Review Draft
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UC SANTA BARBARA

Sea Level Rise Adaptation Strategy

Coastal Planning Science Advisory Board

John Melack, Paul Alessio, Patrick Barnard, Jenifer Dugan, Gary Griggs, Charles Lester, Mark Page, Lisa Stratton, Art Sylvester; *ex officio* Shari Hammond

UC Santa Barbara Staff

Shari Hammond, Campus Planning and Design

Martin Shumaker, Strategic Asset Management

Contents

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Executive Summary

This Sea Level Rise Adaptation Strategy implements the UCSB Long Range Development Plan (LRDP) requirement to address sea level rise. It applies best available science to assess the vulnerability of the campus' built and natural environment to erosion, flooding and other coastal hazards, assuming as much as 2 meters (6.6 feet) of sea level rise by the year 2100.

UCSB's shoreline is an incredible resource. It includes popular recreational beaches and sensitive coastal and wetland habitats of statewide ecological significance. Most of UCSB's built environment is on an elevated marine terrace, relatively safe from coastal hazards. Still, the campus is facing significant environmental change and risks from shoreline erosion, flooding, and rising water tables. Some of these need immediate attention and action, but there are also many longer-term adaptation strategies to consider if UCSB is to protect the significant natural and social benefits of its shoreline.

This strategy applies an "adaptation pathway" approach that uses monitoring of environmental and social change to anticipate and trigger future adaptation actions. The goal is for UCSB to proactively adapt to sea level rise and avoid reactive, maladaptive actions. The strategy also has a strong vision to lead UCSB along a path to a more resilient and sustainable future. Without this vision, UCSB's campus, and the academic experience that it supports, will become increasingly vulnerable to climate change. Ultimately, UCSB could lose the natural resources and related experiences that make the campus environs such a special place for a university.

The specific adaptation pathways of this plan seek to minimize sea level rise impacts to UCSB's human, built and natural environments while meeting the requirements of the California Coastal Act. They rely on assessment of anticipated coastal hazards, regular monitoring, study of implementation options, and the fundamental idea that resilience will flow not from resistance to the forces of the sea, but from pragmatic adaptation to shoreline conditions as they may change with sea level rise and coastal storm patterns. The pathways thus embody the University's vision to maximize campus resilience and protect and restore natural shoreline features and processes through a phased, managed adaptation to climate change-driven shoreline change.

Figure 1.0 summarizes the main adaptation pathways for five campus shoreline areas detailed in Chapter 4. They range from more immediate actions over the short (1-10 yrs), to intermediate (10-30 yrs) and longer-term (30-100 yrs) studies and adaptation actions driven by shoreline monitoring. For example, in Area 1, which encompasses the Coal Oil Point Reserve and North Campus Open Space, the plan proposes to monitor shoreline and ecological change, including recreational use, and prioritize habitat protection and public beach access as sea level rises. In conjunction with beach assessment in other areas, this monitoring will support further planning to address what is likely to be an increasing tension between recreational beach use and sensitive habitat protection. In the longer run, based on study of wetland change along the margins of Devereux Slough, the closing of Slough Road to vehicle traffic and expanded wetland restoration may be triggered.

Other shoreline areas have similar progressions of monitoring, study and adaptation actions. In Area 2 – along the West Campus Bluffs, the plan anticipates removal or relocation of the buildings at Coal Oil Point and incremental realignment of public access trails and amenities as the bluff erodes. Additional access planning will also be needed as the recreational beaches of the campus potentially shrink with sea level rise. In Area 3, which includes the bluffs, beach and interior shoreline around Campus Lagoon, the plan directs an assessment to determine the best way to gradually open up the lagoon to increased tidal action. The plan recognizes that there may be a need for more immediate interim maintenance of the berm at the eastern weir. The plan also contemplates the gradual retreat of public access and habitat resources along the bluff in Area 3, as well as the removal of the existing revetment at Campus Point. This action is subject to further monitoring and planning for blufftop resources, including public access, habitat and potential cultural resources. Consultation with tribal community members is called for to better address tribal concerns and environmental justice.

Area 4, along Lagoon Road from the Marine Science Facilities to the edge of Goleta Beach, presents the most challenging vulnerabilities and adaptation considerations. There is an immediate need to address erosion near Anacapa Hall, where bluff failure could put Lagoon Road and underground utilities in jeopardy. There is also a need to assess the best path forward for the Marine Science facilities adjacent to the lagoon mouth because of their condition and their vulnerable location. Coupled with cliff erosion monitoring and planning for the lagoon mouth and broader Lagoon Road corridor, this may support facility redevelopment in place in the shorter term but eventual relocation of facilities over longer terms. Much of Lagoon Road will be safe for some time, but there likely will be a need to realign or even relocate segments of the road, public access, and utilities as erosion continues. In particular, the viability of the sewer pump station near Goleta Beach and related utility corridors will need to be addressed over the near and longer terms. The goal of monitoring and a managed retreat plan for the entire corridor will be to avoid any permanent armoring of the East Bluffs so natural cliff erosion may continue, while also better anticipating the need for any emergency or interim shoreline protection and other adaptation measures.

Area 5 includes the shared edge of the campus with the Goleta Slough and Storke Wetlands system. The plan contemplates the eventual removal and relocation of development and infrastructure (sewer pump station, communication services) north of Mesa Road, as well as opportunities for wetland restoration and expansion in connection with the redevelopment of housing nodes at Storke and Santa Ynez.

Chapter 5 presents proposed LRDP amendments to implement the pathways, including the establishment of a comprehensive monitoring program, 10 future studies, and 15 specific actions as shoreline conditions may dictate. The amended LRDP would require the updating of the sea level rise adaptation plan every ten years.

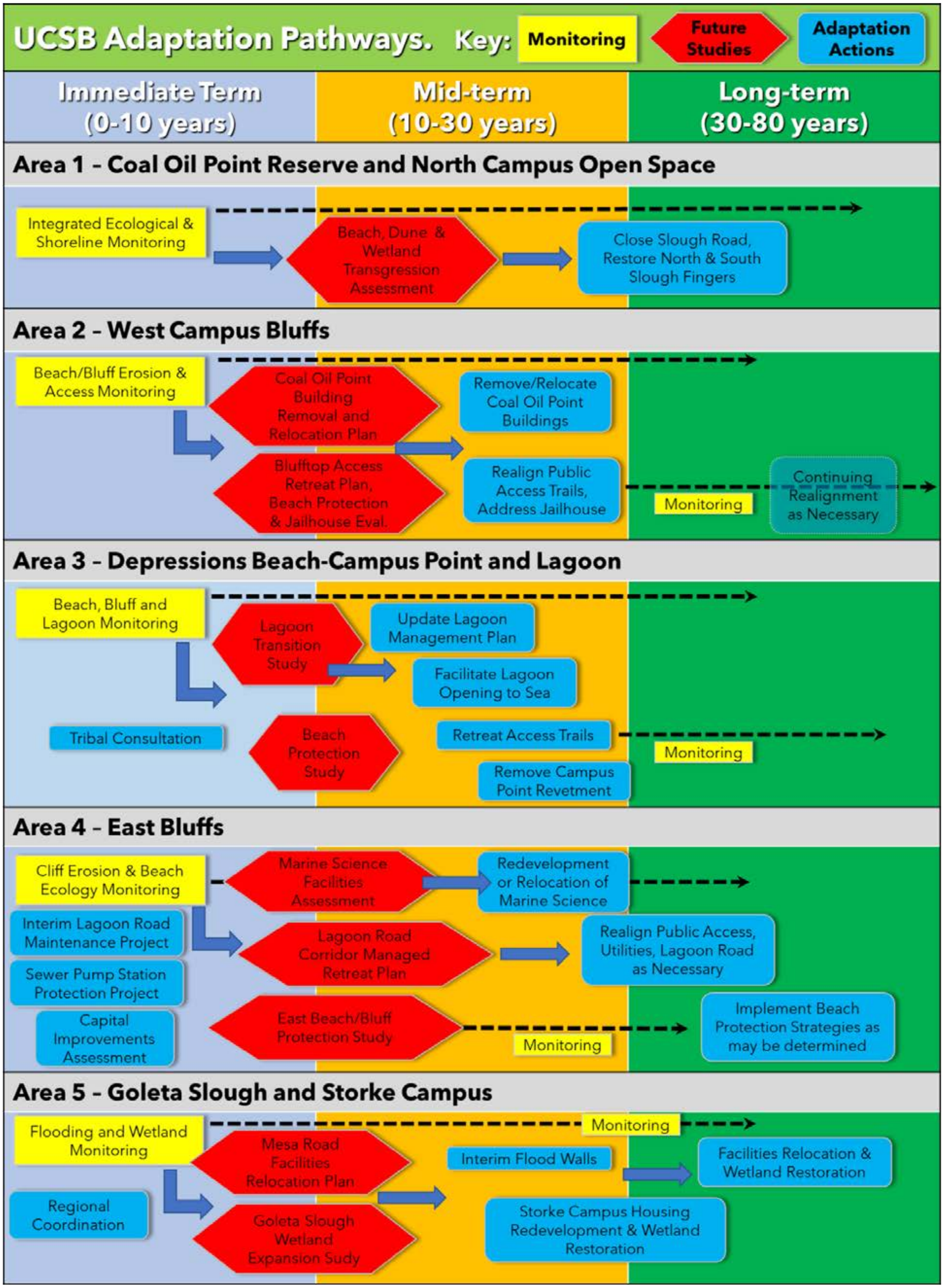

Figure 1.0. UCSB sea level rise strategic adaptation pathways.

1.0 Introduction

This UCSB Sea Level Rise Adaptation Strategy implements Policy SH-01 of the UCSB Long Range Development Plan, which requires UCSB to prepare a "comprehensive sea level rise hazards assessment" or "plan" for submission to the Coastal Commission as an amendment to the LRDP. The plan must include five elements:

> (1) an assessment of campus areas, structures, facilities, and priority coastal resources, such as beach access and wetlands, vulnerable to sea level rise (SLR) along Goleta Slough and the Pacific Ocean shoreline;
>
> (2) identification of needed site-specific, detailed coastal hazards analysis;
>
> (3) recommended adaptation strategies to minimize SLR risks to coastal resources and development;
>
> (4) analysis of campus SLR impacts at site-specific and regional scales; and
>
> (5) identification of recommendations and necessary LRDP amendments.

This Adaptation Strategy addresses these required elements in five chapters. Chapter 2 summarizes the state law and LRDP policy context for the required SLR planning. Chapter 3 reviews relevant sea level rise science, setting the stage for the assessment of sea level rise vulnerabilities and strategies. Chapter 4 evaluates the SLR risks along five geographic segments of the UCSB shoreline, and presents corresponding adaptation strategies for assuring a resilient campus shoreline into the future. Overall, and consistent with the direction of LRDP Policy SH-01, the strategies set out an adaptation path for the campus built on comprehensive monitoring, further detailed study of specific vulnerabilities and strategies to address them, and phased, managed retreat of the built environment over the short, medium and long-term. Finally, Chapter 5 presents the proposed LRDP Amendments to implement the Adaptation Strategy.

UCSB is fortunate to have many incredible shoreline resources, including popular recreational beaches and surf breaks, and sensitive coastal habitats and species. The wetlands of Goleta Slough and the beaches of UCSB are resources of statewide significance, and the entire south-facing campus shoreline is in the "no-take" Campus Point State Marine Conservation Area. These iconic shorelines and their resources serve the entire campus – students, residents, and staff – as well as the surrounding communities of Goleta and Santa Barbara and visitors from around the state. The beaches of UCSB are also the primary coastal access for Isla Vista, which is designated as a severely disadvantaged community by the State of California.

UCSB is also fortunate to be located on an elevated marine terrace in such a way that its built environment is relatively safe from coastal hazards due to rising seas (Figure 1.1). Nonetheless, as this plan shows, there are significant vulnerabilities to sea level rise and storms, including some immediate needs for deliberate action. There are also many important adaptation strategies to consider over the long run if UCSB is to maintain the remarkable natural and social values of its shoreline. This strategy is an effort to anticipate these strategies so that UCSB may *proactively* adapt to sea level rise in a thoughtful and equitable manner, avoiding reactive, maladaptive actions, and protecting the shoreline for all, including those disadvantaged communities and persons that may be most vulnerable to the impacts of climate change.

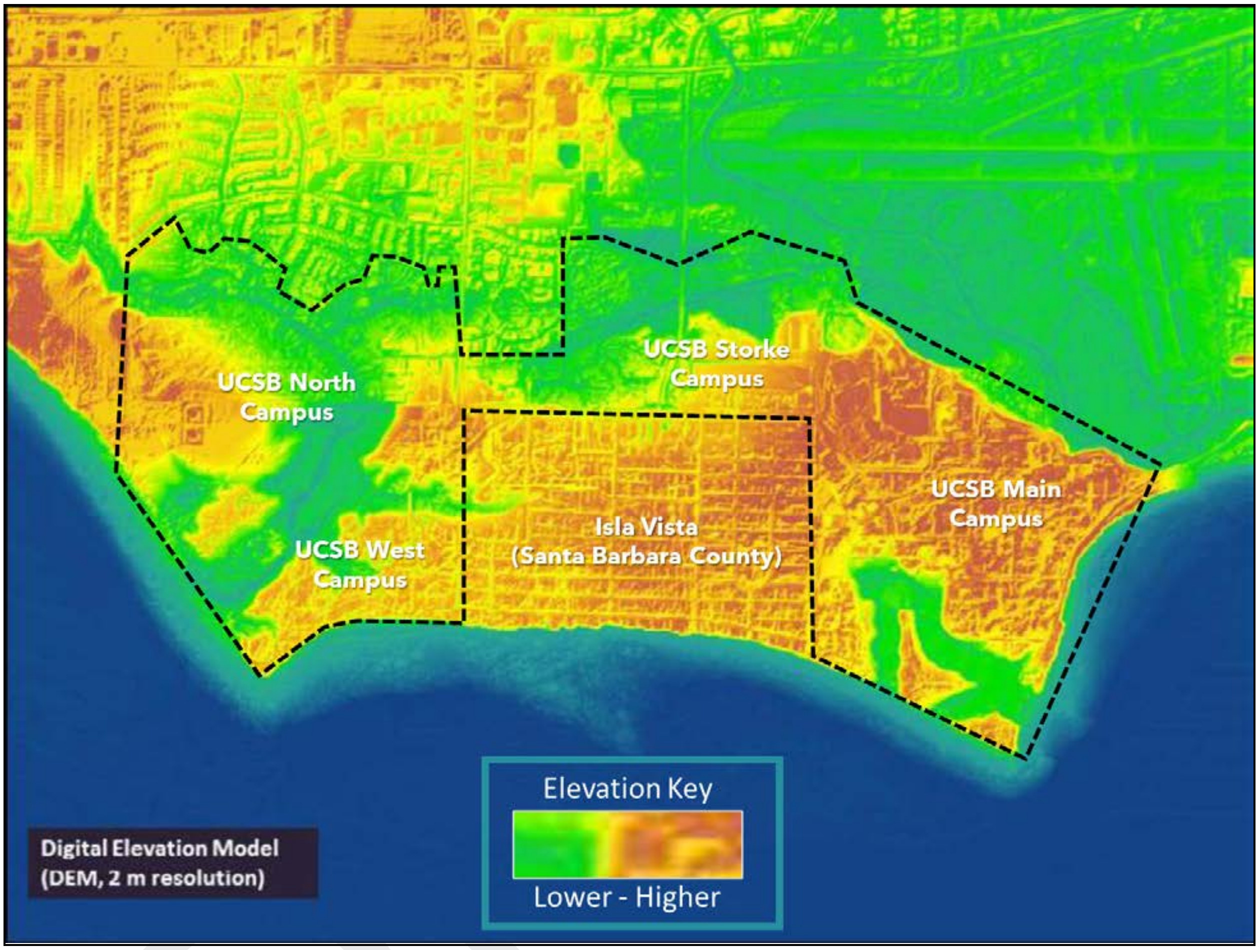

Figure 1.1. LIDAR, relative elevations of UCSB campus area and surrounding waters.[1]

1.1. The UCSB Shoreline Adaptation Vision and Strategic Pathways

This adaptation strategy is founded on the best available scientific projections of global, regional and local sea level rise and effects to the year 2100. The strategy considers more likely outcomes of lower-emission pathways and less-likely outcomes along higher emission pathways, including the potential for catastrophic ice-melt over the next century. The strategy is pragmatic, and Chapter 4 addresses the inherent uncertainty of future sea level rise by proposing adaptation "pathways" for each of the five geographic segments. Each follows the same general strategic path, involving systematic monitoring of environmental and social change, further study of specific

[1] Adapted from Myers, M. R., Cayan, D. R., Iacobellis, S. F., Melack, J. M., Beighley, R. E., Barnard, P. L., Dugan, J. E. and Page, H. M., 2017. Santa Barbara Area Coastal Ecosystem Vulnerability Assessment. CASG-17-009), pg 83.

vulnerabilities and adaptation measures, and adaptation actions in the short, medium and long term based on this assessment and future assessments, and that would be triggered by the environmental changes and related risks being monitored.

The "adaptation pathway" approach is consistent with the guidance of the California Coastal Commission that recognizes the importance of understanding potential future sea level rise scenarios and the need to trigger proactive adaptation based on monitoring of actual environmental change. The pathway approach is also consistent with the work of the Intergovernmental Panel on Climate Change (IPCC), including the idea that there are more and less resilient climate adaptation pathways, depending on the choices society makes about how to adapt. In particular, higher resilience is thought to be enabled by choices that embody ecosystem stewardship, diversified knowledge, equity, social and environmental justice, and inclusion (Figure 1.2).

