hundreds of non-native and invasive species (especially plants, fish, and shellfish) that disrupt native estuarine food webs and, in some cases, the physical structure of Bay/bayland habitats
- Significant reductions in the ability of bayland habitats to transform, assimilate, or eliminate pollution from Bay and tributary waters, resulting in a decrease in water quality

- Increased vulnerability of Estuary shorelines to erosion and inundation from waves, storms, and tides.

Unfortunately, the 69,000 acres of tidal wetlands and mudflats in the Estuary that persisted into the late 20th century, and the approximately 30,000 acres of tidal marshes and mudflats that have subsequently been restored (Goals Project 2015), are now at risk from climate change. The current and likely future impacts of climate change on the region's baylands are discussed further in Section 3.3.2.

3.3.2 Effects of Climate Change on San Francisco Estuary Bayland Habitats

Aside from direct dredging and filling from human activities, there are two primary mechanisms of tidal wetland and mudflat loss in the San Francisco Estuary, both of which are strongly influenced by climate change: (1) vertical downshifting and drowning (loss of elevation resulting in a conversion from vegetated marsh to unvegetated mudflat and eventually open water), and (2) lateral erosion (wetland and mudflat retreat from the bayward edge). These mechanisms, and the factors that contribute to them, are described below.

3.3.2.1 Wetland Drowning, Coastal Squeeze, and the Loss of High Tide Refugia

Multiple teams of researchers have taken different approaches to modeling the long-term resiliency of tidal bayland habitats in the San Francisco Estuary. Despite the differences in modeling approaches, the consensus of these studies is that sea level rise will drive widespread increases in the depth, duration, and frequency of tidal inundation in the Bay's tidal habitats, converting middle and high marsh (dominated by pickleweed, *Sarcocornia* spp.) to low marsh (dominated by cordgrass, *Spartina foliosa*) and/or unvegetated mudflats, and converting mudflats to open water. Generally speaking, modeled scenarios with relatively higher rates of sea level and lower suspended sediment concentrations forecast faster and more widespread marsh drowning than scenarios with lower rates of sea level rise and higher suspended sediment concentrations (Stralberg et al. 2011, Swanson et al. 2013, Schile et al. 2014, Thorne et al. 2016, Buffington et al. 2021). Accordingly, the risk of marsh drowning is greatest in tidal wetlands that are mostly dependent on the accretion of mineral sediment to keep pace with sea level rise (Figure 8). Freshwater and brackish tidal wetlands in the Estuary have greater resilience to sea level rise thanks to their production of abundant organic peat, but these wetlands remain vulnerable to mudflat conversion in high-sea level rise, low-suspended sediment concentrations scenarios (Stralberg et al. 2011 and Schile et al. 2014). The modeling demonstrates that tidal wetland restoration sites throughout the estuary may struggle to keep pace with sea level rise, especially in scenarios with high rates of sea level rise and inadequate sediment supplies.

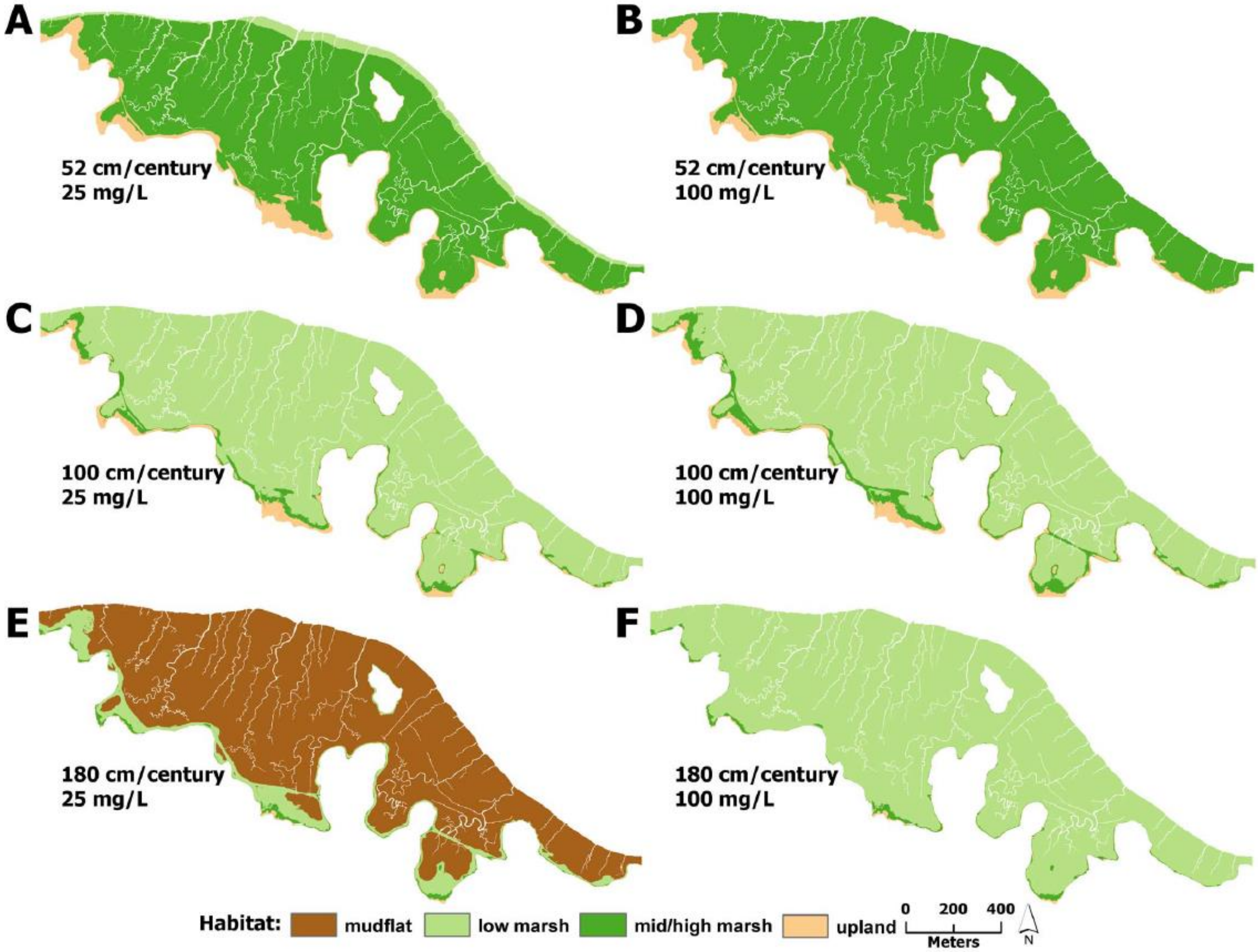

Figure 8. In this graphic from Schile et al. 2014, modeling demonstrates that the combination of rising sea levels and limited suspended sediment concentrations can lead to the gradual downshifting and drowning of tidal marshes. The effects are the most prominent in scenarios with rapid sea level rise and limited suspended sediment concentrations.

In many modeled scenarios, particularly ones with higher rates of sea level rise and lower suspended sediment concentrations, the only locations that are likely to maintain middle and high marsh habitats are places where tidal wetlands can migrate/transgress upslope into the estuarine-terrestrial transition zone (see scenarios C through F in Figure 8). In this way, the morphology of the transition zone, especially its steepness, largely determines the limits of middle to high marsh habitats. In locations where tidal wetlands abut steep headlands or steep levees, middle to high marsh is predicted to persist in narrow bands. In contrast, in locations where tidal wetlands are connected to gradual sloping estuarine-terrestrial transition zones, middle to high marsh is predicted to persist in broad plains. In locations with no functional transition zone, middle to high marsh disappears completely, as it has nowhere to migrate to. This phenomenon, called “coastal squeeze”, is a particular risk for tidal wetlands with highly urbanized landward edges. These marshes are often pinned against levees protecting infrastructure and/or residential, commercial, and/or industrial development. The narrow, steeply sloped, linear nature of the landward edges of these marshes prevents the establishment of a functional transition zone and increases the risk that tidal wetlands will eventually be either substantially reduced or lost entirely as they are squeezed between urban development and rising tides.

The modeling also demonstrates that before tidal wetlands downshift to mudflats, they will first lose their internal high tide refugia[5], such as natural tidal creek levees (Figure 9), flood deposits, and other topographic high points within and along marshes that support taller, shrubby vegetation. This vegetation provides shelter for marsh wildlife from high tides, king tides, storms, and other high-water events. These species are sensitive to prolonged inundation (which is why they colonize higher elevations within tidal wetlands), and they are highly vulnerable to drowning and replacement by more inundation-tolerant species, such as pickleweed. Pickleweed and other high marsh species (e.g. fleshy Jaumea, *Jaumea carnosa*; saltgrass, *Distichlis spicata*) don't typically grow as tall as the shrubbier vegetation they replace, and therefore provide relatively less protection from high water events. The loss of high tide refugia within the marsh plain puts marsh wildlife, such as Ridgway's rail and salt marsh harvest mouse, at an increased risk of drowning and predation.

[5] High tide refugia is habitat that provides refuge for marsh wildlife from high tide events. It is usually provided by the canopy of woody high marsh plants, such as gumplant (*Grindelia stricta*) and coyote bush (*Baccharis glutinosa*) that grow in topographic high points within the interior of tidal marshes (e.g., natural tidal creekbank levees) or along their edges (e.g. in estuarine-terrestrial transition zones, beach ridges).