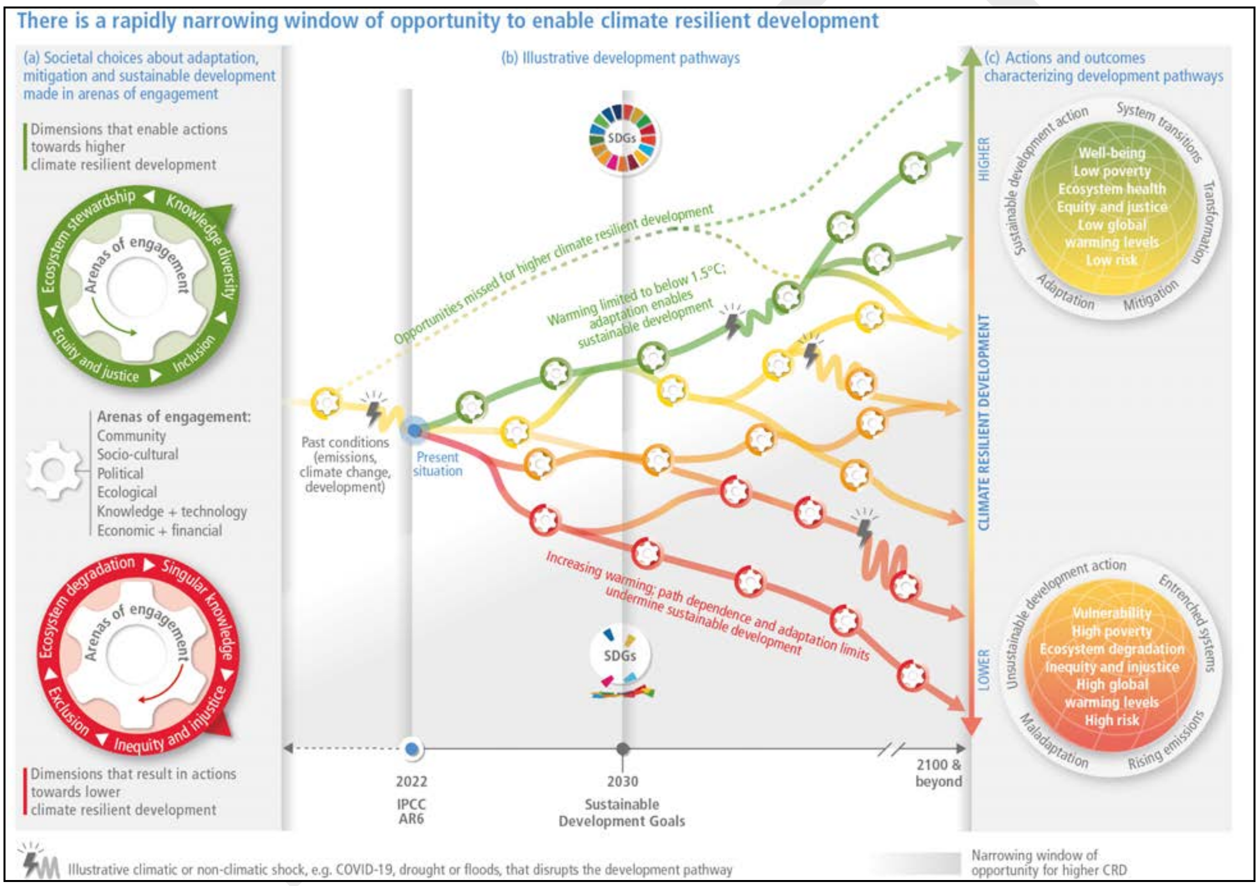

Figure 1.2. IPCC Pathways to and away from climate resilient development[2]

UCSB embraces the pathway approach for addressing sea level rise, but more importantly, it recognizes the need for a strong vision that will lead, and keep, the UCSB community on a path to a more resilient and sustainable future. Without a vision of resilience to guide future adaptation choices, it is more likely that UCSB will become

[2] Figure SPM.5, IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

increasingly vulnerable to climate change. The campus' built and natural environment, and the academic experience that it supports, inevitably will suffer. Without thoughtful, proactive action, UCSB could lose the natural resources and related experiences that make the campus environs such a special place for a university.

The specific adaptation pathways laid out in this plan are designed to minimize SLR impacts to campus development, infrastructure and the human and natural coastal environment, while meeting the requirements of the California Coastal Act. Together, the strategic pathways embody the University's vision to maximize campus resilience and protect and restore natural shoreline features and processes through a phased, managed adaptation to climate change-driven shoreline change.

UCSB aspires to maximize campus resilience and protect and restore natural shorelines, through proactive, phased, managed adaptation to sea level rise and shoreline change.

UCSB's vision for shoreline adaptation would be achieved through the proactive sequencing of distinct actions over time, including continued assessment of coastal hazard risk based on the best available science, future study of refined adaptation options and strategies, monitoring of evolving shoreline conditions, restoration, and incremental movement of campus shoreline development and activities away from hazardous shoreline erosion and flood zones (e.g., beaches and bluffs) as necessary. Implementation of actions along each planning segment's adaptation pathway is considered generally over the near (0-10 years), mid- (10-30 years) and long-term (30-80 years). The pathways include identification of needed studies to refine optimum adaptation actions and capital investments necessary for implementation, as well as monitoring requirements to refine evolving coastal hazard risk and assure that the actions along each pathway occur in a timely and effective fashion.

As an example, Figure 1.3 shows the adaptation pathway proposed for the campus lagoon, moving from present conditions and initial actions to stabilize the shoreline, to further study to identify the best specific actions for facilitating the restoration and transition of the lagoon to a more tidally-influenced condition. Monitoring would dictate the precise timing of actions to allow the opening up of the lagoon berm while protecting public access and other coastal resources.

Chapter 4 of this Adaptation Strategy proposes multiple place-specific pathways for responding to sea level rise. For example, in addition to the Campus Lagoon strategy, the plan identifies the need for increased monitoring of beaches, dunes and wetlands in the Coal Oil Point-Devereux Slough system, to support future restoration and succession of sensitive habitats, particularly that of the threatened Western snowy plover. It also calls for the removal of existing development at Coal Oil Point, and the incremental realignment of public access along the blufftop as necessary from Coal Oil Point to Campus Point, to assure its continuance. The strategy also outlines future shoreline restoration through eventual removal of the revetment at Campus Point, in conjunction with the strategy to facilitate the opening up of the Lagoon.

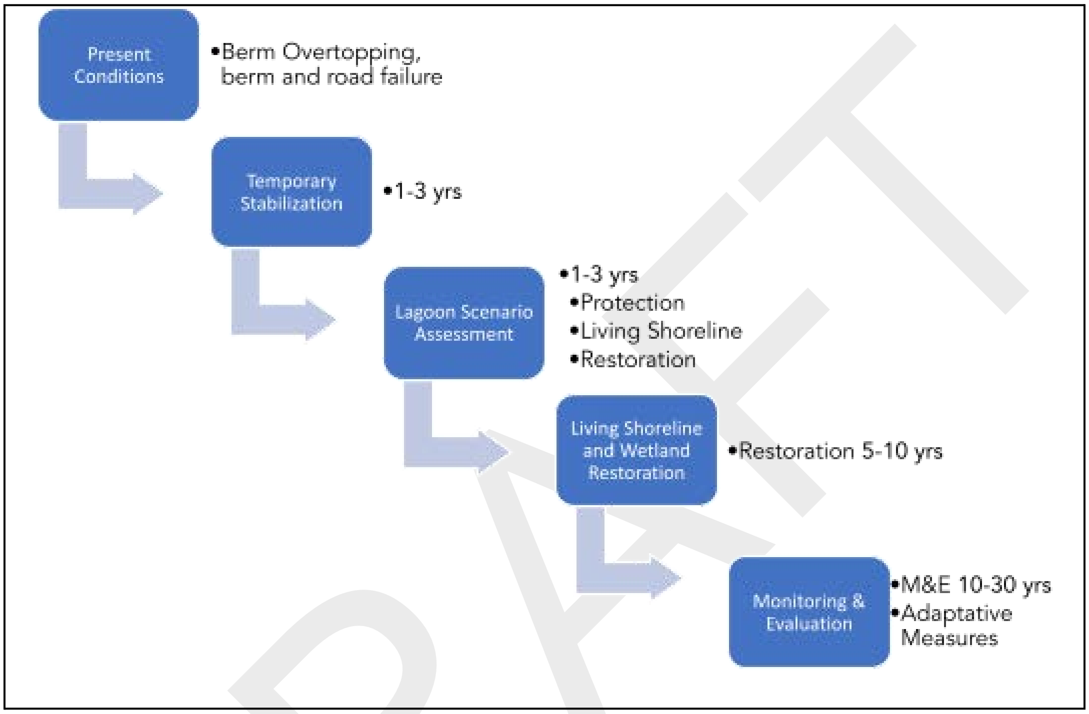

Figure 1.3. Illustrative adaptation pathway for the Campus Lagoon.

One of the most challenging pathways in this strategy is the need to incrementally realign and perhaps remove or relocate, certain buildings and infrastructure along the Lagoon Road corridor over the long term. Specific assessment of the buildings near the Lagoon will be needed. There also is an immediate need to address erosion threats to the road at a “pinch point” near the Anacapa residence hall. Finally, along the Goleta Slough shoreline of the campus, the strategy identifies the likelihood of flooding and extreme events in the long-term, and opportunities for additional wetland restoration to accommodate the inevitable changes to the Slough with sea level rise, including through the redevelopment of the Storke Family Housing, the Santa Ynez Apartments and development in the Public Safety area (Police, Fire, Communications, and sewer pump station), and other facilities in the area.

In the end, the various adaptation pathways of this plan are intended to address state and university policy requirements in the coastal zone, using the best available science about future sea level rise, storms, and the associated coastal impacts. These subjects are addressed in the next two chapters, including a discussion of relevant regional and subregional management concerns.

2.0 California Law and Policy for Shoreline Adaptation Planning

2.1 The California Coastal Act

The California Coastal Act establishes statewide requirements to protect a variety of resources in the coastal zone, including public access and recreation, natural shorelines and habitats, and coastal-dependent developments, such as fishing and boating.[3] The Act includes a land use planning and permit requirement for new development in the coastal zone, largely implemented through Local Coastal Programs (LCPs) adopted by local governments and approved by the California Coastal Commission.[4]

For universities with land in the coastal zone, the Coastal Act requires the Coastal Commission to review the relevant portions of a campus Long Range Development Plan (LRDP) for consistency with the Coastal Act.[5] The contiguous campus of UC Santa Barbara, including Main, West and North Campuses, and the Coal Oil Point Reserve (COPR), sits entirely within the coastal zone except for a portion of Storke Campus around the Santa Ynez student housing project (Figure 2.1)[6]. After an LRDP is approved by the Commission, universities may permit new campus developments through the issuance of a "Notice of Impending Development" (NOID) that is reviewed by the Coastal Commission. Through its review, the Commission may impose conditions on (but not deny) the University projects to assure consistency with the LRDP, after which the projects may be implemented.[7] This SLR plan has been developed as an LRDP amendment. It anticipates various studies, monitoring and adaptation actions that would require a development review under the LRDP. Chapter 5 presents the specific proposed LRDP amendments to implement the sea level rise adaptation strategy.

In addition to various mandates to protect sensitive resources, the Coastal Act has two main policies that address coastal hazards, such as the increased risks of flooding and erosion associated with sea level rise. Coastal Act Section 30253 requires that new development minimize risks to life and property in areas of high geologic, flood, and fire hazard. This policy also requires that development "assure stability and structural integrity," not cause erosion and geologic instability, and also be designed and constructed to not require future shoreline protection. On the other hand, Section 30235 provides for the potential construction of shoreline protective devices (e.g. seawalls or revetments), but only for existing structures in danger from erosion, and with full mitigation of any impacts from such construction. The Coastal Commission interprets "existing structure" to mean structures in existence at the time that Coastal Act became effective (January 1, 1977).[8]

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[3] California Public Resources Code (PRC) 30000 et seq.
[4] CA PRC 30500-30526.
[5] CA PRC 30605.
[6] These approximate 23 acres were excluded from the coastal zone by Coastal Act section 30162(b).
[7] CA PRC 30605-30606.
[8] California Coastal Commission, Sea Level Rise Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits (2018).

Figure 2.1. UC Santa Barbara campus and the coastal zone.

In 2015, the Coastal Commission adopted interpretive guidelines for addressing sea level rise.[9] The guidelines recognize that sea level rise will exacerbate coastal hazards, like cliff erosion and flooding, that are directly addressed by the Coastal Act. The guidance then elaborates on the steps necessary to update local plans for anticipated sea level rise, including through vulnerability assessments of the built and natural environment and the development of adaptation strategies, including relevant planning and policy updates, to adapt to projected sea level rise while continuing to address the requirements of the Coastal Act. The guidance identifies multiple approaches for updating local plans such as the UCSB LRDP. The Coastal Commission has been working with local governments to update LCPs to address sea level rise, including through a local assistance grant program, since 2013. In 2021, the Coastal Act was amended to explicitly direct the Commission to address sea level rise.[10] Finally, in 2016, the Coastal Act was amended to give the Commission new authority to specifically consider environmental justice. In 2019, the Coastal Commission adopted an environmental justice policy to address social equity in the coastal zone, including to recognize that climate change "will have disproportionate impacts on communities with the least capacity to adapt," and underscoring its longstanding mandate to protect California's coast for all Californians.[11]

[9] Id.
[10] Among other things, SB 1 added another legislative goal to "[a]nticipate, assess, plan for, and, to the extent feasible, avoid, minimize, and mitigate the adverse environmental and economic effects of sea level rise within the coastal zone"(Coastal Act 30001.5(f)).
[11] California Coastal Commission, Environmental Justice Policy, 2019, p. 11.

2.2 The UCSB Long Range Development Plan (LRDP)

As detailed in Section B of the adopted UCSB LRDP, UCSB has conducted planning for the campus on an on-going basis since 1945. The 1980 LRDP was the first Master Plan approved by the Coastal Commission as an LRDP pursuant to the Coastal Act of 1976. Since then, both the 1990 and 2010 LRDPs were adopted; the 1990 LRDP was amended 23 times and the 2010 LRDP, which was certified by the Coastal Commission in 2014, has been amended 4 times. Among other things the 2010 LRDP was updated to include policies to address climate change and its effects, such as global sea level rise. As described in the 2010 LRDP:

> *Given the evolving nature of climate change science as well as the site-specific considerations, the policies below rely heavily on research, best available science, vulnerability studies, coastal hazards assessments, and the incorporation of feedback loops and adaptation measures. The campus currently has three areas where shoreline devices protect existing facilities. Large rocks or revetment at the base of the bluff protect the east bluffs from erosion and extend to the south to protect the seawater pump station, the Marine Sciences Laboratory, and the Campus Lagoon. Berms have been constructed on the east and west ends of the Lagoon to prevent the lagoon from draining into the ocean. While some maintenance is necessary to protect the berm between the lagoon and the beach, no other protective devices are anticipated in the LRDP.*

LRDP Policy SH-01 is the origin of this sea level rise adaptation strategy for the campus. It was included in the 2010 LRDP to direct additional shoreline adaptation planning necessary to address coastal hazards exacerbated by global sea level rise. It states:

Policy SH-01 - Within five years of certification of the 2010 LRDP, the University shall prepare a Comprehensive Sea Level Rise Hazards Assessment for submittal to the Coastal Commission as an Amendment to the LRDP that addresses the anticipated impacts of sea level rise on the campus along the Goleta Slough and Pacific Ocean shoreline. The Plan shall be available prior to submitting a NOID for development or redevelopment that is located along the north boundary of the Storke Campus or at the Facilities Management site. The Plan shall:

A. *Identify the most vulnerable areas, structures, facilities, and resources; specifically areas with priority uses such as beaches, public access and recreation resources, ESHA and wetlands, wetland restoration areas, open space areas where future wetland or habitat migration would be possible, and existing and planned sites for critical infrastructure.*
B. *Include a detailed sea level rise vulnerability and risk assessment, either as an independent effort, or in conjunction with other assessments, such as the Goleta Slough multi-jurisdictional planning effort, that includes a specific analysis of the vulnerable areas and coastal resources in subsection "a'' above. The vulnerability and risk assessment shall use best available science and multiple scenarios including best available scientific projections of*

expected sea level rise, such as by the Ocean Protection Council [e.g., 2013 OPC Guidance on Sea Level Rise], National Research Council, Intergovernmental Panel on Climate Change, and the West Coast Governors Alliance.

C. *Based on the vulnerability analysis, identify campus areas that are potentially subject to the effects of sea level rise for the purpose of determining whether a detailed site-specific coastal hazards analysis will be required consistent with Policy SH-02 and Policy SH-04.*

D. *Recommend adaptation management strategies that would minimize risks to coastal resources and development due to hazards associated with sea level rise. Adaptation management strategies may include:*
- *Relocating existing development to safer locations*
- *Siting new development to avoid areas vulnerable to flooding, inundation and erosion;*
- *Modifying land use designations and individual campus uses, and developing siting and design standards for new development, to avoid and minimize risks;*
- *Establishing conservation areas to allow wetland and habitat migration;*
- *Creating an adaptive public access plan that maximizes access to and along the shore as the effects of sea level rise are realized.*

E. *Analyze sea-level rise impacts at both the site-specific and regional scales. The Plan must evaluate how sea-level rise impacts from the littoral cell or watershed (such as expected changes in sediment supply, increases or reductions in stream flows, post-fire sediment pulses, etc.) could affect the campus. Additionally, the Plan must evaluate how options to adapt to sea-level rise could result in cumulative impacts to other areas in the littoral cell or watershed, and should recommend actions to minimize any impacts.*

F. *The Assessment shall identify the recommendations that will require processing through an LRDP Amendment to be effectuated.*

2.3 Other Mandates/Policies

In addition to meeting the requirements of the Coastal Act, this Sea Level Rise Adaptation Strategy addresses other California and UC objectives related to climate change and sustainability. UCSB has a comprehensive campus sustainability program focused on achieving sustainability in multiple and cross-cutting sectors, including the built environment, water, climate, transportation, food and waste management.[12] Going forward, it will be important to integrate the LRDP shoreline policy objectives and anticipated actions into the campus sustainability plan. For example, the long-term sustainability of the built environment, including the location, scale and design of new and existing buildings, may be directly impacted by shoreline change, especially along

[12] See https://sustainability.ucsb.edu/sites/default/files/2017-Sustainability-Brochure.pdf.

Lagoon Road (see discussion in Chapter 4). Understanding the "risk footprint" of new and existing buildings is an important part of achieving higher LEED ratings for the campus, which is already an important component of the UCSB LRDP and its implementation.[13] This plan updates the UCSB LRDP with a shoreline adaptation vision and corresponding policies that will support both appropriate "low-risk" new development, and the reduction of hazard risks to existing development over time.

In addition to addressing sustainability, this plan also addresses other LRDP policies that currently require the University to continue participating in SLR research and coordination with other entities in the region to support SLR adaptation. As detailed below, this is particularly important for effective adaptation to regional shoreline and sand supply dynamics. Coordination with other entities is also important with respect to potential actions related to redevelopment or adaptation along the Goleta Beach/Slough area and adjacent to the City of Goleta's built environment.

As discussed in detail in the Chapter 4 vulnerability assessment, the Main Campus is where the most vulnerable "built" environment is located, primarily along Lagoon Road, which has already been confronting increased risks from beach and cliff erosion. Much of the slough side of the Main Campus does not present significant flooding hazards due to the elevation of the campus terrace above Goleta Slough. However, further inland along this edge, towards the Facilities Management buildings, potential flooding is and will become an increasing concern with higher projected sea levels over longer time periods. The lagoon and Depressions Beach area of the Main Campus, as well as the West and North Campus's ocean shorelines present lower risks to built environments, though there are significant natural resources of concern, particularly at the Coal Oil Point Reserve. Devereux Slough also is a more natural area, and its recent expansion and on-going restoration present opportunities to adapt to rising seas more naturally than do areas with significant shoreline development.

[13] See, for example, https://www.usgbc.org/articles/introducing-riskfootprint-enhancing-resilience-through-climate-risk-analysis.

3.0 Sea Level Rise Science

3.1 Overview

This adaptation strategy addresses shoreline vulnerabilities at UCSB using the best available science about climate change and projected sea level rise. This chapter discusses sea level rise science at the global, state and regional/local scales, as well as general considerations for understanding regional shoreline dynamics and for modeling of coastal changes of concern to UCSB.