Figure 9. The canopy of tall, shrubby vegetation along naturally deposited tidal creek levees provides shelter for marsh wildlife from king tides at China Camp State Park. (Image: Peter Baye)

3.3.2.2 Lateral Movement of the Marsh Edge

The interface where intertidal wetlands transition to mudflats is a highly dynamic region that is subject to change on multiple spatial and temporal scales. Changes in vertical elevations in this region help govern the lateral position of the marsh edge (Willemsen et al. 2018). In San Francisco Bay, the relatively unconsolidated nature of newer Bay Muds, the Bay's tidal regime, and the difficult-to-access nature of the Bayshore make this region particularly difficult to study. One of the most detailed assessments of natural shoreline typology and lateral change in the Estuary is Beagle et al.'s (2015) *Shifting Shores: Marsh Expansion and Retreat in San Pablo Bay*. San Pablo Bay is a unique sub-basin within the greater San Francisco Estuary due to (1) the presence of large expanses of mudflats and shallow open water that facilitate the settlement, re-suspension, and tidal transport of suspended sediment and (2) large tributaries that contribute a significant proportion of the Estuary's overall bedload and suspended sediment loads (Dusterhoff et al. 2017, Dusterhoff et al. 2021). From 1856 to 1887, the sub-basin experienced a 60 percent increase in intertidal mudflat area due to the deposition of a tremendous volume of sediment from hydraulic gold mining (Jaffe et al. 2007). Beagle et al. assessed post-1855 rates of marsh edge retreat and expansion within San Pablo Bay and proposed a conceptual model of marsh edge evolution based on a suite of physical drivers (Figure 10). The study found that much of the sub-basin's marsh edge had expanded bayward, especially near the mouths of large creeks, such as the Napa River, Sonoma Creek, Petaluma River, and Novato Creek. Shoreline retreat was concentrated in protrusions with high wave exposure, especially in locations that were reclaimed on post-Gold Rush sediments.

Beagle et al.'s finding regarding marsh expansion at creek mouth deltas underscores the importance of watershed sediment supply (not just estuarine sediment supply) as critical to the resilience of the Estuary's tidal wetlands. This is especially true in the Estuary's more urbanized regions, where engineered flood control channels limit the movement of sediment from watersheds and fluvial systems into the nearshore environment, reducing the sediment available for marsh accretion and driving expensive dredging activities to achieve flood control objectives (Dusterhoff et al. 2017, Dusterhoff et al. 2021). The impacts of bayland sediment starvation may be magnified in watersheds with abundant bedload (coarser sands, gravels, and cobbles) that, prior to engineered flood control channels, helped maintain coarse beaches and related nearshore features in the Bay. Follow-up work by Dusterhoff et al. suggests that many of the creeks in the region (e.g., Pinole, San Pablo, and Wildcat creeks) retain a significant amount of watershed-derived sediment (including bedload) in their engineered flood control channels, likely limiting the supply of coarse sediment that could nourish beaches in the baylands.

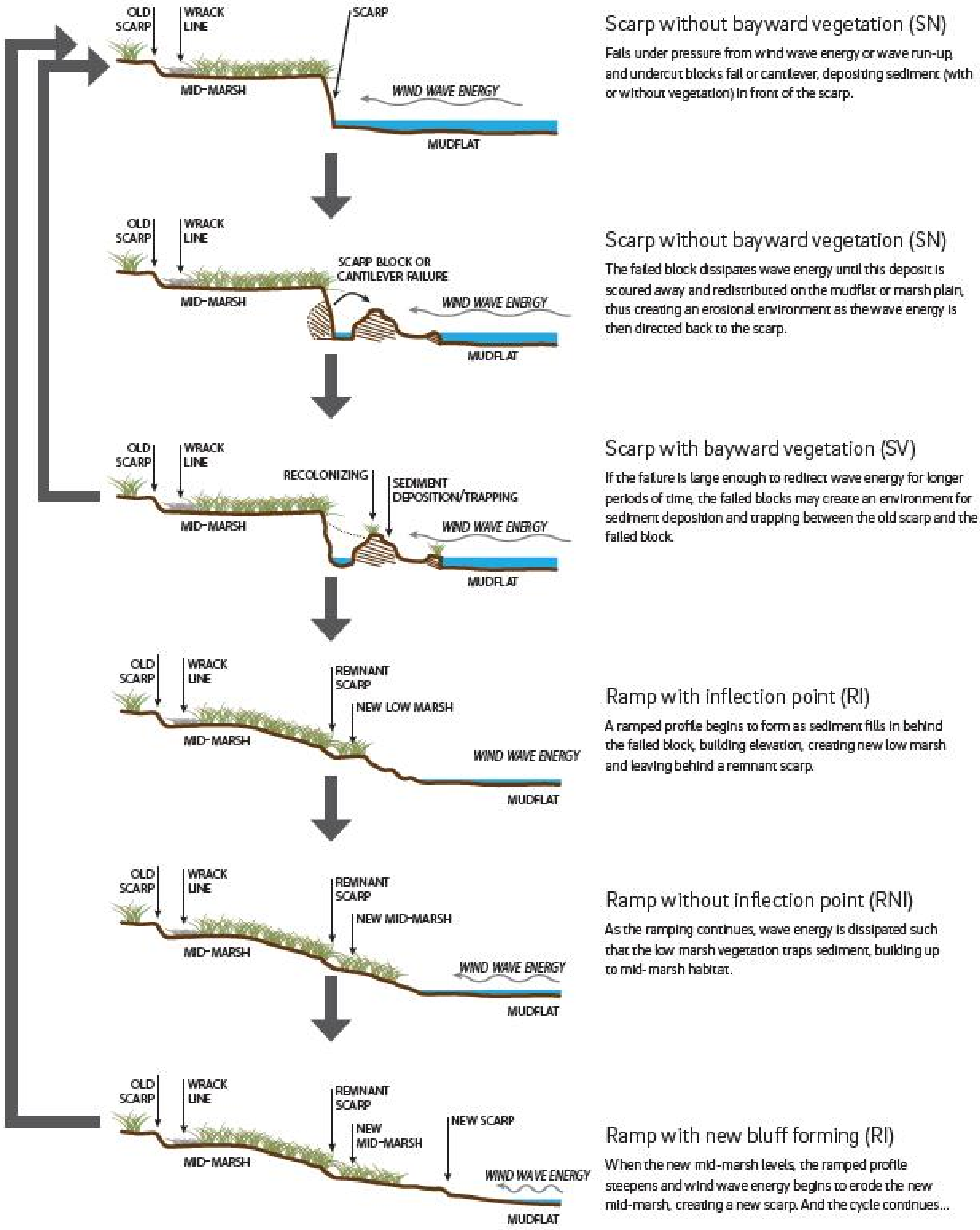

Figure 10. The proposed conceptual model of Bay edge evolution from Beagle et al. (2015), showing how different marsh edge morphologies may represent different phases of evolution and marsh retreat/expansion.

3.3.2.3 Tidal Wetland/Mudflat Loss and Shoreline Flood Risk

The potential sea level rise-driven loss of tidal bayland habitats not only threatens the integrity of bayland ecosystems but increases the risk of flooding and erosion along the San Francisco Estuary shoreline. The wave-attenuating properties of the region's tidal wetlands and mudflats are well documented. A 2011 study by the U.S. Geological Survey in Corte Madera Marsh found that wave height decreased by as much as 80 percent across Corte Madera Bay's shallows and tidal mudflats; what wave height remained at the shoreline was rapidly attenuated within the tidal wetland (Lacy and Hoover 2011). Subsequent modeling of the mechanisms of wave attenuation in the same wetlands (ESA PWA 2012) indicated that they were particularly effective at reducing the impact of waves at lower water levels (Figure 11). The wave attenuation properties of Bay wetlands likely vary with elevation, vegetation, exposure/geography, and other elements, but with adequate width their presence can significantly reduce the risk of wave-driven overtopping of shorelines.

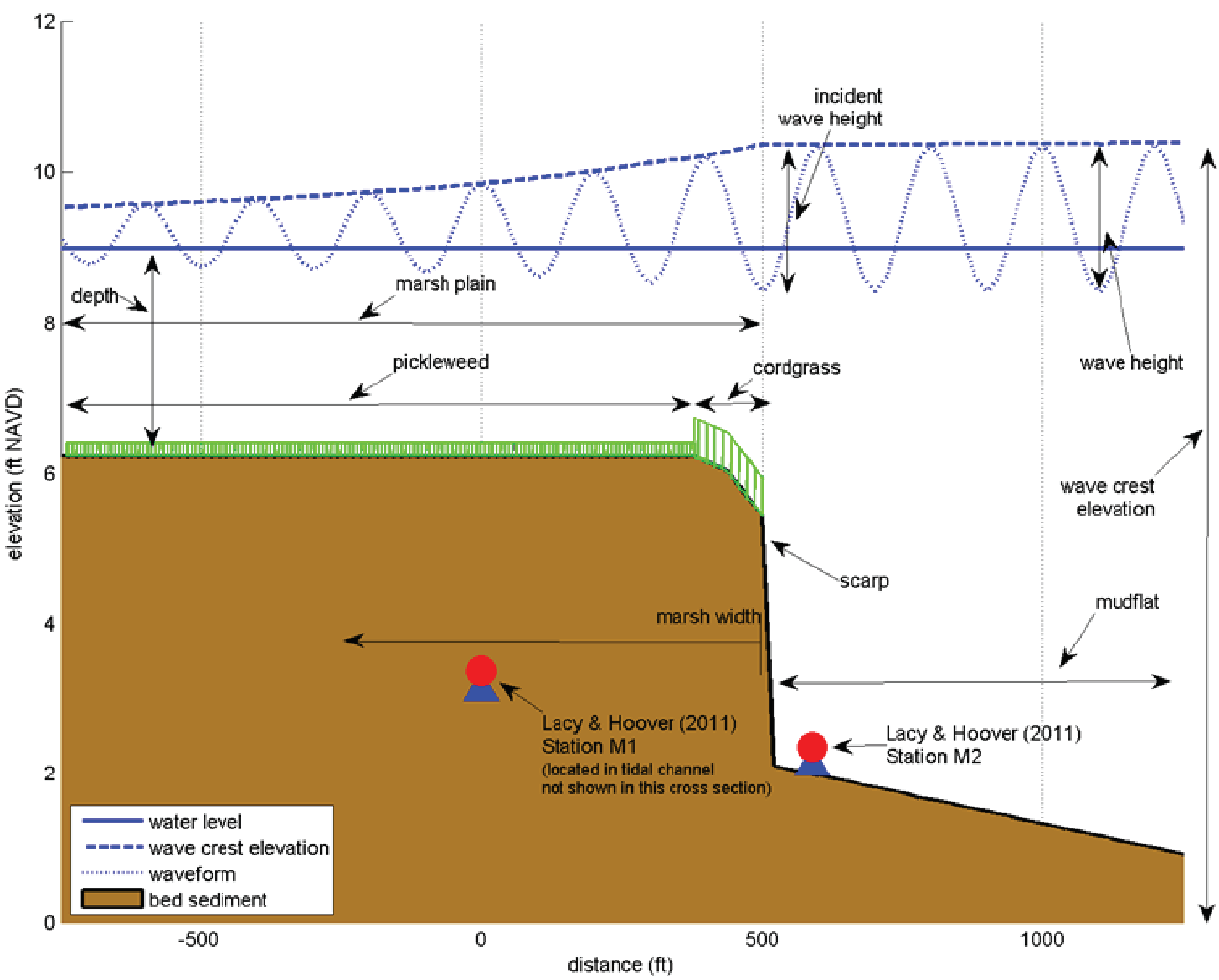

Figure 11. Offshore waves decrease in height when they encounter a vegetated marsh plain. (Image: ESA PWA 2012)

These findings are significant because along the San Francisco Estuary shoreline, climate change will likely drive episodic flooding from waves and storms much sooner than permanent flooding from tidal inundation will occur. This is demonstrated in the USGS Coastal Storm Modeling System (CoSMoS) as well as the data and map products developed by BCDC's Adapting to Rising Tides (ART) program, which are based on modeling done by FEMA for the California Coastal Analysis and Mapping Project (CCAMP). It is important to note that unlike CoSMoS, CCAMP modeling assumes that marshes are static, and do not change vertically or horizontally with sea level rise. Because that assumption will likely prove false (see marsh drowning discussion above), it potentially underestimates flooding associated with sea level rise.

Critically, existing models of San Francisco Estuary sea level rise and flood risk do not incorporate the probability of levee failure, which represents another way in which models likely underestimate future flooding associated with sea level rise.

3.3.2.4 Estuarine Sediment Supply and Demand

Not only will existing tidal wetlands and mudflats throughout San Francisco Bay require additional sediment to keep pace with rising sea levels, but existing and planned restoration sites will need even more sediment to support tidal wetlands in the near- and long-term. Determining the Bay's projected future sediment budget is therefore an active field of research. Approximately 70 percent of the suspended sediment that is available to accrete on existing and restoring tidal baylands enters the Bay from local tributaries, with the remainder entering from the Sacramento-San Joaquin Delta (Schoellhamer et al. 2018). Unlike suspended sediment from the Central Valley/Delta, which can get washed through the North Bay and out the Golden Gate during large storm events, suspended sediment from local tributaries tends to get trapped in engineered flood control channels or deposited on Bay mudflats. Large flood events can flush some sediment from flood control channels into open Bay waters (Livsey et al. 2019), where it can then be tidally transported and deposited elsewhere. Bay mudflats tend to act as local reservoirs for suspended sediment, where wave action can re-work deposited sediments into a suspended form that then becomes available for tidal transport and deposition in marshes (Lacy et al. 2015, MacVean and Lacy 2014).

In 2021, researchers at the San Francisco Estuary Institute completed a regional modeling effort to estimate future suspended sediment supply and demand in the lower Estuary's baylands through 2100 (Dusterhoff et al. 2021). The team estimated future sediment supply from the Delta and local tributaries under both wetter and dryer climate scenarios and estimated future baylands sediment demand for existing tidal wetlands, mudflats, and restoration sites, assuming 1.9 ft of sea level rise by 2050, and 5 ft by 2100 (roughly consistent with the 0.5 percent risk aversion scenario in the 2018 OPC State Sea-Level Rise Guidance, Figure 2). Further, they assessed spatial differences in bayland sediment supply and demand using the operational landscape units (OLU)[6] defined by the San Francisco Bay Shoreline Adaptation Atlas (SFEI + SPUR 2019).

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[6] Unlike traditional planning units, such as towns, cities, and counties, Operational Landscape Units are based on a shoreline's physical and ecological characteristics. OLUs cross political boundaries and have shared geographic, geophysical, and ecological characteristics that make them effective units for planning for climate change adaptation. Please see Section 3.5 for more discussion about OLUs and the Adaptation Atlas.

The resulting report, titled *Sediment for Survival: A Strategy for the Resilience of Bay Wetlands in the Lower San Francisco Estuary*, indicates that there will likely not be enough sediment to support the rates of accretion necessary to maintain all of the lower estuary's tidal wetlands, mudflats, and restoration sites. Because most tidal wetland restoration sites in the region are deeply subsided diked baylands, they tend to require significant volumes of sediment, first to achieve marsh plain elevations suitable to support intertidal vegetation, and then further sediment to keep pace with rising sea levels. Even under wetter future climate scenarios that could deliver relatively more sediment from watersheds to the estuary than under existing conditions, the demand in the baylands due to expected rates of sea level rise is so great that it dwarfs likely future supply (Figure 12). However, some areas have a greater potential than others to support long-term resilient baylands. Multiple OLUs within the North Bay and Suisun regions have relatively high potential to support high rates of vertical accretion, due largely to major inputs of freshwater and mineral sediment from the Delta, Walnut Creek, Napa River and Sonoma Creek. Some OLUs in the South Bay also have the potential to support long-term resilient baylands, if subsided diked bayland restoration sites are first mechanically filled with sediment (Figure 13).

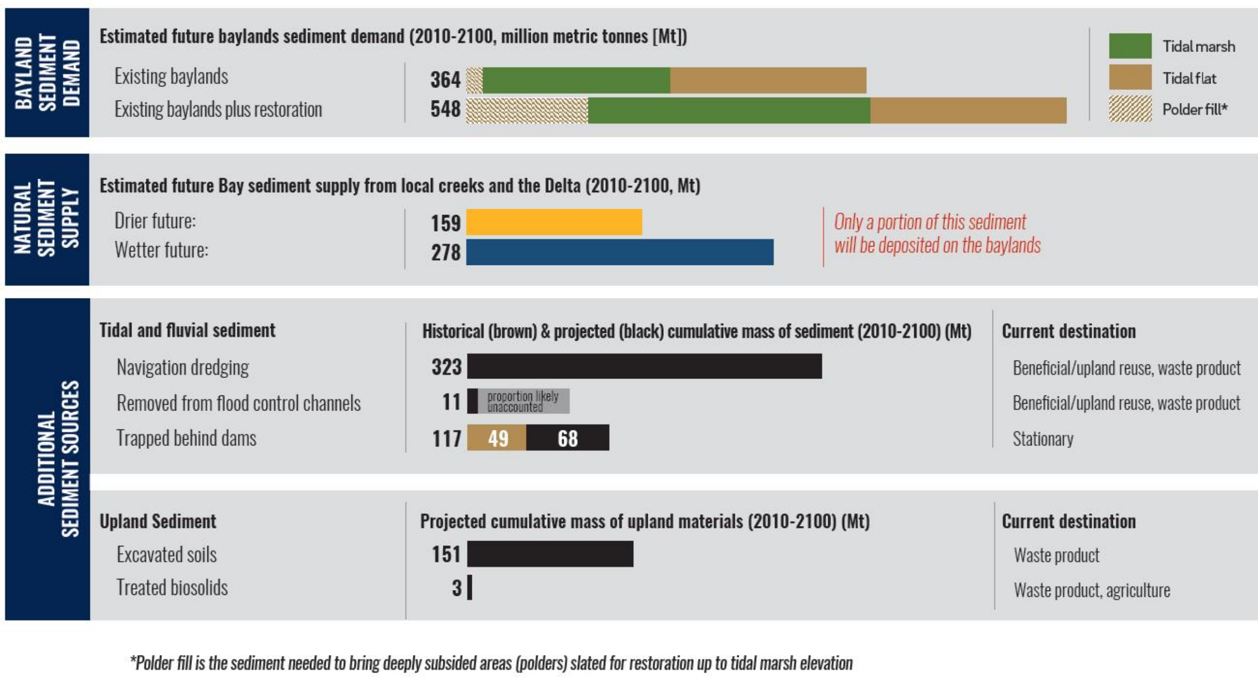

Figure 12. A summary of the findings of Dusterhoff et al. (2021) that compares potential future bayland sediment demand, natural sediment supply to the estuary, and supplies of additional sediment sources.

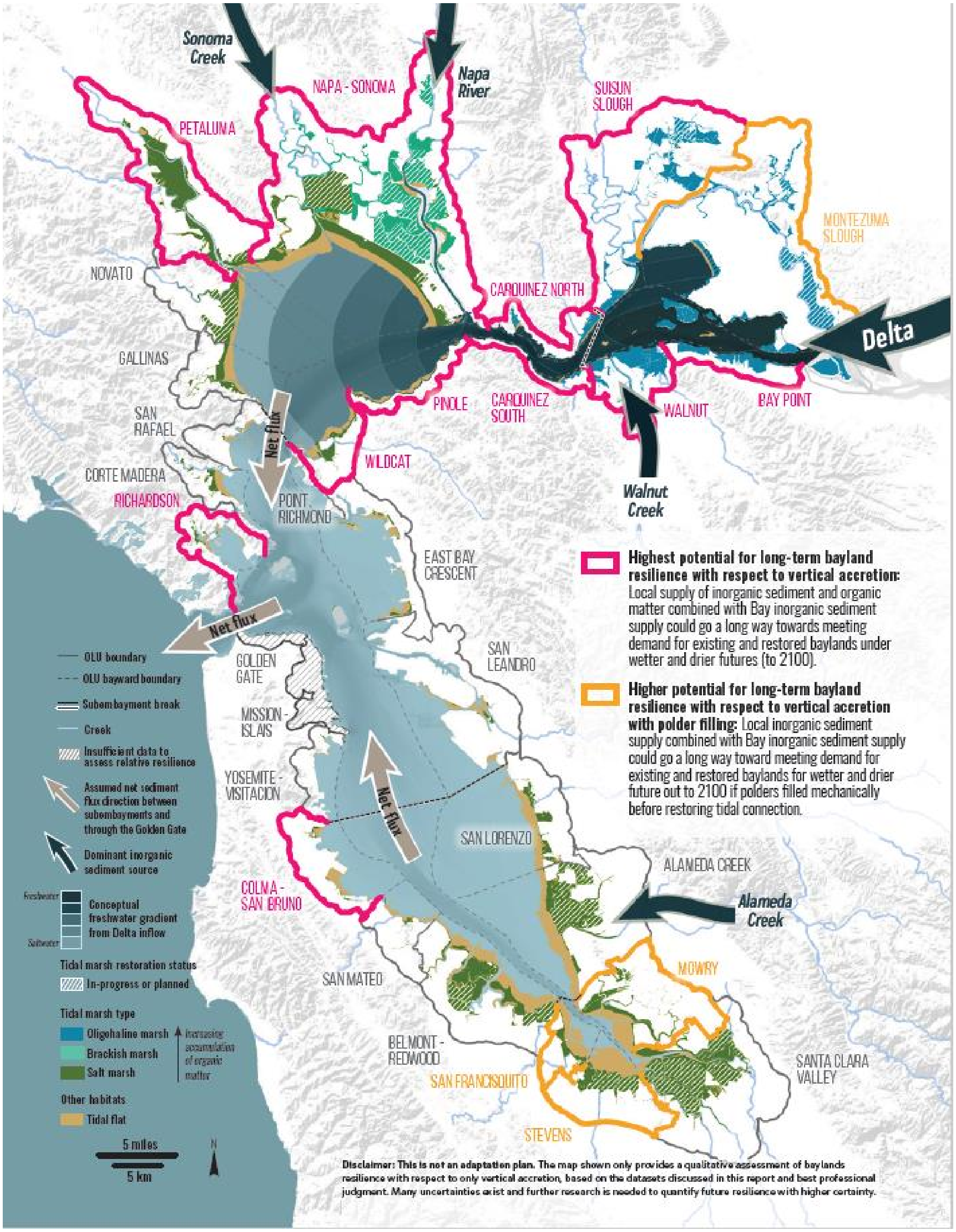

Figure 13. This diagram from the *Sediment for Survival* report (Dusterhoff et al. 2021) summarizes which regions in the lower estuary are most likely to support tidal baylands habitats in the long-term.