3.2 Global Sea Level Rise Science

Sea level rise science has been steadily improving over the last several decades. Each iteration of the Intergovernmental Panel on Climate Change (IPCC) synthesis work has brought a more comprehensive and sophisticated understanding of the drivers of climate change and projected sea level rise. Most recently, the IPCC's Sixth Assessment Report clearly describes the necessity for sea level rise adaptation planning by explaining how significant amounts of sea level rise are now projected to occur regardless of future greenhouse gas emissions. The IPCC explains how the rise in global surface temperature is unprecedented, with the last 150 years being the "warmest multi-century period in more than 100,000 years" (Figure 3.1).

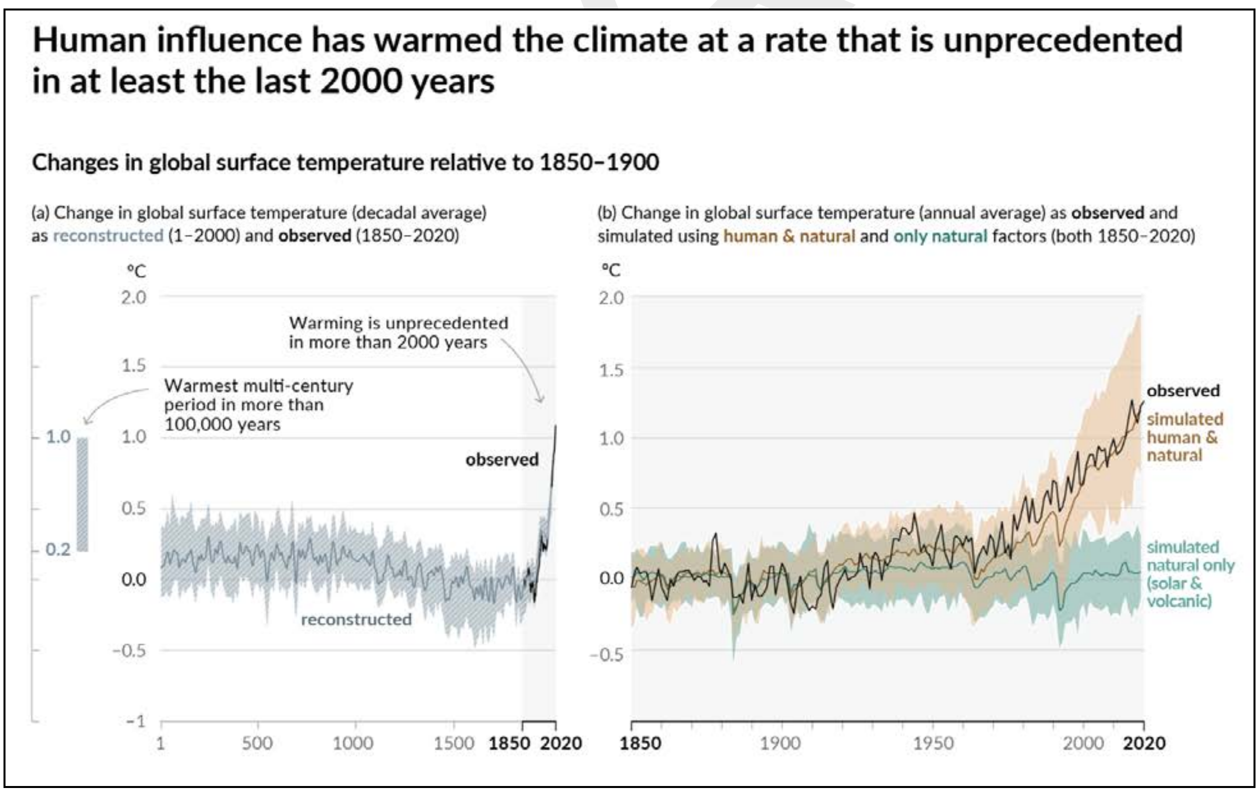


Figure 3.1. Changes in global surface temperature relative to 1850-1900.[14]

[14] FIgure SPM. 1, IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel

The Sixth Assessment Report provides an updated projection of sea level rise based on various potential emission pathways that show sea level rise between a half-meter to over a meter by 2100). These global averages express the potential magnitude of sea level rise, but projections do vary by region. Hence, the California projections, discussed below, are more directly relevant to this plan. The IPCC report also presents a "low-likelihood, high-impact" projection that assumes catastrophic ice sheet instability leading to perhaps 1.75 meters (5.7 feet) of sea level rise by 2100. Even though the IPCC describes a certain amount of unavoidable sea level rise, the potential range of outcomes indicates that there is much that people can do to mitigate the adverse effects of climate change. Still, there is significant uncertainty in projected future sea levels, and this uncertainty increases over longer time horizons – an important overarching reality informing this shoreline adaptation plan.

To address the fundamental uncertainty in future sea levels, this plan proposes distinct adaptation "pathways" driven by monitoring of environmental conditions, phased research, and specific adaptive actions in anticipation of, and in response to, evolving future conditions. In this way the plan seeks to identify the right planning and adaptation actions for the right times of UCSB's future campus conditions. Effective, regular monitoring of shoreline conditions and change will be important in this regard, including to anticipate the events that may follow from the unlikely, but scientifically plausible, extreme ice-melt scenarios in coming decades.[15]

3.3 California Sea Level Rise Science

UCSB's certified LRDP provides direction on best available SLR science to address state concerns. Policy SH-04, which has standards for site-specific hazards assessments of development, states that such studies:

> *. . . shall use the best available science and consider multiple SLR scenarios including best available scientific projections of SLR such as by the Ocean Protection Council, National Research Council, Intergovernmental Panel on Climate Change, and the West Coast Governors Alliance.*[16]

The state of California, through the Ocean Protection Council (OPC), has developed sea level rise guidance and projections for the entire California coastline.[17] This

on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001, p. 6.

[15] The scientific understanding of ice-melt dynamics is evolving quickly. Most recently, scientific studies raise the possibility of more rapid melting of land ice in both the Arctic and Antarctica beginning within decades. https://cires.colorado.edu/news/threat-thwaites-retreat-antarctica%E2%80%99s-riskiest-glacier; DeConto, R.M., Pollard, D., Alley, R.B. et al. The Paris Climate Agreement and future sea-level rise from Antarctica. Nature 593, 83–89 (2021). https://doi.org/10.1038/s41586-021-03427-0.

[16] UCSB LRDP Policy SH-04.

[17] California Natural Resources Agency, Ocean Protection Council, *State of California Sea-Level Rise Guidance 2018 Update* (2018), https://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf.

guidance recognizes the uncertainty in future sea level rise conditions depending on the global community's collective GHG emission pathways. In addition, it recognizes an important evolution in sea level rise science that regional sea level rise projections will vary depending on large scale geophysical forces such as gravitational dynamics and tectonic movements, as well as sub-regional physical conditions, such as ocean current patterns and the presence of subsidence or local uplift. The best California example of this is the observation that the highest and lowest projected sea level rise rates are found next to each other in Humboldt County.[18]

To provide more meaningful regional guidance, the OPC sea level rise projections are based on observations from tide gauges up and down the California coast. There is a tide gauge at the Santa Barbara harbor approximately 9 miles east of UCSB that OPC uses to develop SLR projections useful for UCSB planning.[19] As reported by NOAA, this gauge shows that the relative sea level trend in the region, looking back at monthly mean sea level data from 1973 to 2020, is 1.08 millimeters/year (.04 inches).

Building on regional tide gauge data, the OPC guidance presents sea level rise projections based on their *probability* of occurring under high and low emissions scenarios. For example, the guidance projects that for Santa Barbara in 2050, assuming a high global GHG emission scenario, there is a "likely" or 66% probability of sea level rise of between 0.4 and 1 foot, a 5% probability of the rise being 1.2 feet or more, and only half a percent probability of it being 1.8 feet or higher. The guidance also presents an "H++" scenario that assumes more catastrophic levels of global ice melt, though it does not assign a probability to this potential outcome (Figure 3.2). Figure 3.5 plots the probability curves for projected sea level rise based on the OPC guidance and the Santa Barbara tide gauge.

Since its 2018 guidance, the OPC has led a multi-agency process to coordinate state-level assessment and adaptation to sea level rise. One of the products of this process is a 2020 statement of "principles for aligned state action" concerning coastal resilience and sea level rise. Citing higher statewide projections of 1 foot of sea level rise by 2030 and 7.6 feet by 2100, the principles include the following about sea level rise science and projections:

> *1. Develop and Utilize Best Available Science*
>
> *• Apply best available science to planning, decision-making, project design, and implementation. Prioritize frequent engagement with stakeholders to ensure the science is actionable.*
>
> *• Utilize SLR targets based on the best available science and a minimum of 3.5 feet of SLR by 2050. Develop and utilize more protective baseline 2050 and*

[18] See, *Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping* (Northern Hydrology and Engineering 2015).
[19] NOAA, Tides and Currents, Santa Barbara, CA, Station ID: 9411340, https://tidesandcurrents.noaa.gov/stationhome.html?id=9411340.

2100 targets for road, rail, port, power plants, water and waste systems, and other critical infrastructure.[20]

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)						H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE			1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...			5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
					Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.3	0.2	-	0.4	0.5	0.7	1.0
	2040	0.5	0.3	-	0.7	0.8	1.1	1.6
	2050	0.7	0.4	-	1.0	1.2	1.8	2.5
Low emissions	2060	0.7	0.4	-	1.0	1.4	2.2	
High emissions	2060	0.9	0.6	-	1.3	1.6	2.5	3.6
Low emissions	2070	0.9	0.5	-	1.3	1.7	2.8	
High emissions	2070	1.1	0.7	-	1.7	2.1	3.3	4.9
Low emissions	2080	1.0	0.5	-	1.5	2.0	3.6	
High emissions	2080	1.4	0.9	-	2.1	2.7	4.3	6.3
Low emissions	2090	1.1	0.6	-	1.8	2.4	4.4	
High emissions	2090	1.7	1.1	-	2.6	3.3	5.3	7.9
Low emissions	2100	1.2	0.6	-	2.0	2.9	5.3	
High emissions	2100	2.1	1.2	-	3.1	4.1	6.6	9.8
Low emissions	2110*	1.3	0.7	-	2.1	3.0	5.9	
High emissions	2110*	2.2	1.4	-	3.2	4.2	6.9	11.5
Low emissions	2120	1.4	0.7	-	2.4	3.5	7.0	
High emissions	2120	2.5	1.7	-	3.7	4.9	8.2	13.7
Low emissions	2130	1.5	0.8	-	2.6	3.9	8.0	
High emissions	2130	2.9	1.8	-	4.2	5.6	9.5	16.0
Low emissions	2140	1.6	0.8	-	2.9	4.4	9.1	
High emissions	2140	3.1	2.0	-	4.8	6.4	11.0	18.6
Low emissions	2150	1.8	0.7	-	3.2	5.0	10.5	
High emissions	2150	3.5	2.2	-	5.3	7.2	12.6	21.4

Figure 3.2. California OPC SLR projections (feet) for Santa Barbara (Table 22).[21]

[20]OPC, Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action (2020), https://www.opc.ca.gov/webmaster/_media_library/2021/01/State-SLR-Principles-Doc_Oct2020.pdf.
[21] California Ocean Protection Council, Making California's Coast Resilient to Sea Level Rise: Principles for Aligned State Action (2020).
https://www.opc.ca.gov/webmaster/_media_library/2021/01/State-SLR-Principles-Doc_Oct2020.pdf.
OPC notes:

> *Projected Sea-Level Rise (in feet) for Santa Barbara Probabilistic projections for the height of sea-level rise shown below, along with the H++ scenario (depicted in blue in the far right column), as seen in the Rising Seas Report. The H++ projection is a single scenario and does not have an associated likelihood of occurrence as do the probabilistic projections. Probabilistic projections are with respect to a baseline of the year 2000, or more specifically the average relative sea level over 1991 - 2009. High emissions represents RCP 8.5; low emissions represents RCP 2.6.* ***Recommended projections for use in low, medium-high and extreme risk aversion decisions are outlined in blue boxes*** *below.* [emphasis added]

And,

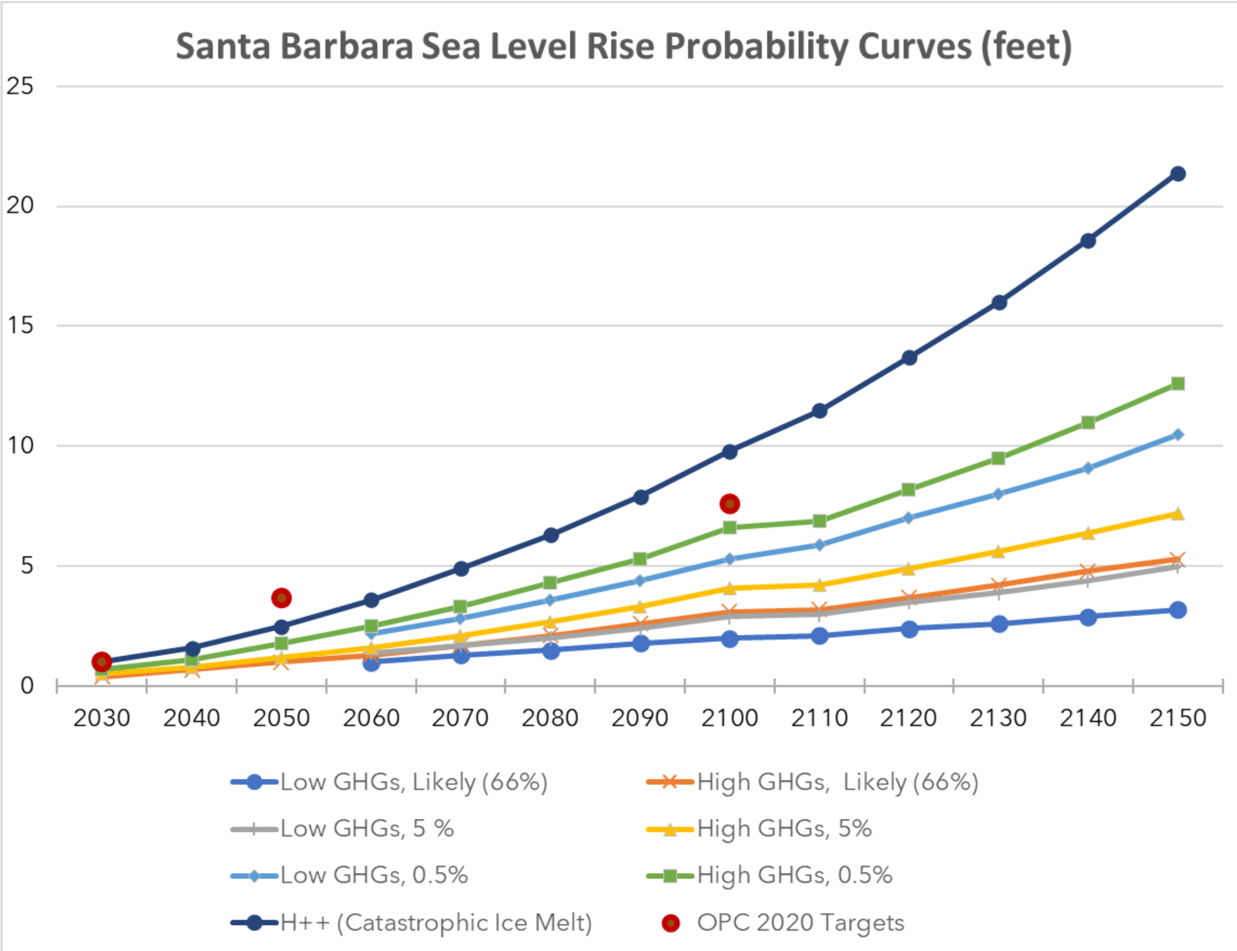


Figure 3.3. OPC probability curves for projected sea level rise.

This latest OPC guidance assumes a much higher level of sea level rise for 2050 than does the 2018 OPC guidance (3.7 feet versus 1 foot of sea level rise as "likely" by 2050 – see Figure 3.3). Under the 2018 guidance, sea levels 3.7 feet or higher than today might occur under the H++ scenario, but not until about 2060.

Recent national-level sea level rise projections help to reconcile the differences in OPC's range of sea level projections. In 2022, the Inter-agency Working Group on Sea Level Rise and Coastal Flood Hazard Scenarios and Tools (IWG-SLR) produced updated sea level rise modeling and projections for each of the regions of the United States by decade, out to the year 2150. The projections are made for every tide gauge in the United States, as well as regionally for every square degree. They account for regional vertical land motion and are based on direct inputs from the latest IPCC projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6).[22]

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

[22] Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks,

Several key observations helpful for this adaptation strategy are made in the new IWG-SLR projections. First, the range of uncertainty is narrowed for the year 2050, irrespective of emissions scenario, based on both model projections and observation-based projections. The rise will also be significant relative to past experience. The report notes:

> *Relative sea level along the contiguous U.S. (CONUS) coastline is expected to rise on average as much over the next 30 years (0.25–0.30 m over 2020–2050) as it has over the last 100 years (1920–2020).*[23]

Second, the report directs attention to the projected changes in coastal flooding – one of the primary shorter-term concerns with global sea level rise:

> *By 2050, the expected relative sea level (RSL) will cause tide and storm surge heights to increase and will lead to a shift in U.S. coastal flood regimes, with major and moderate high tide flood events occurring as frequently as moderate and minor high tide flood events occur today. Without additional risk-reduction measures, U.S. coastal infrastructure, communities, and ecosystems will face significant consequences.*[24]

As discussed in Chapter 4, UCSB has multiple shoreline locations where flooding and erosion events are the primary near-term vulnerability.

Third, the report confirms that the probability of higher sea levels changes significantly with higher emission and temperature scenarios. For example, the probability of exceeding 1 meter (3.3. feet) of sea level rise globally, or about 1.2 meter (3.9 feet) in the U.S., by 2100 goes from less than 5% with 3 degrees of warming celsius, to nearly 25% with 5 degrees C of warming. On the other hand, based on "improved understanding of the timing of possible large future contributions from ice-sheet loss," the report concludes that the most extreme scenario (i.e., similar to OPC's H++) is "less plausible." Hence, it is removed from the projections.[25]

Finally, the report emphasizes the importance of on-going monitoring of large-scale sea level rise forcing mechanisms, especially in the longer-term, in order to potentially trigger adaptive management actions:

M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak, 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf.

[23] *Id.* p. xii.

[24] *Id.* p. 60.

[25] Note 23, *Id.* p. xiii. The report does still recognize that the potential for increased acceleration in the late 21st century and beyond means that the other high-end scenarios could occur in the "the decades immediately following 2100."