The modeling performed for the *Sediment for Survival* report utilizes several key assumptions and caveats that may not hold in future climates, such as sediment rating curves for streams, the influence of climate change on storm timing, frequency, intensity, and duration, Delta levee integrity, and others. It nonetheless underscores that natural sedimentation will likely be inadequate to support the Estuary's tidal baylands, and that sediment management in the region must quickly pivot towards sustaining these resources. The report's recommendations for sediment management practices are discussed below in Section 3.4.

We note that though bedload may be a small component of the Estuary's net sediment supply, it is an ecologically critical one. Coarse sediment, such as sands and gravels, form beaches, wave-built berms, and related habitats that support rare plants and animals and naturally protect tidal marshes and flats from erosion and retreat. In addition, marshes need coarse sediment to develop and sustain the microtopography and substrate that supports diverse tidal marsh plant communities, including habitat for rare plant species and ecotypes (Baye et al. 2000) and high tide refugia along the bayward edges of tidal marshes (Baye 2010, Toms and Baye 2016). Much of the Estuary's coarse bedload is trapped in engineered flood control channels, where natural transport processes are unlikely to move it into Bay nearshore and wetland habitats. Coarse material will therefore need to be actively removed from flood control channels and placed in and along the Bay in order to support beaches and related nature-based features (Dusterhoff et al. 2021, Pearce et al. 2021, Dusterhoff et al. 2017, Baye 2010). Engineered flood control channels can also be modified and re-aligned to improve the likelihood of passive bedload delivery to the baylands (Dusterhoff et al. 2021, Dusterhoff et al. 2017). Additional recommendations for managing coarse sediment to support bayland habitat resilience is discussed in Section 3.4 below.

3.3.3 Effects of Colonization and Climate Change on Pacific Coastal Waters

To date, most detailed assessments of the past impacts of colonization and the ongoing/future impacts of climate change on the region's coastal waters have focused on the baylands surrounding the San Francisco Estuary, which contain roughly 90 percent of the remaining tidal wetlands in California (Goals Project 1999). Less detailed assessments exist for the region's Pacific Ocean coastal waters and embayments, such as Tomales Bay and Half Moon Bay. The reasons for this are complex, but likely include the fact that many of these systems exist within landscapes with special legal protections, such as Point Reyes National Seashore, Golden Gate National Recreation Area, and various State Parks, Beaches, and Ecological Reserves.

Outer coastal waters in the region include beaches and dune fields, coastal stream valleys, embayments, and coastal lagoons. Embayments in the region include estuaries such as Tomales Bay, Bolinas Lagoon, Drake's Estero, and Limantour Estero that are open to tidal and marine influence year-round. Coastal lagoons include systems such as Rodeo Lagoon, Pilarcitos Lagoon, San Gregorio Lagoon, and Pescadero Marsh that are generally open to marine influence via tidal and wave action through an open inlet across a beach berm during the wet season, and become predominantly freshwater systems during the dry season as flows subside, the beach berm grows, and the inlet closes. Since many coastal lagoons typically experience deeper and more extensive flooding in the dry season when the inlet is closed than during the wet season when the inlet is open, these unique ecosystems tend to invert expected patterns of inundation in the region's

Mediterranean climate. They support an especially broad range of beneficial uses, including habitat for rare and special-status species such as salmonids (*Oncorhynchus* spp.), tidewater goby (*Eucyclogobius newberryi*), California red-legged frog (*Rana draytonii*), and San Francisco garter snake (*Thamnophis sirtalis tetrataenia*).

Post-colonial impacts to the region's outer coastal waters generally mirror those within the San Francisco Estuary's baylands. Many low-lying stream valleys, floodplains, and estuaries were diked, drained, filled, or otherwise managed to support development, agriculture, and infrastructure. Embankments constructed to support historic railroads and what would become Highway 1 interrupted or eliminated landscape connections between coastal waters and adjacent floodplains and estuarine-terrestrial transition zones (WWR et al. 2009). Development, agriculture, and water resources development in watersheds changed patterns of freshwater and sediment delivery to coastal waters (CCWG 2016, CCWG 2018, Largier et al. 2019, WWR et al. 2009). Construction of harbors, breakwaters, and similar infrastructure altered nearshore sediment transport processes along the coast, contributing in some cases to localized beach erosion (USACE et al. 2015).

As it did in the San Francisco Estuary, colonization disconnected many of the region's outer coast waters from many of the physical and ecological processes that sustained them, limiting their beneficial uses and increasing their vulnerability to climate change. Beaches and coastal lagoons are threatened in many locations throughout the region by coastal squeeze that would eliminate habitats caught between rising seas and artificial embankments (CCWG 2016, Sievanen et al. 2018). Climate change-driven shifts in watershed hydrology will impact habitat conditions in coastal stream valleys, especially for keystone species, such as salmonids that are sensitive to changes in flows and temperatures (Katz et al. 2013).

Coastal lagoons are especially vulnerable to climate change, because they are influenced by both watershed and coastal processes and conditions. Rising sea levels, changes in coastal storm/wave intensity, and changes in precipitation and runoff patterns will likely alter how, when, and for how long coastal lagoons are open and closed to the ocean, impacting lagoon hydrology, ecology, and beneficial uses (Haines and Thom 2007, Behrens et al. 2015). Similar to tidal wetlands in the Bay, the resilience of wetland habitats in coastal lagoons is dependent on numerous physical and ecological processes, such as freshwater and sediment delivery, vegetation succession, and other factors that are influenced by climate change (Saintilan et al. 2016, Thorne et al. 2021). These processes are generally poorly understood in the region's coastal lagoons, though that is beginning to change; the Ocean Protection Council is currently funding the development of a monitoring framework for estuarine Marine Protected Areas that includes some of the region's coastal lagoons.[7]

[7] See *Monitoring and assessment of California's estuarine MPAs* at https://empa.sccwrp.org/

3.4 Science-Based Strategies to Improve the Health, Diversity, and Resilience of Coastal Waters

The 1999 and 2015 Goals Reports and their supporting technical literature document how the colonization, reclamation, and fragmentation of the region's baylands not only drove tremendous losses of the Estuary's habitats and associated beneficial uses but increased the risk of future climate change-driven losses by isolating baylands from the landforms and physical and ecological processes that sustain them. The 2015 Goals Report emphasizes how nature-based approaches to climate change adaptation could support landscape-scale physical and ecological connectivity between different types of bayland habitats and improve the resilience of the region's built and natural communities to climate change. However, at the time, the region lacked a coordinated, science-based blueprint for determining which nature-based approaches would be most appropriate in different portions of the Bay's diverse 400-mile-long shoreline. This created challenges for planners, designers, and others charged with preparing their communities for sea level rise, as well as for regulatory staff who must assess the potential impacts of proposed projects on natural resources. Meanwhile, some communities proposed traditional shoreline armoring, such as rip-rap revetments and seawalls, as adaptation approaches, increasing the risk of cumulative armoring throughout the Bay, which could drive sea levels in the Bay even higher by minimizing or eliminating space for flooding along the Bay margins (Hummel and Stacey 2021, Wang et al. 2018).

Seeing the value of a science-based framework to help decision-makers select appropriate multi-benefit, nature-based sea level rise adaptation strategies for their communities, the Water Board is funding the San Francisco Estuary Institute to develop the *San Francisco Bay Shoreline Adaptation Atlas*. The Adaptation Atlas uses a rigorous approach rooted in physical processes and geospatial analysis to classify the Bay shoreline into 30 cross-jurisdictional Operational Landscape Units (OLUs), or "nature's jurisdictions" (like a watershed, but for the shoreline).[8] Each OLU has shared geographic, geophysical, and ecological characteristics that make it an effective unit for planning for sea level rise. The Atlas describes the environmental setting of each OLU, including elements of the built landscape (e.g., zoning, housing density, and job density) that influence land use planning. It then pairs each OLU with a suite of potentially feasible nature-based sea level rise adaptation approaches that could be combined with more traditional measures, such as levees and tidegates, and maps where within each OLU these approaches may be appropriate. The Atlas also describes considerations for each nature-based approach, including its potential environmental impacts and benefits and its adaptability to increasing amounts of sea level rise over time. The Adaptation Atlas is a living document; Phase 1 was completed in 2019 (SFEI + SPUR 2019) and a second phase is currently underway.