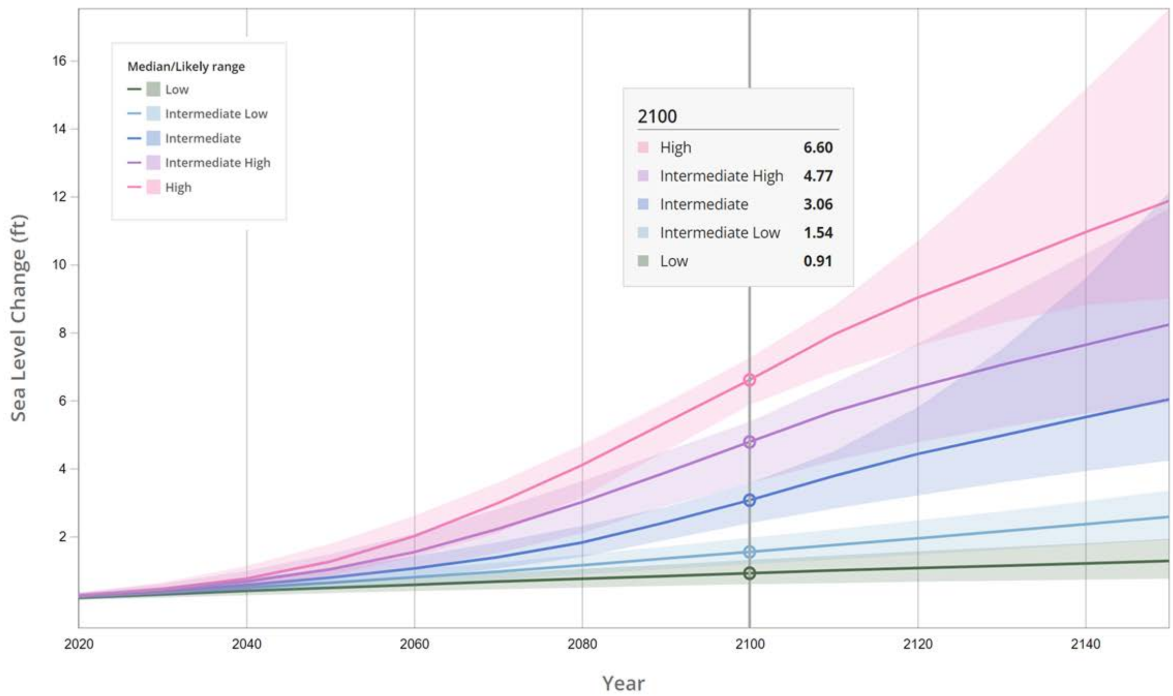
> *Early indicators of changes in sea level rise trajectories can serve to trigger adaptive management plans and are identified through continuous monitoring and assessment of changes in sea level (on global and local scales) and of the key drivers of sea level change that most affect U.S. coastlines, such as ocean heat content, ice-mass loss from Greenland and Antarctica, vertical land motion, and* [on the east coast] *Gulf Stream system changes.*[26]

For this strategy, it is useful to draw on the report's more specific sub-regional projections. Figure 3.4 shows sea level rise projections for the 1x1 degree cell that includes the UCSB shoreline (Latitude 34, Longitude -120). SLR projections range from 0.48 to 1.25 feet in 2050, to 0.91 to 6.6 feet by 2100. By comparison, these projections are similar to OPC's 2018 projections, but do not provide an equivalent H++ scenario by 2100, as the probability is very low (<1%) based on the latest science. The current OPC target of 3.7 (1.13 meters) feet by 2050 also would not occur until sometime between 2080 and 2090, in the worst case high emissions scenario.

The California Ocean Science Trust has recently convened a new SLR task force to begin updating the OPC SLR.[27] It will be important for UCSB to follow the latest scientific updates, and make any strategy updates that may be required. But for purposes of the adaptation pathway planning approach of this strategy, the current OPC projections, particularly as they are essentially affirmed by the recent inter-agency federal work, are sufficient. In particular, with the pathway approach, which relies on regular monitoring of existing conditions, including actual sea level rise, the federal report's projections point to using a projection of sea level rise up to about 2 meters by 2100 as a reasonable higher-end projection.[28] This is because even in the unlikely event of higher sea level rise unfolding more quickly, implementing systematic monitoring tied to triggers for specific actions, as is proposed by this strategy, should be sufficient for generally assessing and adapting to the potential impacts of lower and higher possible sea level rise on the campus's built, natural and social shoreline environments. This approach will enable UCSB to stay on an adaptation pathway that achieves its vision of maximizing natural shorelines and incrementally moving campus shoreline development and activities away from hazardous shoreline erosion and flood zones as necessary. The approach is pragmatic and based on the best available science. At the same time, this "adaptation pathway" approach deemphasizes the need for more precise sea level rise projections, either physically or temporally, by grounding future

[26] *Id*. p. xiv.
[27] https://www.oceansciencetrust.org/projects/slr-update2023/.
[28] For guidance on using the NOAA projections, see Collini, R.C., J. Carter, L. Auermuller, L. Engeman, K. Hintzen, J. Gambill, R.E. Johnson, I. Miller, C. Schafer, and H. Stiller. 2022. Application Guide for the 2022 Sea Level Rise Technical Report. National Oceanic and Atmospheric Administration Office for Coastal Management, Mississippi–Alabama Sea Grant Consortium (MASGP-22-028), and Florida Sea Grant (SGEB 88). https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt02-global-regional-SLR-scenarios-US-application-guide.pdf.

adaptation actions in observed physical changes or events, such as actual cliff recession, beach erosion or flooding.[29]



	Low	Intermediate Low	Intermediate	Intermediate High	High
Total (2030)	0.29	0.35	0.38	0.42	0.45
Total (2040)	0.39	0.49	0.56	0.67	0.75
Total (2050)	0.48	0.64	0.78	1.03	1.25
Total (2060)	0.57	0.79	1.05	1.53	2.00
Total (2070)	0.67	0.96	1.38	2.21	2.98
Total (2080)	0.75	1.15	1.81	3.00	4.09
Total (2090)	0.83	1.35	2.41	3.87	5.34
Total (2100)	0.91	1.54	3.06	4.77	6.60
Total (2150)	1.27	2.57	6.03	8.23	11.87

Figure 3.4. Inter-agency Working Group sea level rise scenarios (feet) (Latitude 34, Longitude -120).[30]

[29] For example, Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., and A. Hurlimann, 2014. "A local coastal adaptation pathway." Nature Climate Change, 4(12), 1103; CoastAdapt, 2020, https://coastadapt.com.au/pathways-approach.

[30] Inter-agency Working Group on Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Projections (California) (2022), https://sealevel.nasa.gov/task-force-scenario-tool/.

3.4 Regional Shoreline Dynamics and Sea Level Rise

Effective shoreline planning and adaptation to sea level rise also requires an understanding of regional shoreline dynamics, particularly those related to the movement of sand. Sandy beaches, for example, are dynamic systems, strongly affected by wave action and sand supply. Sandy beaches are vulnerable to sea level rise, particularly where inland beach migration is impeded by a less erodible backshore, such as cliffs, or coastal development, such as seawalls and revetments.

In California, geologists have identified at least 15 littoral cells that aid in understanding the dynamics of sand flow along the coast (Figure 3.5). A littoral cell is a segment of the coast with ". . . distinct sediment sources, defined longshore transport pathways, and sinks where the sediment is removed from the littoral system."[31] Along the California coast, sand typically moves down coast, into and out of discrete littoral cells. The boundaries of the cells are generally determined by geographic features such as major promontories and submarine canyons. Natural sand sources within these littoral cells include the rivers and streams in the connected coastal watersheds, and eroding coastal bluffs. These sources provide sand to and along the shoreline. Sand sinks are coastal features such as dunes, where sand is stored onshore, and submarine canyons where sand is lost from the littoral shoreline system by flowing offshore into the deep ocean. Longshore transport or littoral drift is the wave-driven current that moves sand along the shoreline and from sources and sinks.

Changes in beach height, width and slope are affected by the rate of sea level rise and the sediment budgets of the shoreline. With sufficient sediment supply and/or retention of this sediment, beaches could possibly maintain, for some time at least, adequate widths and elevations to act as buffers to sea level rise and storm events, thereby mitigating shoreline and bluff retreat while supporting continued recreational, aesthetic and ecological values and functions. This is an area of on-going scientific study and monitoring of beach replenishment and other shoreline management actions, as well as active policy debate.[32] In addition, the current USGS modeling showing potentially significant loss of southern California beaches by 2100 due to sea level rise also suggests that beach replenishment will only delay this ultimate loss.[33] The primary issues threatening Southern California beaches in the coming decades are the lack of migration space for beaches to move inland under the pressures of rising seas, due to coastal development and resistant cliffs in many locations, and limited/diminishing natural sand supplies. Still, despite questions about the efficacy

[31] USGS, National Assessment of Shoreline Change Part 3: Historical Shoreline Change and Associated Coastal Land Loss Along Sandy Shorelines of the California Coast, Open-File Report 2006-1219, p. 22.
[32] See, e.g., Griggs, G., Patsch, K., Lester, C., and R. Anderson, 2020. "Groins, sand retention, and the future of Southern California beaches." Shore & Beach 88(2), 14-36.
[33] Vitousek, S., Barnard, P.L., Limber, P., Erikson, L. and B. Cole, 2017. "A model integrating long-shore and cross-shore processes for predicting long-term shoreline response to climate change." J. Geophys. Res. Earth Surf., 122, 782–806. https://doi:10.1002/2016JF004065.

and other aspects of beach replenishment, regional sand management is an important component to consider when developing adaptation strategies, including in this plan.

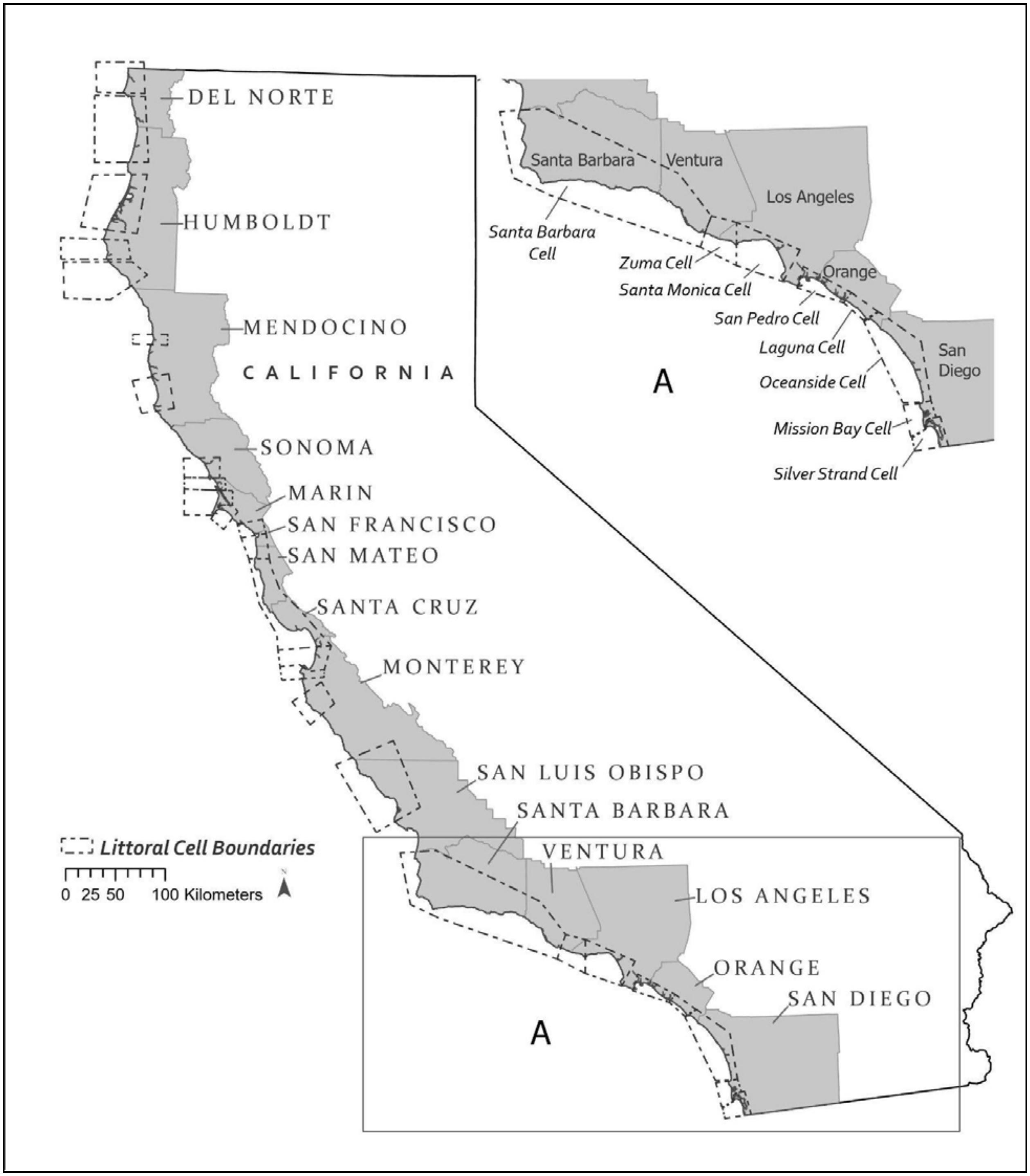


Figure 3.5. California's major littoral cells.[34]

[34] Provided by Dr. Kiki Patsch, Env. Science and Resource Management, California State University Channel Islands; also, Patsch, K. B., & Griggs, G. B (2021). Shore & Beach Vol. 89, No. 3 Summer.

Concerning the UCSB region, as shown in Figure 3.6, beaches in the Santa Barbara area and the UCSB shoreline are part of a littoral cell of longshore transport that begins at the Santa Maria River and ends at the Hueneme and Mugu submarine canyons in Ventura County.[35] The beaches near Point Conception are east-west trending, narrow, and backed by high sea cliffs. Between Ventura and Point Hueneme, beaches are wide and trend southeast. Large quantities of sand, estimated to average 300,000 cubic yards/year, move eastward along the coast via wave-driven longshore transport.[36] Some sediment from the Santa Maria River and Santa Ynez River may leak around Point Conception, nourishing the downcoast littoral cell.[37] The Santa Ynez River historically supplied most of the sand that reached Santa Barbara area beaches; Bradbury Dam, built in 1953, considerably reduced the supply. Small coastal streams provide only minor amounts of sand (Table 1). Other major rivers that supply sediment to the cell are the Ventura River, Santa Clara River, and Calleguas Creek, draining a watershed of 5,237 sq km (2,022 sq mi). In addition, Hueneme and Mugu Submarine Canyons are active sediment sinks at the south end of the region.[38]

Santa Barbara Littoral Cell			
Inputs	Natural (yd3/yr)	Actual (yd3/yr)	Reduction (yd3/yr)
Rivers	3,643,000	2,167,000	1,476,000
	99.6%	99.5%	40.5%
Bluff/cliff erosion	14,500	10,500	4000
	0.4%	0.5%	19.4%
Total Littoral input	3,657,500	1,177,500	480,000
	100%	100%	40.4%
Reductions are due to the damming of rivers and the armoring of seacliffs. “Natural”sand yield refers to the estimated original volume of sand discharged by streams and contributed to the littoral budget through seacliff or bluff erosion. “Actual” sand yield refers to the estimated volume of sand reaching the coast under present day conditions taking into account reductions in sand supply from dams and seacliff armoring as well as additions to the budget from beach nourishment.			

Table 1. Sand sources and sinks in the Santa Barbara littoral cell[39]

[35]Patsch, K. B., & Griggs, G. B. (2008). Development of a Sediment Budget for the Santa Barbara Littoral Cell. Marine Geology, 252(1-2), 50-61.
[36] Kiki Patsch and Gary Griggs, Littoral Cells, Sand Budgets, and Beaches: Understanding California's Shoreline, California Department of Boating and Waterways California Coastal Sediment Management WorkGroup, October 2006.
[37] *Id.*, n.35.
[38] http://coastalchange.ucsd.edu/st3_basics/littoralcell.html.
[39]Adapted from Kiki Patsch, Gary Griggs, A sand budget for the Santa Barbara Littoral Cell, California, Marine Geology, Volume 252, Issues 1–2, 2008, Pages 50-61.

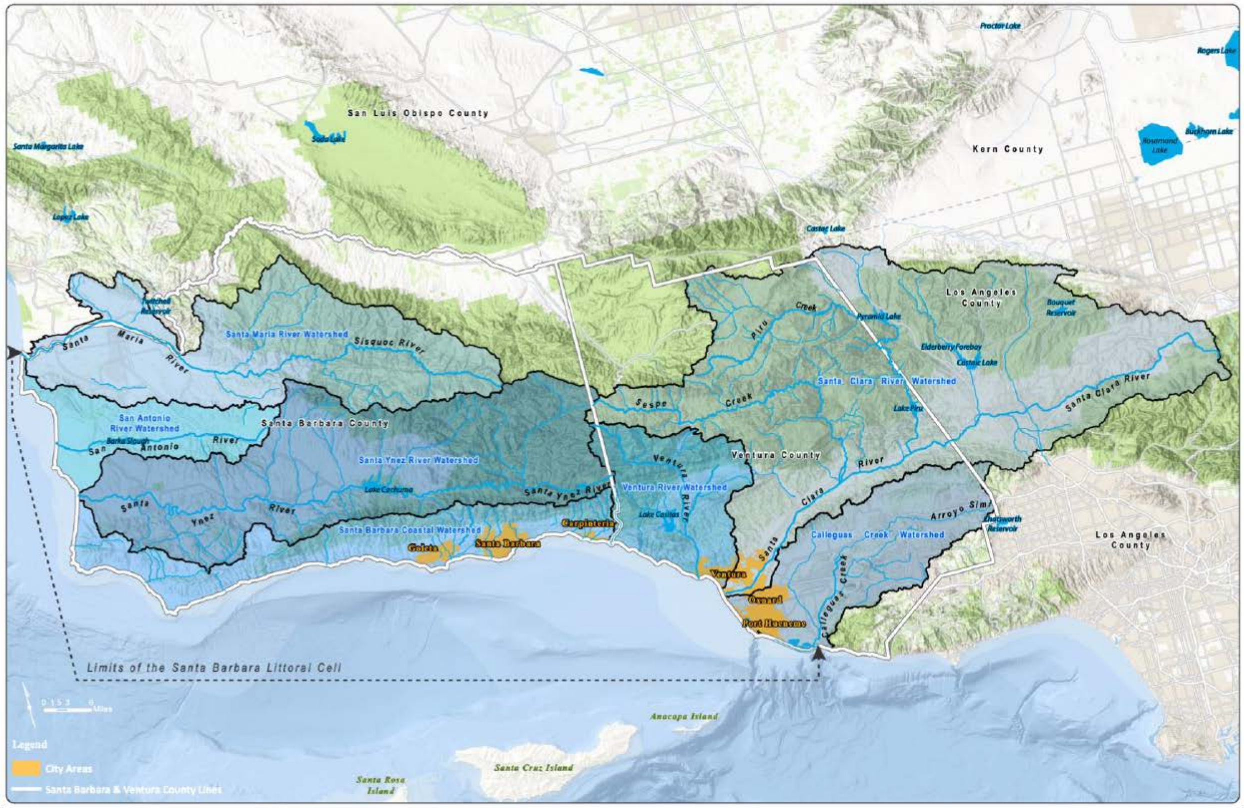


Figure 1. The BEACON "Coast"

Figure 3.6. The Santa Barbara littoral cell and watersheds[40]

UCSB is located approximately midway along the shoreline of the Santa Barbara littoral cell. The basic flows and dynamics of sand along this shoreline are determined by the inputs and outputs of sand to the littoral cell, including seven major coastal watersheds and the longshore sand movements. These sand movements will likely be an important factor in shaping alternatives for adapting to future sea level rise.

The Santa Barbara region is also fortunate to have a regional organization – the Beach Erosion Authority for Clean Oceans and Nourishment (BEACON) – addressing regional sand management. BEACON is a California Joint Powers Agency (JPA) established in 1986 to address coastal erosion, beach nourishment and clean oceans within the Central California Coast from Point Conception to Point Mugu. The member agencies of BEACON include the Santa Barbara and Ventura Counties and the coastal cities of Santa Barbara, Goleta, Carpinteria, Ventura, Oxnard and Port Hueneme. The BEACON Board has ten members – two supervisors from each county and one person from each city council. Among other things, BEACON has recently released a research agenda for the region, and is actively involved in the development and implementation of sand

[40] BEACON RESEARCH AGENDA, A Research Agenda for the Beach Erosion Authority for Clean Oceans and Nourishment (BEACON) Coast, December, 2021.

management strategies, including in relation to sea level rise.[41] The research agenda identifies multiple needs and activities that UCSB is already involved in or should engage with and that could benefit sea level rise adaptation along the campus shoreline in coming years. Related, it will be important for UCSB to coordinate with other jurisdictions, agencies and shoreline managers on activities and projects that may affect regional sand supply and other dynamics.

3.5 Sea Level Rise Data and Impact Modeling for the UCSB Shoreline

Drawing on the best available science, Chapter 4 will apply sea level rise projections of up to 2 meters in order to assess campus shoreline vulnerabilities. Various impacts that will be accelerated by sea level rise include flooding, beach and cliff erosion and rising groundwater. Understanding these impacts requires additional scientific assessment. For the most part, Chapter 4 relies on coastal hazard modeling developed by the U.S. Geological Survey through the Coastal Storm Modeling System (CoSMoS) for Southern California,[42] and excerpted presentations of this information from the Our Coast Our Future (OCOF) tool.[43] In some cases, this science is supplemented with more site-specific assessment, particularly concerning near-term vulnerabilities.

CoSMoS is a sophisticated scenario projection tool for understanding the potential impacts of sea level rise and storms. It provides projections for beach change, flooding, cliff erosion and groundwater elevations. It provides these projections for various sea level rise scenarios, including projected sea level rise ranging from 0 to 5.0 meters, as well as for various storm conditions, including the expected, daily, annual, 20-year and 100-year storm events.[44] That said, as with any model, uncertainty is associated with the data and modeling underlying the projections, which CoSMoS addresses by

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[41] Id.; also, BEACON Strategic Plan (2021), https://beacon.ca.gov/wp-content/uploads/2021/03/Final-BEACON-Strategic-Planning-Goals-2021-26.pdf.

[42] Barnard, P.L., Erikson, L.H., Foxgrover, A.C., Limber, P.W., O'Neill, A.C., and Vitousek, S., 2018, Coastal Storm Modeling System (CoSMoS) for Southern California, v3.0, Phase 2 (ver. 1g, May 2018): U.S. Geological Survey data release, https://doi.org/10.5066/F7T151Q4; also Barnard, P.L., Erikson, L.H., Foxgrover, A.C., Finzi Hart, J.A., Limber, P., O'Neill, A.C., van Ormondt, M., Vitousek, S., Wood, N., Hayden, M.K. and Jones, J.M., 2019. Dynamic flood modeling essential to assess the coastal impacts of climate change. Scientific Reports, Volume 9, Article #4309, 13 pp., http://dx.doi.org/10.1038/s41598-019-40742-z.

[43] https://ourcoastourfuture.org/.

[44] The overarching concept of CoSMoS is to utilize projections of global climate patterns over the 21st century from Global Climate Models (GCMs) developed for the 5th Assessment Report of the Intergovernmental Panel on Climate Change, coupled with process-based oceanographic and geomorphic models to produce flood and coastal change projections at management-relevant scales due to both SLR and storms. Coarse resolution GCM projections are dynamically downscaled to the local level and used as boundary conditions for several physics-based, numerical ocean models to predict local coastal waves, water levels, flooding, and erosion for the range of plausible SLR (10 scenarios: 0.00-2.00 m in 0.25 m increments, and 5.00 m) and storm scenarios (4 scenarios: average daily conditions [i.e. typical atmospheric conditions representative of average wind and sea level pressures] and annual, 20-year and 100-year storms) over the 21st Century. In the last year, a model to assess the influence of rising sea levels on coastal groundwater levels was also completed.

showing the potential range of hazard zones for each scenario. This uncertainty derives from various aspects of the data and modeling assumptions. There are also data gaps, such as the spaces in between the shoreline transects used for projections. This means that the model is not necessarily useful for a site-specific hazard assessment or to support engineering or design decisions, as opposed to a larger area-wide assessment of potential change or trends over time. The OCOF site has information and links to more detailed discussion of the model, assumptions and limitations.[45] Still, similar to the sea level rise projections themselves, the inherent uncertainty in the CoSMos model is not a limitation when coupled with an adaptation approach incorporating regular monitoring and triggers for action. What is important is understanding the general direction and potential magnitudes of change in environmental conditions over different time horizons.

3.5.1. Overview of Primary Shoreline Change Concerns at UCSB

The USCB Coastal Planning Science Advisory Board evaluated core shoreline change concerns, including flooding, beach and wetland change, and cliff erosion. This section summarizes certain scientific information useful for interpreting the vulnerability assessment of Chapter 4.

3.5.1.1. Sandy Beaches

Chapter 4 discusses the potential for significant impacts to the beaches along UCSB with sea level rise, depending on how the university adapts in specific locations. Beaches play a critical role in regulating the rate of bluff retreat by buffering the cliff base from wave action. Sandy beaches are dynamic ecosystems, strongly affected by wave action and sand supply, and are vulnerable to sea level rise, particularly where beach migration is constrained by coastal bluffs or infrastructure. Along the coast of the UCSB campus sandy beaches extend for approximately 1.5 miles, and most have bluffs (77%) or armoring (16%) with only a small portion backed by dunes. Beaches are iconic and economically valuable coastal assets for the campus with high levels of recreational and educational use. Sandy beaches absorb wave energy (thus the first line of defense during storms), recycle nutrients, and support a diverse biota including invertebrates that are important prey for shorebirds and fish.[46]

The dynamic boundary of the upper intertidal zone is located at the highest reach of the daily tides (Figure 3.7) and is associated with the accumulation of algal wrack and a diversity of associated crustaceans and insects.[47] The landward-most edge of the upper

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[45] https://ourcoastourfuture.org/science-and-modeling/; and https://ourcoastourfuture.org/wp-content/uploads/2021/07/CoSMoS3.0_FAQ_FINAL.pdf.

[46] Dugan, J. E., D. M. Hubbard, and M. McCrary, and M. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science 58S: 25-40.; Dugan, J. E. and D. M. Hubbard 2016. Sandy beach ecosystems. Chapter 20, Pages 389-408 in Ecosystems of California (eds. E. Zavaleta, H. Mooney) University of California Press.

[47] Dugan, J.E., D. M. Hubbard, H. M. Page, and J. Schimel. 2011. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts 34: 839-850., Dugan, J. E., D. M. Hubbard and

beach zone can support coastal strand vegetation during periods of accretion where the beach is wide.[48] During periods with sufficient sand supply and low wave energy, hummocks and dunes may build, enhancing shoreline habitat diversity and increasing the buffering of the cliff base from erosive wave action.

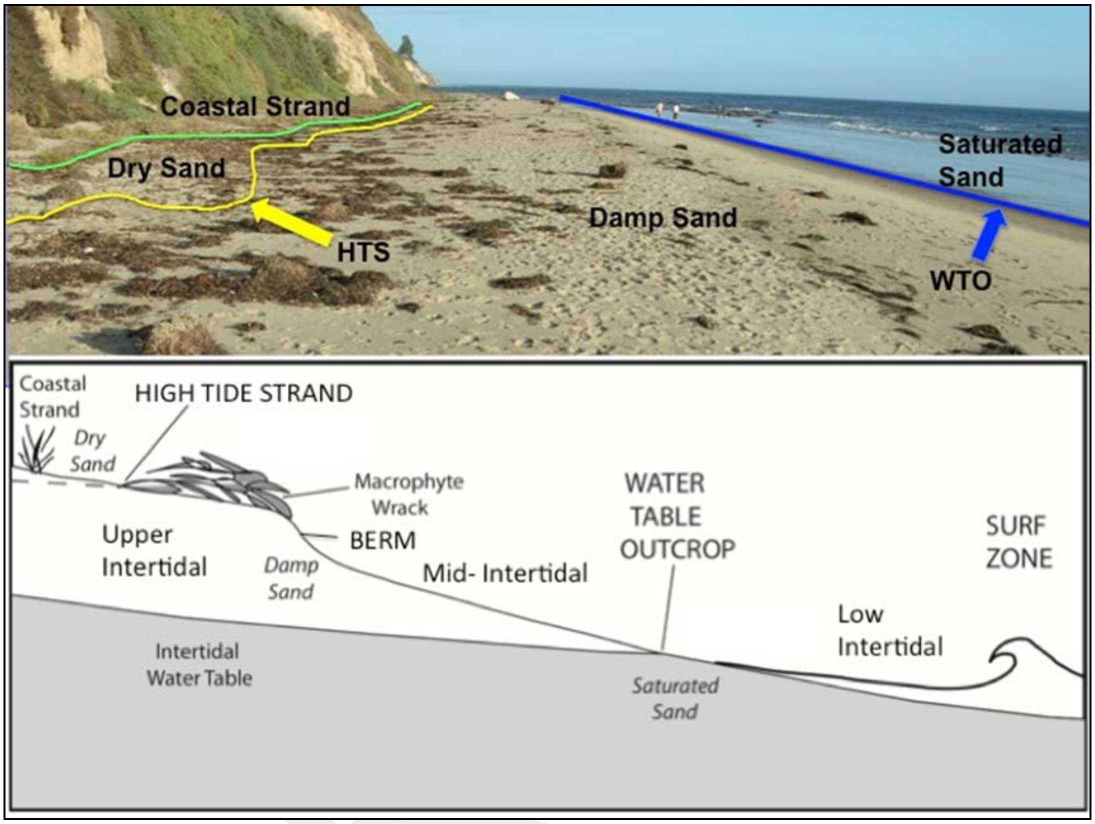

Figure 3.7. Illustration of the major beach zones and ecological features.[49]

The widths of sandy beaches are determined by a range of factors including sediment supply, waves, sea levels, and geologic and anthropogenic controls including the space available for the beach to migrate, termed accommodation space. The responses of beaches to sea level rise will depend on the potential for the shoreline to migrate and retreat.[50] Natural landward boundaries include coastal dune fields,

B. J. Quigley. 2013. Beyond beach width: Steps toward identifying and integrating ecological envelopes with geomorphic features and datums for sandy beach ecosystems. Geomorphology. 199:95-105. Myers, M. R., D.R. Cayan, S.F. Iacobellis, J.M. Melack, R.E. Beighley, P.L. Barnard, P. L., J.E. Dugan and H.M. Page. 2017. Santa Barbara Area Coastal Ecosystem Vulnerability Assessment. California Sea Grant report 17-009. 207.

[48] Dugan J. E., and D. M. Hubbard. 2010. Loss of coastal strand habitat in southern California: the role of beach grooming. Estuaries and Coasts 33:67-77.

[49] Dugan J. E. and D. M. Hubbard. 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach 74:10-16.

[50] Vitousek, S., P.L. Barnard, P. Limber, L. Erikson, and B. Cole 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. Journal of Geophysical Research: Earth.

floodplains, estuaries and lagoons, bluffs and cliffs. Landward boundaries where the coastline has been developed or urbanized include coastal armoring, such as seawalls, rock revetments, breakwaters, groins, jetties, and beach filling. Projected responses of sandy beaches to sea level rise developed for the Santa Barbara area, including the UCSB campus beaches, are strongly affected by the potential for the shoreline to retreat and availability of accommodation space determined by any landward barrier.[51]

Beaches backed by bluffs 3 to 30 meters high can be narrow at times but their width varies over time and with climatic regimes, such as ENSO and other events.[52] A wave-cut rock platform and/or offshore rocky habitat commonly underlies these beaches along the UCSB campus, adding another geologic control not considered in most models.[53] Rocky shelves or benches may be exposed in the winter months and covered with sand in the summer and autumn. Intertidal sand is suspended and moved offshore and alongshore by large winter swells and waves associated with storms, then it re-accretes on the intertidal platform as the swell regime shifts in the summer and fall months.

The extent of retreat for UCSB's bluff-backed beaches will be limited by the ability of the back beach boundary to erode in equilibrium with rising seas. Bluff-backed beaches in the region are projected to lose 85% of the upper beach zone with 50 cm of sea level rise using CoSMoS 3.0 model projections, *assuming a fixed back beach and no change in sediment supply*.[54] For East Campus, the 1 km of the UCSB sandy beach on Goleta Bay that has been modeled indicated approximately 40% of the dry upper beach zone would remain with 50 cm sea level rise, but the zone would be inundated on the west and east ends of the beach. With 100 cm of sea level rise, both the upper beach zone and damp sand zone are projected to disappear for this stretch of beach if the back bluff of the beach is unable to retreat.

Beaches backed by armoring or other structures are present on approximately 16% of the main UCSB campus beaches (Areas 3 and 4), particularly around Campus Point. Beaches with shoreline armoring that occupy upper beach zones are projected to lose approximately 99% of upper and mid-beach zones with 50 cm of sea level rise. Beaches backed by dunes and/or lagoons are limited on the main campus to approximately 7% of the beaches. Dune-backed beaches are projected to maintain more of their upper beach zones with higher levels of sea level than bluff-backed beaches, but dune areas would be lost to shoreline and beach retreat unless sufficient sand and space for dune recession remained.

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[51] (Myers et al. 2017, Id.
[52] Revell, D. L., and G. B. Griggs. 2006. Beach width and climate oscillations in Isla Vista, Santa Barbara, California. Shore & Beach 74:8-16. Revell et al. 2010, Id.; Barnard et al 2016, Id.
[53] Jackson, D. W. T. and Cooper, J.A.G. 2009. Geological control on beach form: accommodation space and contemporary dynamics. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), 69 - 72. Lisbon, Portugal.
Revell, D. L., J. E. Dugan and D. M. Hubbard. 2011. Physical and ecological responses of sandy beaches to the 1997-98 El Nino. Journal of Coastal Research 27:718-730.
[54] Myers et al. 2017, Id.

The responses of beaches to sea level rise are strongly affected by the sediment budget of the shoreline, regardless of the beach backing. As discussed earlier, with sufficient sediment supply and retention of sediment, even bluff-backed beaches could retain sufficient widths and elevations to provide buffers to sea level rise and storm events, at least for some time. According to some studies, beaches of the Santa Barbara coast, including those along the UCSB campus, exhibit considerable seasonal and interannual variations in profile and width rather than having long-term trends.[55] Episodic storms and ENSO events strongly influence the sediment supply to local beaches and their profile and condition.[56] The variation in sediment supply from upcoast sources to UCSB's beaches results in wide variation in intertidal widths, as illustrated by upper beach widths for 2009 - 2017 at the East Campus beach, adjacent to the Anacapa stairs and west Isla Vista beach (Figure 3.8). Wider beaches can coincide with the phasing of larger oceanographic cycles, such as La Niña periods and the cold phase of the multidecadal Pacific Decadal Oscillation (PDO) (Figure 3.9). During El Niño periods and the warm phase of the PDO, the UCSB campus beaches are narrower and waves and high tides reach the coastal bluffs more frequently.

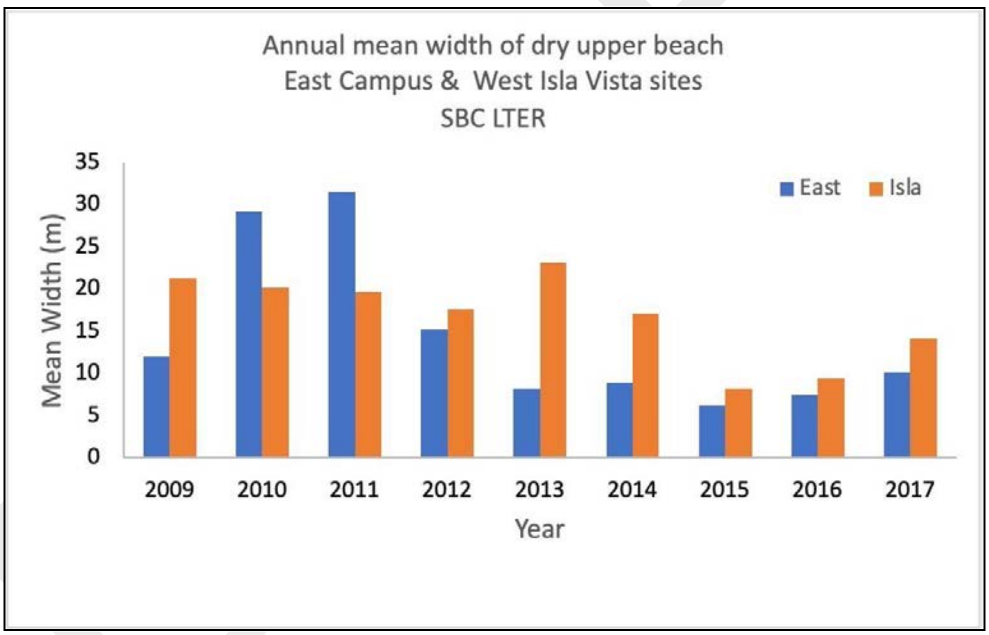

Figure 3.8. Mean widths of the dry upper beach zones of two campus beaches Blue bars = East Campus beach Orange bars = west Isla Vista beach.[57]

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55 Revell and Griggs 2006, Id., Revell et al. 2011, Id.

56 (Revell et al 2011, Barnard, P. L., Revell, D. L., Hoover, D., Warrick, J., Brocatus, J., Draut, A. E., Dartnell, P., Elias, E., N. Mustain, P. E. Hart, and H. F. Ryan. 2009. Coastal processes study of Santa Barbara and Ventura County, California. U.S. Geological Survey Open-File Report 2009–1029 <http://pubs.usgs.gov/of/2009/1029/>. Barnard, P. L., D. Hoover, D. M. Hubbard, A. Snyder, B. C. Ludka, J. Allan, G. M. Kaminsky, P. Ruggiero, T. W. Gallien, L. Gabel, D. McCandless, H. M. Weiner, N. Cohn, D. L. Anderson and K.A. Serafin. 2017. Extreme oceanographic forcing and coastal response due to the 2015–2016 El Nino. Nature Communications 8:14365.