Collectively, the Goals Reports, Adaptation Atlas, and related scientific literature (e.g., Dusterhoff et al. 2021, Dusterhoff et al. 2017, Beagle et al. 2015) are informative resources related to the

[8] The OLUs in the Adaptation Atlas reflect current conditions in the Bay and opportunities for future adaptation, while the segments in the Baylands Goals reports are based on historic ecology. Therefore, the boundaries of the 30 OLUs in the Atlas do not match those of the 20 geographic units in the Baylands Goals reports.

protection and improvement of beneficial uses in the region's coastal waters. Though these reports are focused on San Francisco Estuary habitats, their underlying scientific principles and resulting management recommendations are broadly applicable to coastal and estuarine habitats on the Pacific coast. These reports, which in part inform the proposed Basin Plan amendment, propose a suite of general recommendations, including:

- ***Natural and nature-based infrastructure is preferable to traditional infrastructure (e.g., levees, seawalls, rip-rap, revetments, and related armoring approaches) to support beneficial uses of the region's coastal waters.*** Natural and nature-based infrastructure typically support multiple beneficial uses, such as habitat for estuarine, rare and endangered, and marine species, that are not supported by traditional shoreline infrastructure/armoring approaches. Project designs that facilitate and/or leverage natural physical and ecological forms and processes in the long-term on a landscape scale are more likely to support beneficial uses now and in the future than designs that impede those processes. Nature-based approaches, and hybrid measures that integrate nature-based and traditional engineering approaches: (1) provide important co-benefits, such as habitat for native species and recreational opportunities; (2) are likely to be more sustainable; (3) may perform better than traditional engineered infrastructure alone; and (4) can cost less over time. Because nature-based approaches largely rely on natural forms and processes to adapt to climate change, it is critical that their location and design be tailored to site-specific conditions. Nature-based design approaches include, but are not limited to:

    - *Estuarine (including tidal, lagoonal, and floodplain) wetland protection, enhancement, and restoration.* Nature-based estuarine projects have extensive histories in the region and will continue to be important tools to support the health and resilience of the region's natural and built communities. Given the anticipated future acceleration of sea level rise and changes in freshwater and sediment flows to the Estuary and the outer Pacific coast, it's important that estuarine wetland projects be located and designed such that they maximize the connectivity and resilience of complete wetland habitats (Figure 4). Project design should consider the physical and ecological processes that support (1) accretion of both mineral and organic sediment, (2) native plant diversity and succession, (3) high water refugia within and along the edge of the wetland, and (4) connectivity to subtidal, fluvial/floodplain, and terrestrial habitats. Examples of estuarine wetland restoration in the San Francisco Estuary include the South Bay Salt Pond Restoration Project, the Napa River Salt Marsh Restoration Project, and the Wings Landing Restoration Project in Suisun Marsh. Examples of estuarine wetland restoration on the outer coast include the Giacomini Wetland Restoration Project in Tomales Bay, Horseshoe Pond Restoration in Point Reyes National Seashore, and ongoing efforts to improve conditions in Pescadero Marsh. Guidance documents for estuarine wetland restoration in the region include the 1999 and 2015 Goals Reports and the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS 2013).

- *Ecotone and treated wastewater "horizontal" levees.* These are flood control levees with gradually-sloped (typically 15:1 horizontal:vertical or greater) bayward sides that can increase the footprint and functions of the estuarine-terrestrial transition zone at the landward edge of tidal wetlands. When designed to include subsurface seepage of treated wastewater, they are often called "horizontal" levees. Ecotone levees can create estuarine-terrestrial transition zones and attenuate wave energy; horizontal levees can perform these functions as well as remove pollutants, such as nutrients, metals, and contaminants of emerging concern, from treated wastewater, and restore freshwater-brackish-saline wetland gradients that have largely been lost throughout the region. Ecotone and horizontal levees are best-suited for locations where they will be fronted by tidal wetlands, both to improve landscape-scale ecological functions and to reduce the risk of erosion of the levee toe. They typically require considerable volumes of material to construct, and therefore should be built as far landward as feasible to minimize settling and maximize the footprint of in-estuary habitat restoration. Both levee types are relatively newer design approaches that should be carefully monitored and, if needed, adaptively managed to ensure their long-term resilience and functionality. Examples of ecotone levees can be found at the Sears Point Tidal Wetland Restoration Project and Hamilton Wetlands Restoration Project. A pilot-scale horizontal levee is in operation at the Oro Loma Sanitary District plant in San Lorenzo; full-scale projects are currently planned for the Oro Loma facility as well as at the Palo Alto Regional Water Quality Control Plant. Design guidance for horizontal levees is currently being developed by the San Francisco Estuary Partnership's Transforming Shorelines Project.[9]
- *Living shorelines.* In San Francisco Bay, living shorelines typically include shallow subtidal elements, such as nearshore oyster reefs and beds of submerged aquatic vegetation. These features can attenuate wave energy along shorelines, help stabilize nearshore sediment, provide valuable subtidal nursery habitat for estuarine fish and invertebrates, and support pelagic food webs. Living shorelines are best suited for areas of the Bay with appropriate depths, salinities, and turbidity to support target species (e.g., native oysters (*Ostrea lurida*), eelgrass (*Zostera marina*), sago pondweed (*Stuckenia pectinata*), and widgeongrass (*Ruppia maritima*)). Examples of living shoreline projects include the eelgrass and oyster restoration efforts implemented by the California Coastal Conservancy along the San Rafael and Richmond shorelines. Guidance documents including the *San Francisco Bay Subtidal Goals Report* (Subtidal Goals Project 2010) and information from the San Francisco Bay Living Shorelines Project and related efforts can help inform the location and design of living shorelines projects.
- *Beaches composed of sand, shell, gravel, and/or cobble, held in place by either natural or artificial headlands (groins)*. Beaches can dissipate wave energy, respond dynamically to changing wave conditions, naturally armor shorelines from erosion,

[9] https://www.sfestuary.org/transformingshorelines/

provide valuable habitat for estuarine plants and wildlife, and support coastal access and recreation. Beaches are generally well-suited for wave-exposed areas and can be combined with other nature-based approaches, such as living shorelines and wetland restoration. In some locations, beaches can be coupled with dune systems to support additional ecosystem services and protection from high water events. Examples of beach projects include the Aramburu Island Beach Enhancement Project in Marin County, and the Albany Beach Enhancement Project in Albany. Guidance documents including *New Life for Eroding Shorelines: Beach and Marsh Edge Change in the San Francisco Estuary* (SFEI and Baye 2020) can help inform the location and design of beach projects.

- ***Where practicable, different nature-based climate change adaptation approaches can be combined to provide enhanced shoreline protection and beneficial uses.*** For example, beaches can be designed and constructed such that they help reduce wave impacts on wetlands landward of the beach. In this approach, the beach provides the primary protection against waves and reducing wetland erosion, while the wetland provides further wave attenuation and temporary storage of floodwaters. Multiple examples of this type of combined system occur naturally throughout the San Francisco Estuary at locations such as Point Pinole Regional Shoreline (Figure 14), the Outer Bair Island unit of the San Francisco Bay National Wildlife Refuge, and Brooks Island. Most of the region's coastal lagoons are arranged with beaches protecting landward wetlands (Figure 15). These beach-wetland ecosystems are especially valuable to wildlife, because the high beach crests and dependent vegetation communities provide abundant refuge from storms and high-water events.

Figure 14. Pinole Regional Shoreline supports one of the few remaining "complete" tidal marshes in the Bay, with a broad marsh plain dissected by tidal channels, ponds, an estuarine-upland transition zone, a barrier beach, and mudflats along the Bay shore. (Image: Google Earth)

Figure 15. San Gregorio Lagoon has a large beach that fronts estuarine and floodplain wetlands along the lower stream channel. (Image: Google Earth)

- ***Where natural and nature-based infrastructure is not practicable, hybrid approaches that combine traditional and nature-based measures are preferable to alternatives that only include traditional infrastructure.*** The region's highly urbanized and armored shorelines impede natural physical and ecological processes needed to sustain nature-based adaptation approaches, such as beaches and estuarine wetlands. This can be true even in less urbanized areas, such as the North Bay, due to landscape-scale disruptions in water and sediment delivery to the Estuary. Hybrid approaches that integrate nature-based and traditionally engineered features can be used to support multi-benefit climate adaptation in locations where strictly nature-based solutions may not be practicable. Compared to traditional infrastructure alone, hybrid approaches are more likely to (1) provide important co-benefits, such as wildlife habitat and recreational opportunities, (2) be more sustainable, (3) support better performance, and (4) cost less over time. Examples of hybrid approaches include pocket beaches hemmed in by artificial headlands (groins), seawalls and revetments with integrated tidepools and subtidal habitats, managed wetlands, and estuarine wetlands fronting flood risk management levees.
- ***Utilize phased adaptation pathways to develop long-term, landscape-scale plans for climate change adaptation that integrate nature-based and hybrid approaches.*** Many climate change adaptation measures require long lead times to accommodate planning,

design, permitting, and implementation. Phased adaptation pathways provide a framework for identifying appropriate suites of action at different climate change thresholds and create a mechanism for addressing uncertainty and allowing for flexibility over time. When utilized as part of a comprehensive, long-term climate resilience strategy, phased, place-based adaptation pathways can identify opportunities for the long-term landward movement of defenses from tidal flooding (i.e., managed retreat). Over time, this approach can create space for the restoration of complete estuarine wetland systems and other nature-based adaptation measures. Figure 16 below depicts a phased adaptation pathway that uses sea level rise thresholds as decision triggers (e.g., deciding to acquire, prepare, and restore migration space once sea levels have risen 0.5 ft to create space for wetland restoration before sea level rise exceeds 2 ft).