57 Santa Barbara Coastal Long Term Ecological Research, UCSB.

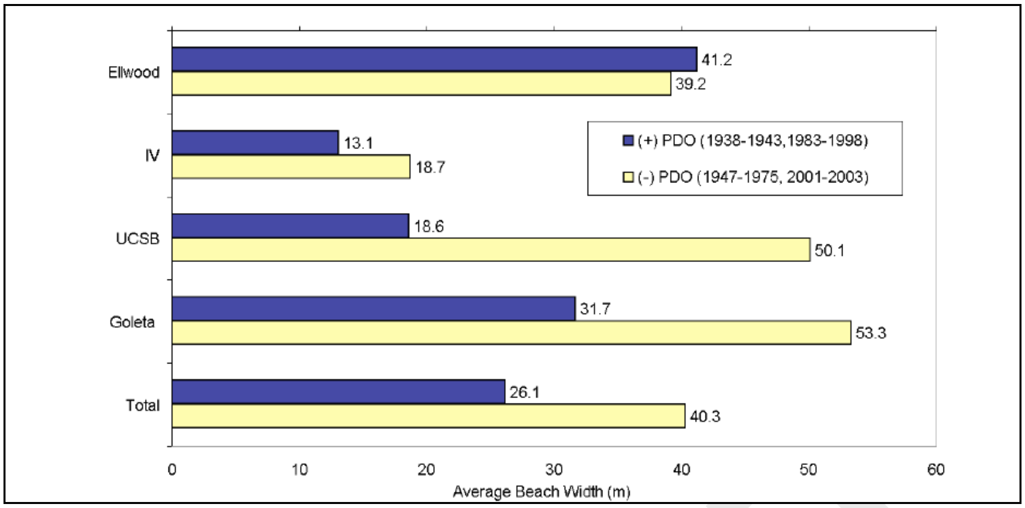

Figure 3.9. Average beach widths in PDO+(warm) and PDO-(cool) time periods for the Santa Barbara coast, including UCSB beaches, from analysis of aerial photos.[58]

Biodiversity and ecological function of beach ecosystems are greater in the cold phases of the PDO and ENSO cycles than during the warm phases. ENSO events can serve as proxies for impacts of higher sea levels and climate change for shorelines and are useful for projecting the ecological response of beach ecosystems.[59] The erosion from high wave energy and elevated sea levels associated with El Niño events can leave beaches sand-starved and narrow for more than a year.[60] The significant effects of these events on the widths and distribution of upper beach zones, nearshore kelp beds and wrack inputs, the survival of intertidal invertebrates, and habitat and prey resources available for birds can require recovery periods stretching from months to years (Revell et al. 2011). Research results indicate that beach habitat and wrack abundance were reduced for >3 years after the 1997-1998 ENSO event.[61]

The high rate of longshore sand transport typical of the Santa Barbara littoral cell (~300,000 cubic yards/year) due to the oblique wave approach and geologic controls on the shoreline orientation, combined with the lack of prominent headlands that can retain sand and maintain wider beaches means that once sand has moved off a beach by waves, it is likely to move eastward down the coast. Beach management approaches may be available that could be used to change the trajectory for campus beaches and preserve recreational and ecological values and functions while providing a buffer to climate forcing. For example, well-designed ecologically-sensitive beach nourishment

[58] Revell and Griggs 2006, Id.
[59] Barnard et al. 2015; Barnard, P.L., J.E. Dugan, H.M. Page, D.R. Cayan, L.H. Erikson, D.M. Hubbard, M.R. Myers, J.M. Melack, N.J. Wood, S.F. Iacobellis and J.A. Finzi Hart. Barnard, P.L., J.E. Dugan, H.M. Page, D.R. Cayan, L.H. Erikson, D.M. Hubbard, M.R. Myers, J.M. Melack, N.J. Wood, S.F. Iacobellis and J.A. Finzi Hart. 2021. Multiple climate change-driven tipping points for coastal systems. Scientific Reports 11:15560, doi.org/10.1038/s41598-021-94942-72021. Multiple climate change-driven tipping points for coastal systems. Scientific Reports 11:15560, doi.org/10.1038/s41598-021-94942-7.
[60] Barnard, P.L., J. Allan, Hansen, J.E., Kaminsky, G.M., Ruggiero, P., Doria, A., 2011. The impact of the 2009–10 El Niño Modoki on U.S. West Coast beaches. Geophysical Research Letters 38 (L13604).
[61] Revell et al 2011

could enhance beach widths, especially in the reach between Campus Point and Goleta beach. Beach nourishment is commonly used to combat shoreline retreat, particularly for beaches of high recreational value, and commonly involves the addition of sediments from various sources including harbors or river mouths, dredge sites, terrestrial or offshore sources. Growing evidence indicates that the grain size used has major implications for the retention and quality of recreation and ecosystem values, and that matching the local sand grain size is the most reliable approach.[62]

However, beach nourishment can cause ecological damage and loss of biota for the recipient sandy beach habitats, and can damage adjacent marine habitats, such as rocky reefs, estuary mouths, seagrass beds and kelp forests due to an increase in sedimentation and the generation of turbidity plumes. The sensitivity of marine resources adjacent to UCSB is recognized in the designation of the Campus Point State Marine Conservation Area – a "no-take" zone. Minimizing the footprint of beach nourishment and allowing longshore transport to distribute sand reduces ecological impacts along the shoreline, including in the Campus Point SMCA (Figure 3-10). The beach that directly receives the added sand is sometimes termed a feeder beach. In the case of the campus beaches, establishing a feeder beach for sand addition just upcoast of the Campus Point bath house would allow the added sand to move to the bluff-backed east facing campus beaches.

Retention of filled sand on a beach reach affects the longevity of any benefits from nourishment activities. Careful design and ecologically-sensitive implementation of very low relief, permeable, sand retention structures could provide a means to increase sand residence time on campus beaches while reducing any potential impacts to down coast beaches and sediment sensitive subtidal habitats, like surfgrass and eelgrass beds and kelp forests.

An adaptation approach that combines ecologically-sensitive beach nourishment with strategically-placed, permeable, low profile sand retention features (groins or sills), could create wider beaches that would protect bluffs along the east facing campus coast and maintain both ecological and recreational values of these dynamic ecosystems. In contrast to approaches that rely on coastal armoring, adaptation approaches that seek to enhance sand retention and add sand at appropriate locations and intervals have the potential to slow the rate of bluff retreat, and maintain and enhance the cultural, social and recreational values, biodiversity, and ecosystem function of UCSB campus beaches. They would need to be supported with systematic monitoring. At UCSB, the USGS has been monitoring beach behavior across the UCSB campus shoreline semi-annually since 2005, and has extracted shoreline behavior from the satellite imagery dating to 1984.

[62] Viola, S., J.E. Dugan, D.M. Hubbard, N.K. Schooler. 2014. Burrowing in beach fill, implications for recovery of sandy beach ecosystems. Estuarine, Coastal and Shelf Science 150: 142-148; Peterson et al. 2014).

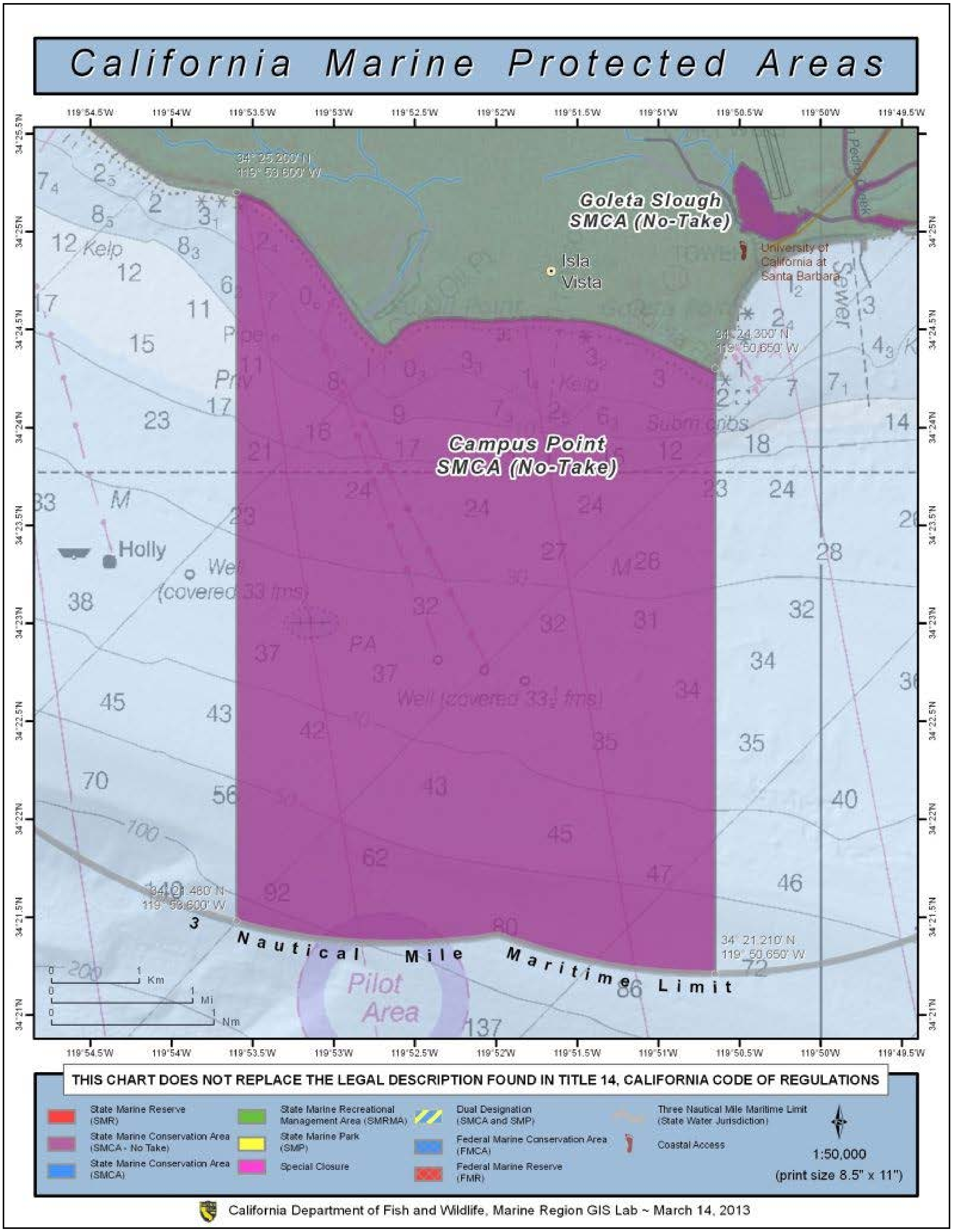

Figure 3-10. Campus Point State Marine Conservation Area.[63]

[63] https://californiampas.org/mpa-regions/south-coast-region/campus-point-smca.

3.5.1.2. Cliff Erosion

Cliff or bluff erosion is a significant hazard on the UCSB campus. The scientific consensus is that the long-term retreat of coastal cliffs is driven primarily by wave action, and the rate of retreat is controlled by the amount of wave energy over a threshold (Figure 3.11).[64] The amount of wave energy imparted to the cliff base is governed by the water level, wave energy flux, and width of the beach. Theoretical models and laboratory-scale physical experiments have indicated that, for a given rock strength, the width of the beach plays a critical role in regulating the rate of cliff retreat. [65]

For example, sediment can amplify cliff-base erosion through the process of abrasion where beaches are narrow, or dampen erosion by dissipating wave energy where beaches are wide. Wider beaches buffer the cliff from wave action by causing waves to shoal farther offshore, where some or all of their energy is dissipated before reaching the cliff base. Sea level rise is expected to cause an increase in long-term cliff retreat by increasing water levels and narrowing beaches. As the base of the cliff erodes landward, the top of the cliff can experience episodic failures, which are controlled by various other factors, such as rainfall, rock strength and fracture density,that govern slope stability. Over time, the episodic erosional processes of the cliff base and the cliff top equilibrate and the cliff retreats landward, often in a shape-preserving manner.[66] Therefore, facilitating wider beaches may help to reduce the impacts of SLR by acting to buffer the cliff from wave action thereby slowing the rate of bluff retreat. The development of a framework to assess how coastal cliffs will respond to various sediment supply, beach management, and sea level rise scenarios is currently an area of active research, and further understanding the interplay between beaches and coastal-cliff evolution will be necessary for comprehensive planning and the development of adaptive management strategies that aim to enhance resilience and mitigate hazard during changing environmental conditions.

[64] Alessio, P. and Keller, E.A. 2020. Short-term patterns and processes of coastal cliff erosion in Santa Barbara, California. Geomorphology, 353,106994; Huppert, K.L., J.T. Perron and A.D. Ashton. 2020. The influence of wave power on bedrock sea-cliff erosion in the Hawaiian Islands. Geology, 48: 499-503; Trenhaile, A.S. 2010. The effect of Holocene changes in relative sea level on the morphology of rocky coasts. Geomorphology 114: 30–41.

[65] Limber, P. W., A. Brad Murray, P. N.Adams, and E. B. Goldstein (2014),Unraveling the dynamics that scale cross-shore headland relief on rocky coastlines: 1. Model development,J. Geophys. Res. Earth Surf.,119, 854–873,doi:10.1002/2013JF002950; Sunamura T. Rocky coast processes: with special reference to the recession of soft rock cliffs. Proc Jpn Acad Ser B Phys Biol Sci. 2015;91(9):481-500. doi: 10.2183/pjab.91.481. PMID: 26568322; PMCID: PMC4754505.

[66] Alessio and Keller, *Id*.

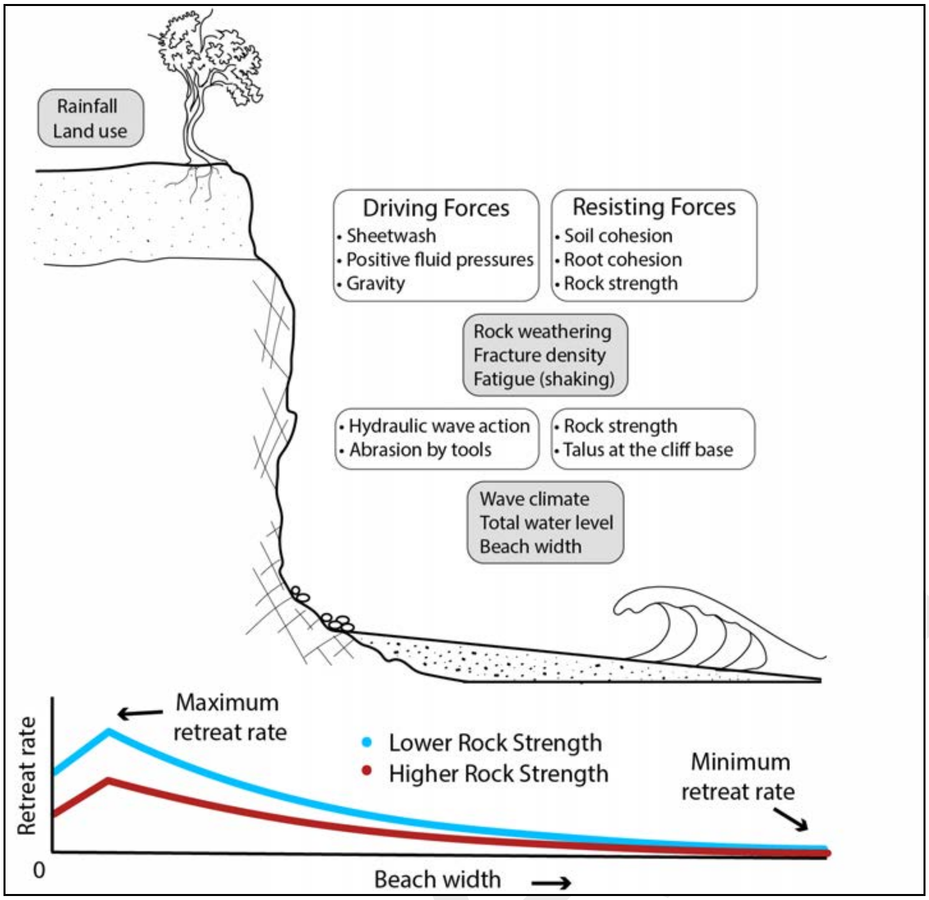

Figure 3.11. Driving and resisting forces associated with coastal cliff erosion. The efficacy of the driving and resisting forces of erosion (white boxes) is modulated by the variables listed in the gray boxes. The diagram at the bottom shows the theoretical relation between beach width and time-averaged cliff retreat rates from Sunamura (2015), *Id*.

Regional and local cliff retreat rates for Santa Barbara County and the UCSB shoreline have been reported by several authors, and can vary by an order of magnitude (~0.05 – 0.5 m/yr) depending on the location and time between measurements.[67] Observations and repeat measurements of cliff face erosion along the coast of UCSB suggest that erosion at the base of the cliff is the primary driver of long-term retreat rates[68], and that cliff-top failures are caused by the water content added from precipitation and irrigation. Cliff retreat rates have been measured to be higher where beaches are narrow, and cliff base and cliff-top retreat rates equilibrate over multi-year timescales.[69]

[67] Norris, R., Seacliff retreat at Santa Barbara, California: Mineral Information Service (California), v. 21, p. 87–91, 1968; Hapke, C. and Reid, D. National assessment of shoreline change, part 4: Historical coastal cliff retreat along the California coast, Open-File Report 2007-1133, 2007; Sylvester, Arthur Gibbs, and E. O'Black Gans. Roadside Geology of Southern California. Missoula, Montana: Mountain Press Publishing Company, 2016; Young, A. P. (2018). Decadal-scale coastal cliff retreat in southern and central California. Geomorphology, 300, 164–175. https://doi.org/10.1016/j.geomorph.2017.10.010; Alessio and Keller, *Id.*; Zuzanna M. Swirad, Adam P. Young, Spatial and temporal trends in California coastal cliff retreat, Geomorphology, Volume 412, 2022, 108318, https://doi.org/10.1016/j.geomorph.2022.108318.
[68] Alessio and Keller, *Id.*
[69] Alessio and Keller, *Id.*

These cliffs consist of weak and fractured Sisquoc Formation shale. Abrasion from wave action carrying sediment is the dominant process at heights up to ~0.8 m above the cliff toe, whereas block removal from wave action dominates above ~0.8 m.[70] During the winter, beaches are eroded and become narrower, allowing larger waves to reach the cliff base more frequently. Cliff-top failures can be induced via undermining, or landsliding from the addition of water. Large rotational landslides that extend to the cliff base, observed in the Monterey Formation to the east and west of campus, do not appear to occur frequently, or at all, in the Sisquoc shale (Figure 3.12). The USGS made long-term projections of retreat as part of CoSMoS using an ensemble of cliff retreat models and tuned by local historic rates of cliff retreat (Limber et al., 2018).

Figure 3.12. Landslide Modes of the Sisquoc (A) and Monterey Formations (B).[71]

3.5.1.3. Flooding and Goleta Slough

Flooding is a primary concern along the Goleta Slough shoreline of the campus. The CoSMoS flooding model and projections applied in this assessment are built on modeling multiple drivers of flood exposure (Figure 3-13).