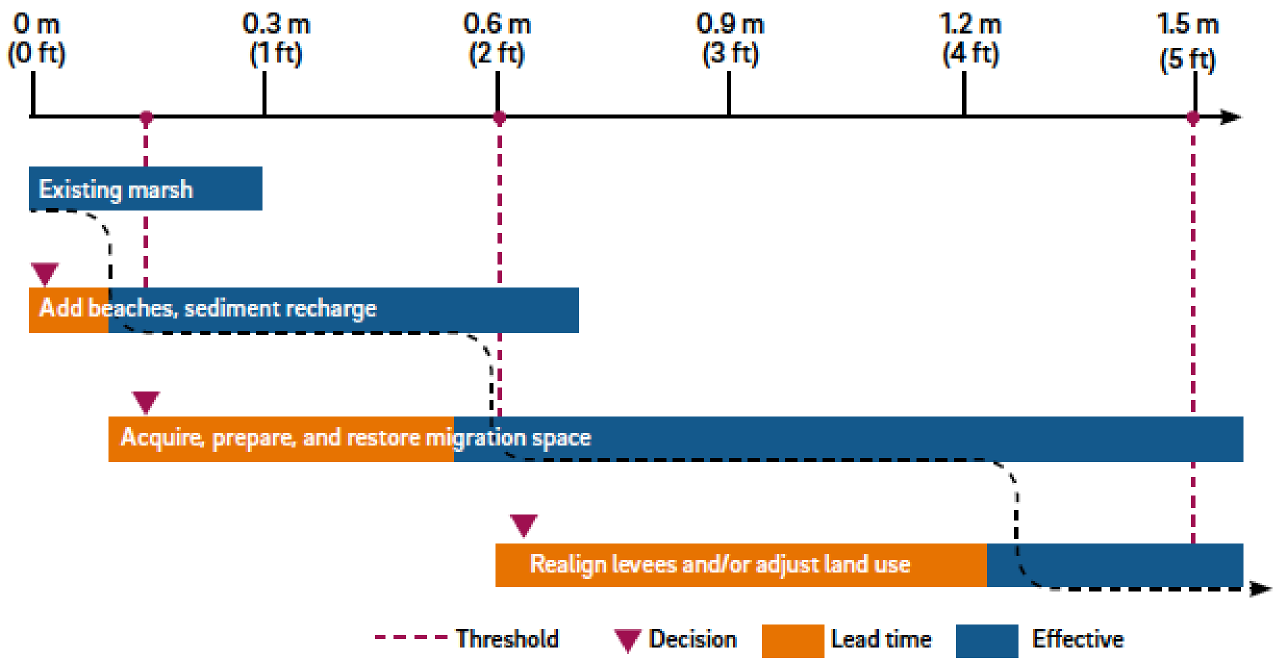

Figure 16. A conceptual phased adaptation pathway for nature-based measures triggered by different amounts of sea level rise (from the Adaptation Atlas, adapted from the 2015 Habitat Goals report).

- ***Restore estuary-watershed connections that nourish estuarine wetland habitats with sediment and freshwater.*** Coastal waters, especially estuarine wetlands, mudflats and sand flats and coastal lagoons, need watershed-derived sediment to maintain rates of accretion that are commensurate with sea level rise. In estuarine wetlands, pulses of freshwater and flood deposits of coarse sediment support diverse native plant communities, which can help buffer these ecosystems from disturbance from extreme events. Estuarine wetland restoration should be prioritized in locations with high watershed-derived sediment loads (e.g., Dusterhoff et al. 2021), and where practicable, stream/river channels should be re-aligned/re-engineered to facilitate more robust hydraulic connections and sediment delivery pathways to existing wetland habitats and potential future wetland restoration sites. Channel realignment can include floodplain restoration, which can improve a channel's capacity for extreme events, and create space for the future sea level rise-driven transgression of estuarine wetland habitats over the floodplain. See Dusterhoff et al. 2021 and 2017 for additional details.

- ***Where restoring natural estuary-watershed connections is not practicable, use artificial means to mimic the natural delivery of freshwater and sediment to wetlands and mudflats.*** To support accretion, clean sediment (from flood control channels, reservoirs, navigational dredging, and other sources) suitable for beneficial reuse should be delivered to estuarine wetlands and mudflats in ways that mimic natural geomorphic processes. For example, sediment slurry can be directly placed on wetlands in thin lifts, similar to flood deposits (Raposa et al. 2020), sprayed directly onto wetlands and mudflats (Thorne et al. 2019), or placed into nearby channels or mudflats where tidal and/or fluvial currents can move the sediment into the wetlands (Stantec and SFEI 2017, Figure 17). Dam and flood control operations in heavily managed watersheds can be altered to imitate pulse flows and other natural patterns of freshwater and sediment delivery from upper watersheds to estuaries. Treated wastewater can be applied to ecotone levees with gentle side slopes ("horizontal levees") to re-create historic freshwater-brackish-saltwater gradients along estuarine margins.

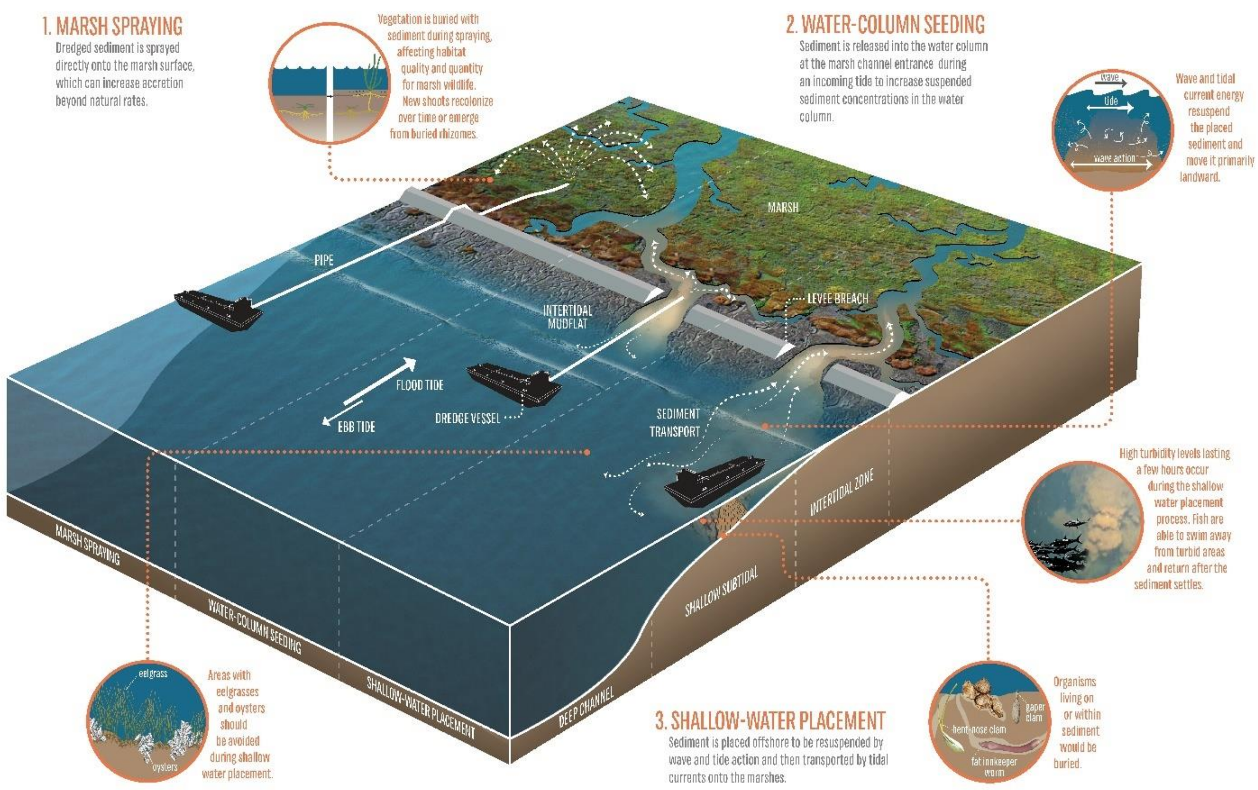

Figure 17. Marsh spraying, water column seeding, and shallow-water placement are all techniques to enhance the delivery of clean sediment to estuarine wetlands for beneficial reuse. (Image: Stantec and SFEI 2017)

- ***Projects to restore and enhance coastal waters, including wetlands and mudflats, should incorporate geomorphic, hydrologic, and ecological connectivity and complexity at site-and landscape-scales.*** Geomorphic/topographic complexity within estuarine wetlands generates within-site gradients in inundation frequencies, depths, and durations, driving ecological diversity, complexity, and resilience. At the site scale, managers should aim to preserve or create geomorphically complex and complete wetland systems that include estuarine-terrestrial transition zones, sinuous channel networks, natural channel levees, point bars, slump blocks, undercut banks, wave-built berms, beaches, ponds, subtidal habitats (e.g., oyster reefs, eelgrass beds), and internal high water refugia. Geomorphic complexity can be enhanced through both natural and artificial means (see discussion of sediment management above). At the landscape scale, managers should foster robust physical connections between coastal habitat mosaics, between estuaries and local watersheds/fluvial habitats, and between estuaries and pelagic (open water) habitats. Barriers to landscape connectivity, such as artificial levees/embankments, roads, water control structures, and other infrastructure, should be minimized when practicable.

- ***Plan for coastal habitats to migrate and adjust in response to sea level rise, extreme storm events, saltwater intrusion, and other processes influenced by climate change.*** When making decisions about the benefits and impacts of projects, managers should consider how climate change will influence landscape processes, functions, and evolution, as well as the regional distribution and connectivity of coastal habitats over the long-term. The ability of coastal habitats to transgress, expand, erode, accrete, and/or subside is driven by multiple factors including but not limited to topography, fluvial, tidal, and groundwater hydrology, mineral sediment supply, organic sediment (peat) production, wave exposure, vegetation establishment and succession, and the myriad interactions between these processes and conditions (Figure 18). Decisions about coastal adaptation in the near-term and long-term must consider these potential interactions, how they may change in the near- and long-term due to climate change and other factors, and how the resulting landscape is likely to respond. Conceptual models, such as those compiled for the San Francisco Estuary Wetland Regional Monitoring Program (WRMP 2020), are helpful in this regard. Decision-making in support of coastal resilience should prioritize protecting and preparing migration space adjacent to estuarine wetlands and mudflats, including existing and potential estuarine-terrestrial transition zones, and floodplains along the farthest upstream reaches of the tides (Dusterhoff et al. 2014). Where coastal habitats are at risk of coastal squeeze, managers should retrofit steep and/or armored features, such as levees, revetments, seawalls, and embankments, to support the gradual migration and long-term persistence of habitats upslope. Decision-makers should discourage the development of new built environments in locations that are likely to be impacted by sea level rise and/or extreme events, and encourage the long-term modification and/or relocation of nearshore infrastructure and related built features that impede tidal habitat migration. The balance, diversity, and distribution of habitats that currently exist within the region’s coastal habitats will naturally shift in the future, and projects should be planned and permitted to maximize collective ecological functions in the long-term across different habitats on a landscape scale. Prioritizing one type of habitat at every location at the expense of other habitats will result in coastal waters that are neither healthy nor resilient.

In almost all cases, implementing these recommendations would require a permit from the Water Board to place fill in waters of the State (including wetlands), convert one type of water to another, or a related action. The potential permitting implications of these recommendations are discussed in Chapter 4.