[70] Alessio and Keller, *Id.*

[71] The evidence for deep-seated rotational landslides in the Monterey Formation (B) is expressed as large escarpments that cut through the entire cliff face, whereas the cliffs composed of the Sisquoc Formation along Lagoon Road at UCSB (A) do not show evidence for this mode of failure. Instead, the cliffs typically experience toppeling and maintain a vertical cliff profile. Photos: California Records Project (https://www.californiacoastline.org.

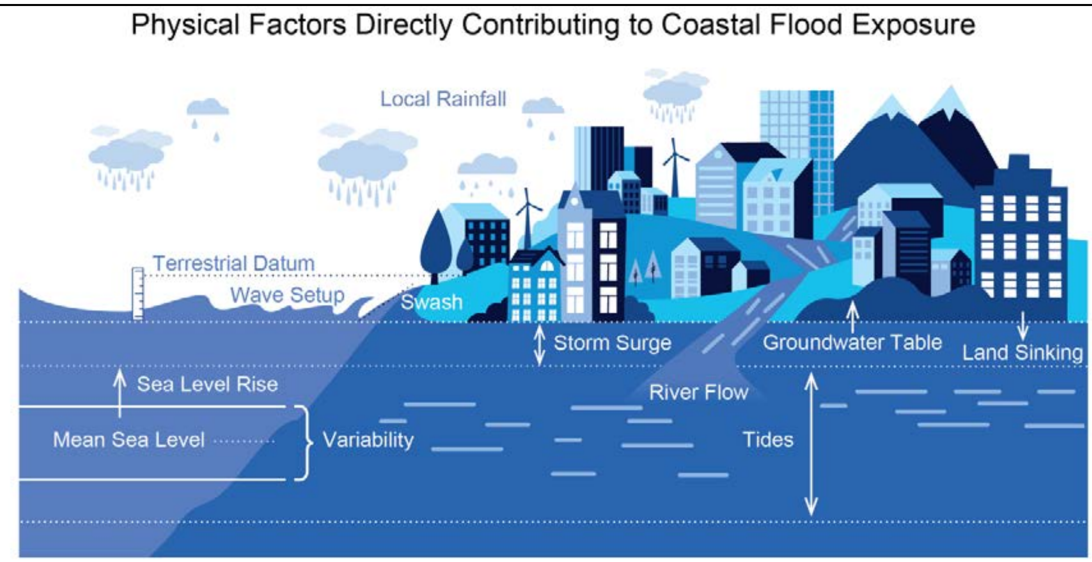

Figure 1.1: Schematic (not to scale) showing physical factors affecting coastal flood exposure. Due to the clear and strong relative sea level rise signal (i.e., combination of sea level rise and sinking lands), the probability of flooding and impacts are increasing along most U.S. coastlines.

Figure 3.13. Factors Contributing to Flood Exposure.[72]

Goleta Slough is a wetland system that shapes potential flood risks and strategies for resilience. The Slough is a manipulated, altered system with tidal flows restricted or eliminated in its western and southwestern extent by berms, and a tide gate that was established in the mid-1900s. The Slough had been managed to maintain tidal flushing beginning in the mid-1990s (ESA 2015). However, in 2013 management changed, and the Slough is now an intermittently-open tidal estuary with the inlet dredged only when infrastructure, such as the airport, is threatened by rising water levels. With berms and tidal gate restricting tidal flushing, much of the wetland habitat abutting UCSB is brackish or freshwater seasonal marsh.

ESA (2015) conducted a modeling analysis to explore how habitats in Goleta Slough might evolve in response to sea level rise. This modeling effort had considerable uncertainty regarding future management of the inlet and no information on tidal hydrology in areas that currently have restricted or no tidal connectivity, on sediment accretion rates, or on future freshwater runoff from local catchments. Assuming fully tidal conditions throughout the wetland, both the SLAMM (Sea Level Affecting Marshes Model) and inundation frequency-based modeling predicted the extensive conversion of vegetated marsh habitat in Goleta Slough to mudflat under two accretion rate scenarios by the end of the century, a prediction congruent with that made for fully tidal UC Carpinteria Salt Marsh Reserve (Myers et al. 2017, 2019) and other wetlands along the California coast (Thorne et al. 2018). However, the trajectory and timing of habitat evolution with sea level rise will depend on 1) whether the estuary is managed as a fully tidal or intermittently open estuary, 2) whether tide restricting structures

[72] *Id.* note 23, p. 1.

remain in place or entirely or partially removed, and 3) the extent of tidal attenuation with an entirely or partially open inlet.

In one scenario considered (ESA 2015), under fully open inlet conditions and tidally connected habitat, and based on the relationship between tidal elevation and plant distributions, the slough that now supports primarily freshwater vegetation could support vegetated salt marsh habitat. In another scenario with the inlet closed for an extended period of time, large areas of Goleta Slough would likely evolve to resemble conditions more similar to intermittently open Devereux Slough, with unvegetated areas surrounded by transition habitat. ESA modeling anticipates that with up to an approximately one foot of sea level rise, there is an increased likelihood of extended inlet closure, especially during dry years. It is anticipated that the inlet would remain open with three feet of sea level rise. Should tidal flushing be restored to certain areas, freshwater vegetation would at first be replaced by halophytes, with pickleweed (*Salicornia pacifica*) likely most abundant. But the conversion of habitats will be determined by specific elevations and longer-term tidal dynamics. For example, tidal muting would result in less tidal flooding for a given tidal elevation compared to that predicted from ocean tides, affecting the elevational distribution of habitats. Tidal muting might be exacerbated during periods of partial inlet closure that restricts tidal flows into the wetland.

The rates of habitat evolution with sea level rise will be accelerated by events that elevate water levels in the Slough and increase the time spent submerged for a particular elevation. The consequences of an increase in submergence time was illustrated at Carpinteria Salt Marsh, when elevated water levels associated with the El Nino of 2015 increased tidal flooding of the vegetated marsh for a period of several weeks, resulting in the dieback of pickleweed in lower areas (Myers et al. 2017, 2019). This dieback over a relatively short time period illustrates how rapidly increases in submergence time can affect marsh habitats. An increase in the frequency and magnitude of extreme events illustrated in CoSMoS (see Chapter 4) or inlet closure, could accelerate habitat conversion, for example of mid-marsh to mudflat, and of upland to transition through effects on soil moisture and salinity. Conversely, elevated sediment transport into the slough during flooding events could act to ameliorate effects of sea level rise.

3.5.1.4. Tsunami Risks and Sea Level Rise

Tsunami risk maps have recently been updated for the UCSB campus area by the California Geological Survey. Generally, they reflect the maximum risk of flooding from various potential events generated across the Pacific Basin , with a maximum near shore elevations of 16 feet above mean sea level for the Goleta Slough area and 23 feet for Devereux. This general risk is shown in Figure 3.14. The potential tsunami events are summarized in Figure 3-15. As discussed briefly in Chapter 4, sea level rise will incrementally raise these potential maximum extreme tsunami events. For example, six feet of sea level rise will raise the maximum tsunami elevation in Goleta Slough to

~22 feet above current mean sea level. This will have incremental implications for extreme event and emergency response planning, particularly over the longer-run.

Figure 3.14. Maximum tsunami runup estimations.[73]

Tsunami Source Scenario Model Results for Santa Barbara County

Near shore tsunami heights (flow depths) for both local and distant source scenarios, in FEET above Mean Sea Level. NOTE: The projections do not include any adjustments for ambient conditions, such as storm surge and tidal fluctuations, and model error (it is very important to note this difference, as those numbers can increase the projected water height during an event).

	TSUNAMI SOURCES	Approximate Travel Time	Santa Maria River	Surf	Arguello	Refugio	Devereaux	UCSB - Airport	Inside SB Harbor	SB Beach	Montecito	Summerland	Sand Point - Carpenteria	Rincon Point
Local Sources	M7.2 Anacapa-Dume Fault	10-15min				3	4	5	7	7	7	8		
	M7.5 Channel Isl. Thrust Fault	10-15min				3	4	5	7	7	7	8	8	8
	M7.7 Ventura-Pitas Pt Fault	10-15min				7	8	8	10	11	10	10	11	10
	M7.2 Pt Arguello 1927 EQ	10-15min	3	6	7									
	Goleta 1 Landslide	10-15min				15	23	13	8	9	12	10	0	0
	Goleta 2 Landslide	10-15min				11	16	16	10	18	16	14	14	13
Distant Sources	M9 Cascadia-full rupture	1hr	4	4	3									
	M9.2 Alaska 1964 EQ	5hr	15	15	8							6	4	7
	M9.3 Eastern Aleutians-Alaska	5hr					9	10	14	12	12	14	15	18
	M8.9 Central Aleutians I	5hr	10	10	6							6	5	5
	M8.9 Central Aleutians II	5hr	5	5	4									
	M9.2 Central Aleutians III	5hr	25	22	11	6	5	7	10	9	9	9	10	10
	M8.8 Kuril Islands II	9hr	3	3	3									
	M8.8 Kuril Islands III	9hr	4	4	4									
	M8.8 Kuril Islands IV	9hr	4	4	4									
	M8.8 Japan II	10hr	5	6	3									
	M9.5 Chile 1960 EQ	13hr	5	6	4	4	4	4	4	4	5	5		
	M9.4 Chile North	13hr	4	5	3	6	6	6	7	6	6	7	7	6
	Maximum Runup - Local Source		**4**	**6**	**8**	**17**	**26**	**14**	**12**	**20**	**19**	**18**	**16**	**15**
	Maximum Runup - Distant Source		**28**	**24**	**12**	**8**	**8**	**8**	**11**	**10**	**10**	**10**	**11**	**11**
	UPDATED Maximum Runup - Distant Source						**11**	**11**	**15**	**13**	**13**	**15**	**16**	**20**

CGS · Cal OES · USC · NOAA · FEMA · THE NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM (U.S.)

Figure 3.15. Tsunami scenarios for Santa Barbara County.[74]

[73] https://www.conservation.ca.gov/cgs/tsunami/maps.
[74] Santa Barbara County Tsunami Hazard Area Map Release Talking Points, California Department of Conservation, CalOES (2022).

4.0 Campus Vulnerabilities and Adaptation Strategies

This chapter presents a shoreline vulnerability assessment and adaptation strategy for the UCSB campus, organized around the five planning areas shown in Figure 4.1. Discussion for each area includes a description of existing conditions, projected climate change driven shoreline changes, vulnerabilities to the campus' natural, built and human uses of the shoreline, and adaptation pathways and associated LRDP amendments to help UCSB achieve its vision for coastal resilience.

UCSB is located approximately midway along the narrow marine terrace that generally characterizes the east-west trending coastline between Point Conception and the Ventura-Oxnard plain (USGS, 2006). Much of the campus edge consists of steep bluffs about 35 feet high. The campus also includes two large water bodies: the Campus Lagoon on the Main Campus and Devereux Slough on the West Campus. Goleta Slough is adjacent to the University's northern border, and its management area includes the wetlands on the Storke campus. In total, the campus includes approximately 2.75 miles of open coast, excluding the section of coast fronting Isla Vista, and nearly 6 miles miles of slough- or wetland-influenced shoreline along Goleta Slough and the interior of Devereux Slough (Figure 4.1).

This plan assesses the campus shoreline across five planning areas, each defined by geophysical and built environments (Figure 4.1). Planning Area 1 encompasses the shorelines and adjacent areas of the combined Coal Oil Point Reserve and North

Figure 4.1. Sea level rise campus shoreline planning areas.

Campus Open Space. Area 2 includes the West Campus Bluffs and Devereux Beach, up to the Isla Vista beach area. Area 3 extends from the Depressions Beach and Bluffs, around Campus Point and including the Lagoon area. Area 4 continues along the East Bluffs and Lagoon Road. Finally, Area 5 includes the shoreline along the North Bluffs/Goleta Slough edge, Storke Wetlands, and Adjacent areas. More detail on each planning area is provided in following sections.

4.1 Area 1 – Coal Oil Point Reserve and North Campus Open Space

The Area 1 planning area is on the West and North Campuses, running easterly from the western edge of Sands Beach to Coal Oil Point (approximately 0.6 mile of beach) and includes the interior edge of the upper and lower Devereux Slough (Figure 4.2). The primary adaptation strategy addresses vulnerabilities to the important ecological values in this area. Strategies focus on monitoring of changing habitat and wetland conditions, management along and relocation of Slough Road, habitat management and adaptation strategies, and managed retreat along the ocean shoreline.

Figure 4.2. Area 1 Shoreline – COPR and NCOS/Upper Devereux Slough.

4.1.1. Shoreline Characterization

As shown in Figure 4.2, the shoreline within Area 1 consists of the Coal Oil Point Reserve (COPR), which includes Sands Beach and adjacent dunes; Devereux Slough, including the North Slough Finger, South Slough Finger, and Slough Road; the North Campus Open Space (NCOS) Restoration Project; the Sierra Madre Restoration Area; and adjacent development on the periphery of the NCOS, including West Campus Family Student Housing, Sierra Madre Villages, residential housing in the City of Goleta, and Ocean Walk Faculty Housing.[75]

Sands Beach is an approximately 0.6-mile long dune-backed sandy beach, ranging in width from 5 to 50 meters depending on season and year; the dunes backing the beach can be up to 70 meters wide (Figure 4.3). The dunes and its Coastal Dune Scrub habitat represent a pristine remnant of this habitat type in Santa Barbara County. Together, the beach and dunes provide habitat for a variety of special status plant and animal species, including the Western Snowy Plover, for which the U.S. Fish and Wildlife Service has designated Critical Habitat at the COPR.

Figure 4.3. Sands Beach and dune habitat at the Coal Oil Point Reserve.

Devereux Slough and surrounding lands include several types of wetlands such as vernal pool, dune swale, salt flat and salt marsh, and important species habitat, such as the pickleweed habitat where the Belding's savannah sparrow breeds. Elevations in the

[75] Management plans, monitoring reports, analyses (e.g., flooding, watershed modeling) and other information for COPR are available at https://copr.nrs.ucsb.edu/ and for NCOS at https://www.ccber.ucsb.edu/ecosystem/management-areas/north-campus-open-space and https://www.openspace.vcadmin.ucsb.edu/.

Slough range from 3-15 feet above sea level in the North Slough Finger to 35-40 feet above sea level on the surrounding mesa. The South Slough Finger, formerly connected to Devereux Slough, has been partially infilled with alluvium and artificial fill such that it is at a slightly higher elevation (by approximately 1-2 feet) than the tidal flats of the Slough itself. Slough road lies along the majority of the eastern edge of the Devereux Slough. No active utility lines are located under or west of Slough Road, though one water line, and several sewer lines, run underneath or along the edge of the slough's fingers. Additional utilities are located under West Campus Point Lane (Figure 4.4).

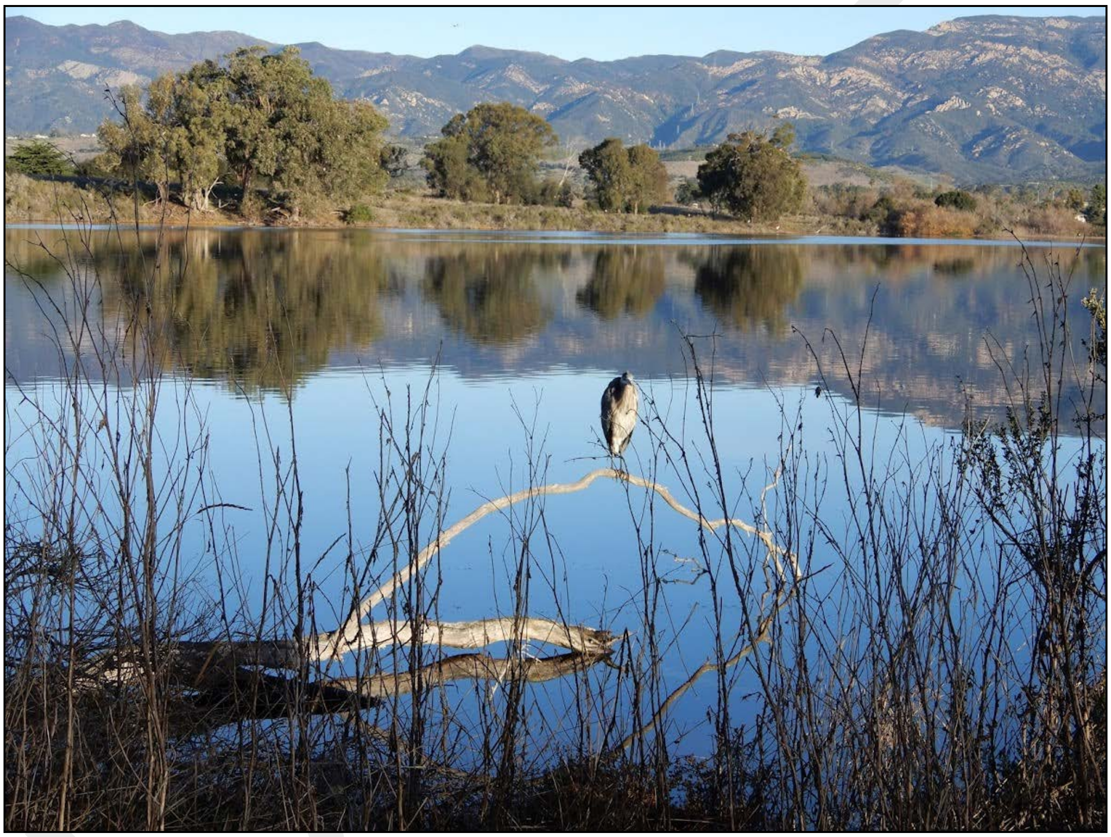

Figure 4.4. COPR - Lower Devereux Slough.

The NCOS Restoration Project commenced in 2017 to restore wetland and upland habitat that existed before the area was converted to the Ocean Meadows golf course in the 1960s.[76] Extensive analyses were performed to design the project, including flood analyses, hydrologic (watershed) modeling, and geotechnical engineering. The project was also designed to be adaptive to anticipated sea level rise while simultaneously reducing then-existing flood risk to adjacent development (see below).

The Sierra Madre Restoration Site is contiguous with the easternmost portion of the NCOS Restoration Area and west of Storke Road. The restoration project helped

[76] The former golf course that is now the North Campus Open Space was donated with the obligation that it be maintained as permanent open space and provide passive recreation, coastal wetland and wildlife habitat conservation and restoration, and associated research and environmental activities.

mitigate impacts associated with the Sierra Madre Villages construction. More than 28,000 native plants, comprising over 70 species, were planted.

The West Campus Family Student Housing complex provides 250 apartments and is situated near the Devereux Slough and NCOS. The Sierra Madre Villages provides 151 units and is situated near NCOS and along a tributary to Devereux Slough where the restoration site is located. Residential housing, within the City of Goleta on the northern border of the NCOS, includes the Meadowtree Condominiums as well as single-family dwellings to the east and west of the Meadowtree Condominiums. Ocean Walk Faculty Housing with 161 planned units, 90 constructed to date, is situated on the northern border of NCOS and along Phelps Creek which drains into the northern, restored, Devereux Slough.