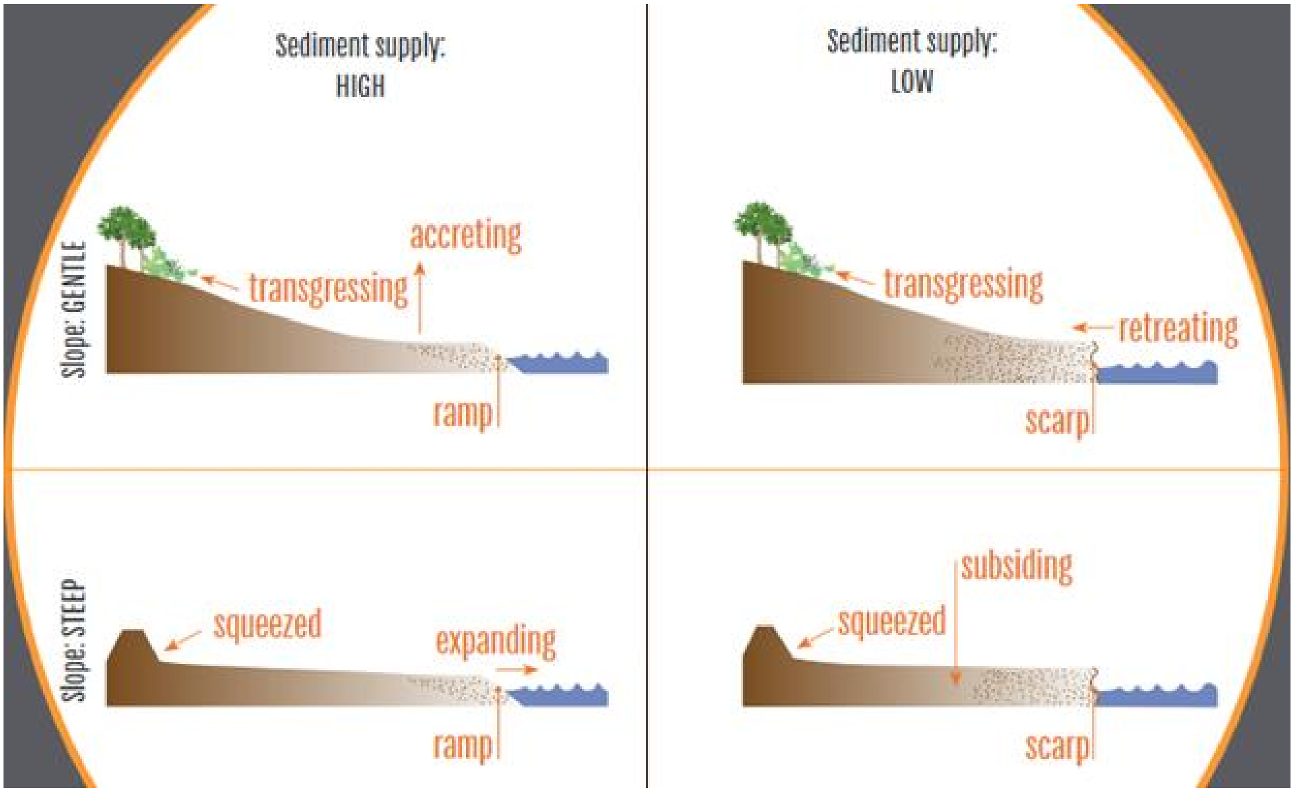

Figure 18. Coastal habitats can shift vertically and/or horizontally in response to drivers that include antecedent topography, sediment supply, and sea levels. (Image: Beagle et al. 2015).

4 Proposed Basin Plan Amendment

The Basin Plan is the Water Board's master planning document that contains descriptions of the legal, technical, and programmatic bases of water quality regulation in the region. The Basin Plan lacks any reference to climate change (except briefly in Chapter 7), despite the fact it will affect the waters in the region. Therefore, the Basin Plan amendment is the start of the effort to remedy this, beginning with non-regulatory updates in Chapters 1, 2, and 4.

4.1 Amendments to Chapter 1 of the Basin Plan

The revisions to Chapters 1 and 2 include minor revisions and updates to include new information. Revision 1(1) removes unnecessary text comparing the size of the San Francisco Bay to the size of the state of Connecticut and updates the list of factors affecting estuaries. Revision 1(2) inserts a new section to describe the effects of a changing climate on water quality based on the latest information. Revision 2(1) updates the name of the California Department of Fish and Game to the

California Department of Fish and Wildlife to reflect a change in their name, and updates references to the Baylands Ecosystem Habitat Goals Report and EcoAtlas to reflect the most recent report and nomenclature changes.

4.2 Amendments to Chapter 4 of the Basin Plan

The revisions to Chapter 4 include minor revisions to include new information in Sections 4.23, Wetland Protection and Management, as well as the addition of a new Section 4.27, Climate Change and Aquatic Habitat Protection, Management, and Restoration. None of these changes are regulatory.

Revision 4(1) updates references to the San Francisco Estuary Partnership’s Estuary Blueprint: Comprehensive Conservation and Management Plan (Estuary Blueprint) in the introduction to Section 4.23. It updates references to the Baylands Ecosystem Habitat Goals Report in Section 4.23.1, and briefly summarizes the content of the 1999/2000 and 2015 Goals Reports. In Section 4.23.4, it updates a reference to the Estuary Blueprint, and adds references to the San Francisco Bay Shoreline Adaptation Atlas, the Aquatic Resource Type Conversion Evaluation Framework, and the California Rapid Assessment Method to reflect the most recent report and nomenclature changes. These are technical references the Water Board may use to determine appropriate mitigation for impacts to waters of the state.

Revision 4(2) corrects an incorrect reference to Table 2-4 in two locations in Section 4.23.2, and adds the Bay Area Aquatic Resource Inventory (BAARI) as a scientific reference for the designation of beneficial uses in wetlands.

Revision 4(3) renames Section 4.23.4 from “Wetland Fill” to “Wetland Dredge or Fill” to more accurately describe the section and be consistent with the language in the Dredge and Fill Procedures. It edits the language in Section 4.23.4 to be consistent with existing law that wetlands are included in the definition of waters of the state, and that all can be affected by dredging, diking, and filling. It deletes an obsolete reference to the Wetland Ecological Assessment, and replaces it with the more advanced California Rapid Assessment Method developed by the California Water Quality Monitoring Council.

Revision 4(4) adds Section 4.27, Climate Change and Aquatic Habitat Protection, Management, and Restoration to Chapter 4. As background, the Water Board regulates dredge or fill discharges into waters of the U.S. and state under the federal Clean Water Act and the state Porter-Cologne Water Quality Control Act (Porter-Cologne), respectively. The Dredge and Fill Procedures were adopted in 2019 and revised in 2021. Section 4.23 of the Basin Plan has been in effect since 1995. Both conform to the 1993 California Wetlands Conservation Policy (Executive Order W-59-93) by ensuring that the Water Boards’ regulation of dredge or fill activities will be conducted in a manner to ensure no overall net loss and long-term gain of wetlands. Commonly referred to as the No Net Loss Policy, the California Wetland Conservation Policy addresses the need to incentivize, coordinate, and implement wetland restoration across the state. The No Net Loss Policy lists three primary objectives:

1. *Ensure no overall net loss and a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property.*
2. *Reduce procedural complexity in the administration of State and federal wetlands conservation programs.*
3. *Encourage partnerships to make restoration, landowner incentive programs, and cooperative planning efforts the primary focus of wetlands conservation.*

The No Net Loss Policy directs the Water Boards and other state agencies to implement a range of measures aimed at growing wetland acreage, functions, and values, including developing policies to incentivize multi-benefit wetland conservation projects that also benefit flood control, groundwater recharge, recreation, and other needs. The policy is clear that its objectives are not meant to be achieved on a permit-by-permit basis; rather, implementation should be guided by regional wetland conservation strategies. It was in this spirit that the original 1999/2000 Habitat Goals Report was conceived. The policy does not differentiate between the functions and values of different kinds of wetlands (e.g., seasonal freshwater marsh vs. tidal salt marsh vs. open water vs. mudflat).

To help achieve the No Net Loss Policy objectives, the Dredge and Fill Procedures and Section 4.23 of the Basin Plan prescribe how the Water Board regulates projects that would result in diking, dredging, or filling of waters of the state. Under these regulations and the federal Clean Water Act Section 404(b)(1) Guidelines (40 C.F.R. Part 230), no discharge of dredged or fill material can be permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. The primary method to demonstrate this is to prepare an alternatives analysis that documents direct, indirect and cumulative impacts to waters of the state have first been avoided and then minimized. Once impacts have been avoided and minimized, compensatory mitigation is required to ensure no net loss of wetland acreage and functions. When evaluating the adequacy of compensatory mitigation proposals, preference is given to proposals that are on-site[10] and in-kind[11], and the quantity of mitigation is adjusted based on the distance of the mitigation site from the impact site, the type of mitigation (whether it is in-

[10] On-site means an area located on the same parcel of land as the impact site, or on a parcel of land contiguous to the impact site and off-site means an area that is neither located on the same parcel of land as the impact site, nor on a parcel of land contiguous to the parcel containing the impact site. (Dredge and Fill Procedures.) Thus, on-site compensatory mitigation is when the mitigation project occurs relatively close to the location of impacts. Generally, to be considered on site, the mitigation project must be in the same landscape position within the same watershed as the impact location. Off-site compensatory mitigation is when the mitigation project is not close to the location of impacts.

[11] In-kind means a resource of a similar structural and functional type to the impacted resource and out-of-kind means a resource of a different structural and functional type from the impacted resource. (Dredge and Fill Procedures.) In-kind compensatory mitigation is when the mitigation project restores, creates, or enhances the same type of waterbody as the waterbody being impacted. Out-of-kind compensatory mitigation is when the mitigation project restores, creates, or enhances the different type of waterbody from the waterbody being impacted.

kind or out-of-kind), temporal losses in function[12], and uncertainty (the likelihood of the mitigation supporting its intended habitat functions). This tiered strategy for addressing potential impacts is often summarized by the phrase *"first avoid, then minimize, then compensate."*

As described in Chapter 3 of this staff report, climate change is impacting California through multiple mechanisms including but not limited to rising sea levels and increasing frequencies and severities of drought and extreme precipitation events. These trends affect a broad range of physical and ecological conditions and processes that support beneficial uses in waters of the state. They also can influence the near-term and long-term impacts of dredge and fill activities, and the success of mitigation that may be required to compensate for those impacts. Chapter 3 also explains how the colonization, reclamation, and fragmentation of the region's aquatic habitats resulted in tremendous impacts to their quantity, quality, and beneficial uses, and increased the risk of future climate change-driven impacts and losses by isolating habitats from the landforms and physical and ecological processes that would otherwise sustain them. Though the precise rate and magnitude of future impacts to aquatic habitats from climate change are uncertain, the overall direction of these impacts is clear: without thoughtful and deliberate intervention (which in many cases is likely to include dredge and fill activities), the region could lose much of its remaining estuarine wetlands, mudflats, beaches, and related habitats.

Due to uncertainties about future rates of sea level rise, the influence of extreme events, local and regional planning decisions, and how landscapes could change in response to these and other factors, it can be challenging for the Water Board to identify whether proposed dredge or fill projects in or near coastal waters are compliant with the Basin Plan, the No Net Loss Policy, the Dredge and Fill Procedures, and the 404(b)(1) Guidelines. The new Section 4.27 – Climate Change and Aquatic Habitat Protection, Management, and Restoration – therefore provides additional information to help the Water Board consider the reasonably foreseeable influence of climate change and related factors. It does this by proposing a series of questions that may be relevant to permitting dredge or fill activities, especially climate adaptation activities, based on the informative resources in the Baylands Goals Reports, Adaptation Atlas, and related scientific literature. These questions, and the reasoning for their inclusion in the Basin Plan, can be summarized as follows:

1. **Is the proposed project design, as well as assessment of its near-term and long-term impacts at site- and landscape-scales, based on the best available science describing climate change and its influence on the environment?**

The science of climate change, climate change adaptation, habitat restoration, and related fields is rapidly evolving. Therefore, utilizing the most up-to-date and relevant climate change science in project design and impact assessment is important. Projects that are not based on the best available science may be less likely to achieve their desired endpoints and performance measures.

[12] Temporal loss is the time lag between the loss of aquatic resource functions caused by the permitted impacts and the replacement of aquatic resource functions at the compensatory mitigation site. (Dredge and Fill Procedures.)

2. **Is the proposed project designed as part of a phased adaptation strategy that anticipates potential future projects and accommodates these projects in a manner that protects future beneficial uses of the site and its landscape?**

Phased adaptation strategies are actions to provide flood protection at different climate change thresholds over time. Initial actions are designed to provide flood protection in the near-term while allowing for a range of future actions to address uncertainty and allow flexibility over the long term. For example, maintaining long-term lines of flood defense along San Francisco Bay and the Pacific Ocean as far landward as practicable minimize the isolation of wetlands and waters behind flood management infrastructure, reduce the risk of flooding of low-lying areas by surface water or groundwater, and create space for the restoration of complete estuarine wetland systems and other nature-based adaptation measures. Such strategy minimizes both impacts to waters of the state and the likelihood of projects having to be removed, replaced, or significantly retrofitted in the future due to climate change and is, therefore, a preferable approach to climate adaptation.

3. **Is the proposed project designed within a landscape-scale, cross-jurisdictional framework, such as an operational landscape unit?**

Since climate change operates at a landscape scale, strategies to address climate change are more likely to be successful if they are implemented at a landscape scale. Projects that consider current and anticipated future conditions at the landscape-scale are likely to have fewer long-term direct, indirect, and cumulative impacts than projects that only address near-term, site-scale conditions. Operational landscape units, which are described in the Adaptation Atlas, are an example of a landscape-scale, cross-jurisdictional framework.

4. **Does the proposed project utilize practicable natural and/or nature-based design features, or a combination of traditional and nature-based features?**

A project that incorporates natural and/or nature-based approaches such as living shorelines, beaches, wetlands, estuary-watershed reconnection, strategic sediment placement, ecotone/treated-wastewater horizontal levees, or migration space preparation is more likely to support beneficial uses now and in the future. These approaches – and those that combine nature-based features with more traditional grey infrastructure – generally have fewer cumulative impacts, support more benefits (e.g., habitat, flood protection, recreation, etc.), and are more adaptable to a changing climate than approaches that rely solely on grey infrastructure. Nature-based climate change adaptation features, however, should be appropriate to the physical setting in which they are located.

5. **For a proposed dredge or fill activity, what are the near- and long-term direct, indirect, and cumulative impacts to the acreage, functions, and values of waters of the state when considering the reasonably foreseeable conditions from climate change?**

This question proposes a series of sub-questions that are meant to illuminate key, complex interactions between climate change, proposed dredge and fill activities, and landscapes, and the physical and ecological processes and conditions that affect all three across space and time. Identifying and understanding these interactions can help Water Board staff assess a project's potential impacts, and reduce uncertainties related to the development of mitigation requirements and performance metrics. Informational resources such as the State Sea Level Rise Guidance, Baylands Goals reports, Adaptation Atlas, their supporting scientific literature, and related documents/tools can help answer these questions and support science-based decision-making by the Water Board. The sub-questions generally address environmental drivers, the impacts of no action, activities that support coherent landscapes, and type conversion between different types of waters of the state:

a. Environmental drivers:
   i. What are the primary hydrologic, geomorphic, and ecological drivers of beneficial uses and habitat resilience at the site- and landscape-scale, and how are they likely to influence the landscape in the near- and long-term?
   ii. Where and how are processes such as upland migration (transgression), erosion, progradation, accretion, and/or drowning likely to impact the condition, location, and distribution of different habitat types?
   iii. How might the proposed dredge or fill activities influence these drivers?
b. Impacts of no action:
   i. How would the affected landscapes be likely to evolve in the absence of the proposed dredge or fill activities?
   ii. Given the likely range of anticipated environmental drivers, would the absence of the proposed activities likely result in less diverse, resilient, and/or complete habitats in the long-term?
c. Coherent landscapes:
   i. Are the proposed dredge or fill activities geographically and geomorphically situated and designed to work with both site-scale and landscape-scale natural processes, such as the movement of water and sediment, shifts in plant communities, and the movement of fish and wildlife between different habitats?
   ii. Will the proposed activities enhance or impede the ability of these natural processes to exert work on the landscape?
d. Type conversions: Some dredge or fill activities may convert one type of water of the state to another (e.g., salt pond to tidal flat/tidal wetland), or convert one component of the estuarine wetland ecosystem to another (e.g., tidal wetland to estuarine-terrestrial zone, tidal wetland to high tide refugia, or tidal wetland to tidal channel). The overall impacts of proposed wetland type conversions can be assessed using technical guidance such as the Aquatic Resource Type Conversion Evaluation Framework.
   i. Does the landscape setting, including but not limited to local climate, hydrology, sediment supply, degree of urbanization, habitat connectivity, and geomorphic setting, support the intended habitat type?
   ii. Does the intended habitat type require intensive management that will have to be funded and implemented in the long-term?
   iii. What ecosystem functions will be gained or lost through type conversion, and what is the potential timing and magnitude of these changes? How are these changes likely to influence ecosystem functions within the broader landscape?

iv. Is the proposed type conversion consistent with strategies developed by collaborations of stakeholders to achieve regional goals such as recovering rare and/or historic habitat types, improving landscape connectivity/complexity, and/or supporting long-term habitat resilience?

5 California Environmental Quality Act

CEQA authorizes the Secretary of the Resources Agency to certify a regulatory program of a state agency as exempt from the requirements for preparing environmental impact reports (EIRs), negative declarations, and initial studies if certain conditions are met. (Pub. Res. Code, section 21080.5, Cal. Code Regs., tit. 14, section 15250.) The Regional Water Board's water quality control planning program is a certified regulatory program and, thus, this staff report has been prepared in lieu of an EIR or negative declaration. (Cal. Code Regs., tit. 14, section 15251, subd. (g).) This staff report and its appendices serve as the substitute environment document required for Basin Plan amendments. (Cal. Code Regs., tit. 23, section 3777.) A CEQA checklist (Appendix A) has been prepared and is included with this staff report (Cal. Code Regs., tit. 23, section 3777, subd. (a)(2).). The proposed project is the adoption of a non-regulatory Basin Plan amendment as described in Section 2.2 of this report. -The project is informational and does not change or add any regulations. It will not have any physical impact on the environment. No fair argument exists that the project could result in any reasonably foreseeable significant adverse environmental impacts. Because the project would not have any significant or potentially significant effects on the environment, no alternatives or mitigation measures are proposed to avoid or reduce any significant effects on the environment. (Cal. Code Regs., tit. 14, section 15252, subd. (a)(2)(B); see also Cal. Code Regs., tit. 23, section 3777, subd. (e).) In addition, there are no environmental impacts from the reasonably foreseeable methods of compliance because the project does not propose to adopt any new rule or regulation requiring the installation of pollution control equipment or a performance standard or treatment requirement. (See Pub. Res. Code, section 21159.)

6 Peer Review Requirements

The scientific basis of any regulation or policy adopted under the Porter-Cologne Act that has the effect of a regulation and that is adopted in order to implement or make effective a statute is subject to external scientific peer review. (Health and Saf. Code, § 57004.) "Regulation" means every rule, regulation, order, or standard of general application or the amendment, supplement, or revision of any rule, regulation, order, or standard adopted by any state agency to implement, interpret, or make specific the law enforced or administered by it, or to govern its procedure. (Gov. Code, § 11342.600. The "scientific basis" and "scientific portions" are those "foundations of a rule that are premised upon, or derived from, empirical data or other scientific findings, conclusions, or assumptions establishing a regulatory level, standard, or other requirement for the protection of public health or the environment." (Health and Saf. Code, § 57004, subd. (a)(2).)

Peer review is not required because the proposed Basin Plan amendment contains no regulations. The amendment is informational and updates the Basin Plan with missing information about climate change and how it might affect the region's waters. It describes efforts made to support the long-term resilience of aquatic habitats in the region and provides references related to the protection and improvement of beneficial uses. It also includes a suite of questions and information that may be relevant when the Water Board permits dredge or fill activities in or near coastal waters, especially climate adaptation projects. It updates references, corrects errors, and makes minor, non-substantive edits for clarity. The Basin Plan amendment includes no mandatory actions or requirements for either the Water Board or the regulated community. Nor does it require the Water Board to exercise its permitting authority in any particular way or follow specific procedures.

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Appendix A – Environmental Checklist