4.1.2 SLR Hazards and Vulnerability Assessment

The most significant vulnerabilities in Area 1 are potential impacts to sensitive habitats and species, public access and recreation, and access to and along the Slough as sea level rises. There is perhaps a small possibility of long-term flooding of residential development inland of the slough. The COPR management plan, which is part of the LRDP, also is being updated to address specific habitat and recreational access issues in relation to climate change and sea level rise.

4.1.2.1. Sands Beach

Sands Beach runs the length of the ocean frontage of Area 1. It is an important area for sensitive habitat protection and management, particularly the Western Snowy Plover. It is also a popular public access and recreation beach for the campus and surrounding community. The LRDP and the COPR Management Plan both have extensive discussions and policy prescriptions for protection and management of Sands Beach.[77] There is little structural development along this shoreline.

The most significant sea level rise threat to Area 1 is the future erosion of the shoreline and dune system. As shown in Figure 4.5, CoSMos modeling predicts that erosion will move the shoreline steadily inland, perhaps 200 feet or more at the slough mouth, for example, as sea level rise approaches 2 meters. Depending on the response of the dune and lagoon system behind the beach, this shoreline recession could have significant impacts on both habitats and public recreation space.[78]

[77] For example, LRDP Policy OS-10: Habitat of the western snowy plover, including resting, foraging, and nesting habitat, shall be preserved and protected from disturbance. Access to trails near plover habitat may be managed to protect plover populations during nesting season. Also, LRDP Policy PA-03 requires that the University maintain general public access to Sands Beach. Land use in the COPR is strictly limited to such things as environmental interpretation displays, scientific study, habitat creation and restoration, parking for COPR personnel, public access trails, minor fencing, signage or natural barriers to protect public safety and manage open space and access, the existing Reserve Director's residence and Field Station facilities, and utilities and drainage infrastructure.

[78] The CoSMoS model includes projections of future shoreline topography as the the shoreline erodes, and then uses the projected shoreline in the next iterations of flood modeling. The projected shoreline is

Sea level rise, though, is just one of many climate change concerns in COPR. For example, climate change in the Santa Barbara region will likely cause an increase in temperatures and may cause fewer total rain days but more intense storms.[79] All these factors may adversely impact COPR's landscape and species. The most vulnerable species to climate change will likely be species that are endemic, sedentary, and near the coast such as the globose dune beetle (*Coelus globosus*), dune spiders (*Lutica maculata*), red sand verbena (*Abronia maritima*), tidewater goby (*Eucyclogobius newberryi*), Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*), Wandering Skipper Butterfly (*Panoquina errans*), (Western Snowy Plovers (*Charadrius nivosus nivosus*). Sea level rise surely will affect the snowy plovers by flooding current nesting habitat.[80]

The Santa Barbara County Coastal Ecosystem Vulnerability Assessment (CEVA) makes several predictions regarding the impact of climate change to habitats at COPR, including that beaches will narrow.[81] The assessment also concludes that upper beach habitat will be greatly reduced, though the dune system may provide capacity for retreat of habitat areas. Importantly, Ellwood-Dunes Beach is one of the few remaining in the UCSB region without armoring or fringing development, making it an important location for the potential persistence of dune-backed beaches in the face of climate change.[82] Another significant observation from the CEVA is the potential for inland migration of habitats in the beach/dune/slough system, such as salt marsh. This highlights both the importance of connections between the lower and upper Devereux

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represented as a zone to account for uncertainty in the projections. See, fhttps://ourcoastourfuture.org/science-and-modeling/.

[79] As summarized in the Santa Barbara County Climate Change Vulnerability Assessment (2021):

> *Although there will likely be a slight increase in precipitation throughout the 21st century, the seasonality may change (i.e., timing during a given year). There will likely be more rain during periods of precipitation (e.g., storms with higher rainfall totals), fewer total days with precipitation, and an increase in year-to-year variability. This means that more rain may fall during fewer storms throughout the year.*

https://s3-us-west-2.amazonaws.com/mysocialpinpoint/uploads/redactor_assets/documents/29baa3db6e78f84f6dca44393f76fcdf775c4838e2f3876efb16adabb64543c1/48273/SantaBarbaraCounty_CCVA_Report_Final_Clean.pdf, p. 45.

[80] Kerr, Alexa, 2021. Snowy Plovers and Sea Level Rise: Modeling the effects of sea level rise scenarios on Western snowy plover nesting habitat at Coal Oil Point Reserve. Senior Thesis, BA Environmental Studies, University of California, Santa Barbara.

[81] Myers, M. R., Cayan, D. R., Iacobellis, S. F., Melack, J. M., Beighley, R. E., Barnard, P. L., Dugan, J. E. and Page, H. M., 2017. Santa Barbara Area Coastal Ecosystem Vulnerability Assessment (CEVA). CASG-17-009.

[82] According to the CEVA (p. 150):

> *Dune-backed beaches with greater potential for retreat are now very limited in extent. Historically up to 19% (14.6 km, 9 miles) of sandy beaches were backed by coastal dunes in southern Santa Barbara County. Dune-backed beaches are or were formerly associated with the major structural basins of Devereux Slough, Goleta Slough, Mission Creek, and Carpinteria Salt Marsh and Carpinteria Creek. However, of these, the only remaining unarmored and/or undeveloped dune-backed beaches are Sands Beach located at the mouth of Devereux Slough and a stretch of Carpinteria State Beach, just west of Carpinteria Creek, making up only 3% (~2.4 km, 1.5 miles) of the region's beaches.*

Slough system, and the overall importance of Devereux as a relatively unaltered ecological system in the region.[83]

Figure 4.5. Shoreline erosion at Sands Beach with 0.5 to 2.0 meters of SLR (CoSMoS).

[83] CEVA, p. 177.

4.1.2.2. Devereux Slough

Devereux Slough has undergone a major restoration effort in its upper reaches. This has substantially increased both its value as a wetland system, and increased its flood mitigation capacity.[84] However, the restoration was only completed in 2018, and there is some uncertainty as to how it will function over time, including with sea level rise. The restoration, which involved substantial regrading of elevations, also means that CoSMoS flood projections based on pre-elevation data are less helpful at the neighborhood scale, such as along the upper edges of the restored Slough.

Sea level rise flooding projections are informative with respect to general changes in vulnerability, and opportunity, in the lower Slough along Slough Road and in the north and south slough fingers. Figure 4.6 shows the CoSMoS projections for minimum and maximum flooding in the lower slough under current and future sea level rise conditions and with the annual and 100-year storm. As illustrated, even with 2 meters of SLR, the most significant change along the slough shoreline is the expansion of flood potential into the fingers, across Slough Road, which actually can occur under current conditions and the 100-year storm.

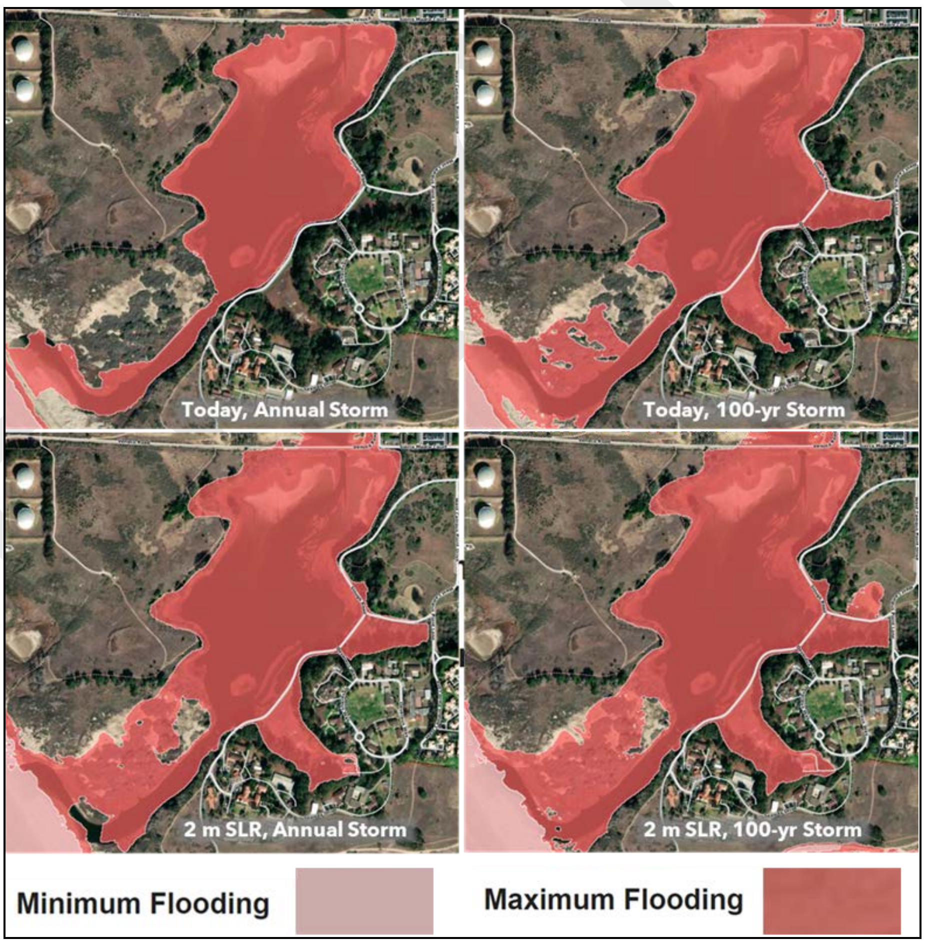

Figure 4.6. Min-Max Flooding, Lower Devereux, Current & 2 meters SLR.

[84] See, CCBER, https://www.ccber.ucsb.edu/ecosystem/management-areas/north-campus-open-space.

With certain development triggers on West Campus and the Devereux property, the LRDP currently calls for the closure of Slough Road to automobile traffic to reduce impacts on the COPR and provide for potentially increased wetland restoration in the two fingers (Policy TRANS-12). The policy also directs the potential conversion of road crossings of the fingers to bridges, to provide for enhanced wetland functions ("as funding is available").[85]

In the upper slough, CoSMoS projections show a similar increase in flood risk under current conditions with a 100-year storm (Figure 4.7). Sea level rise merely expands the potential footprint of this flooding, particularly with extreme events. However, the CoSMoS projections do not account for the changes in topography and thus hydrology that were implemented as part of the NCOS restoration project. In addition to expanding wetland habitat, one of the benefits of the project was the reduction of flood risk in the upper reaches of the slough, perhaps by 1.5 to 2 feet.[86] These improvements have been captured through updates to FEMA's flood maps that show little, but still some, development exposed to flood risk in the North Campus area in the Ocean Walk development, and the edges of Sierra Madre (Figures 4.8, 4.9).

More important, perhaps, the restoration also provides for long-run transition of habitat with sea level rise, reducing vulnerability of the ecology of the Slough. For example, the Western Arm was left at a slightly higher elevation; project-wide, this allowed nearly 20 acres of high marsh habitat to serve as a refuge for salt marsh habitat as sea level rise occurs and the lower Devereux salt marsh converts to mud flats.[87] Overall, the expectation is that the slough system would eventually convert from an intermittently tidal, currently "perched" wetland above the elevation of the ocean, to a nearly fully tidal system due to increased tidal prism created by the enlarged wetland. This, in turn, would essentially lower the elevation of the wetland by 3 feet, thus "resetting" the SLR clock for the system to one that protects salt marsh habitat up through 6 feet of SLR and protects and buffers the neighborhood from flooding by lowering the elevation of the wetland. The trail and public access components of the site have been situated at 15 feet elevation which is about 8 feet above the current highest tides, so during extreme events and much higher sea level rise, there is still significant room to accommodate, though perhaps not entirely avoid, flood waters and impacts to public access.[88]

[85] Though not related to sea level rise or wetland enhancement, LRDP Policy ESH-51 requires the removal of the greenhouse on West Campus located between the Devereux North Knoll and Devereux South Knoll (by 2024). The location is potentially subject to flooding in the very long run, and wetland restoration could be important eventually.
[86] CCBER, https://www.ccber.ucsb.edu/news-events/ncos-flood-reduction-benefits-recognized-fema.
[87] See Figure LH-1.1 of the 2016 Restoration Plan for the North Campus Open Space Restoration Project: https://www.openspace.vcadmin.ucsb.edu/files/docs/Final_Restoration_Plan_NCOS_2016_1221.pdf.
[88] Personal communication, Lisa Stratton, CCBER.

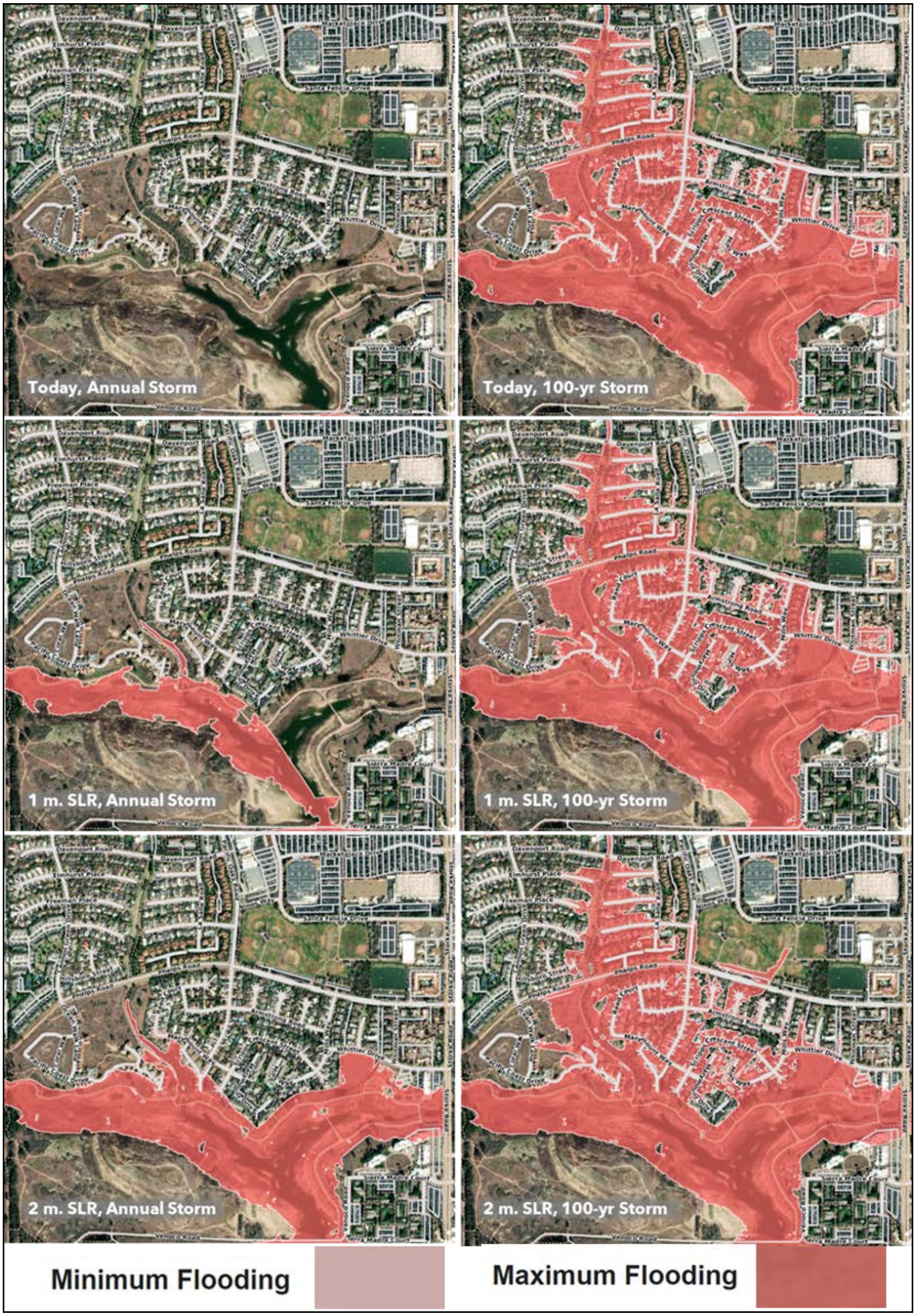

Figure 4.7. CoSMoS flood risk projections with SLR in Upper Devereux Slough using pre-restoration topography.

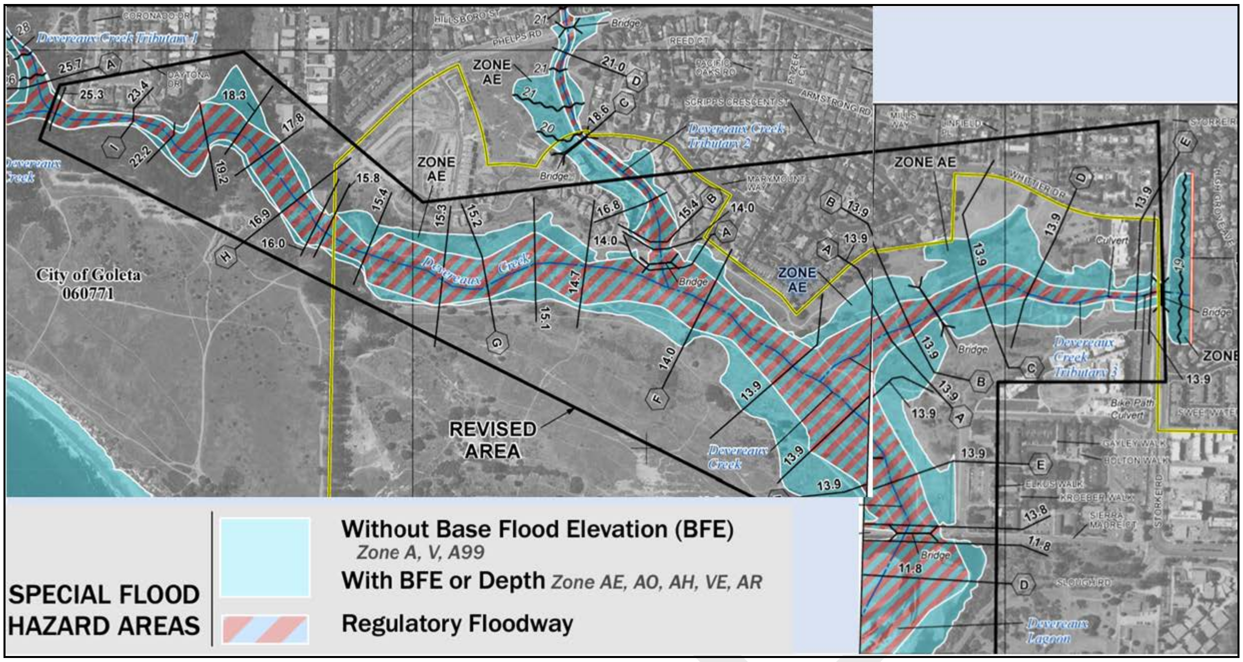

Figure 4.8. Revised FEMA flood map excerpts (post-restoration) Upper Devereux.

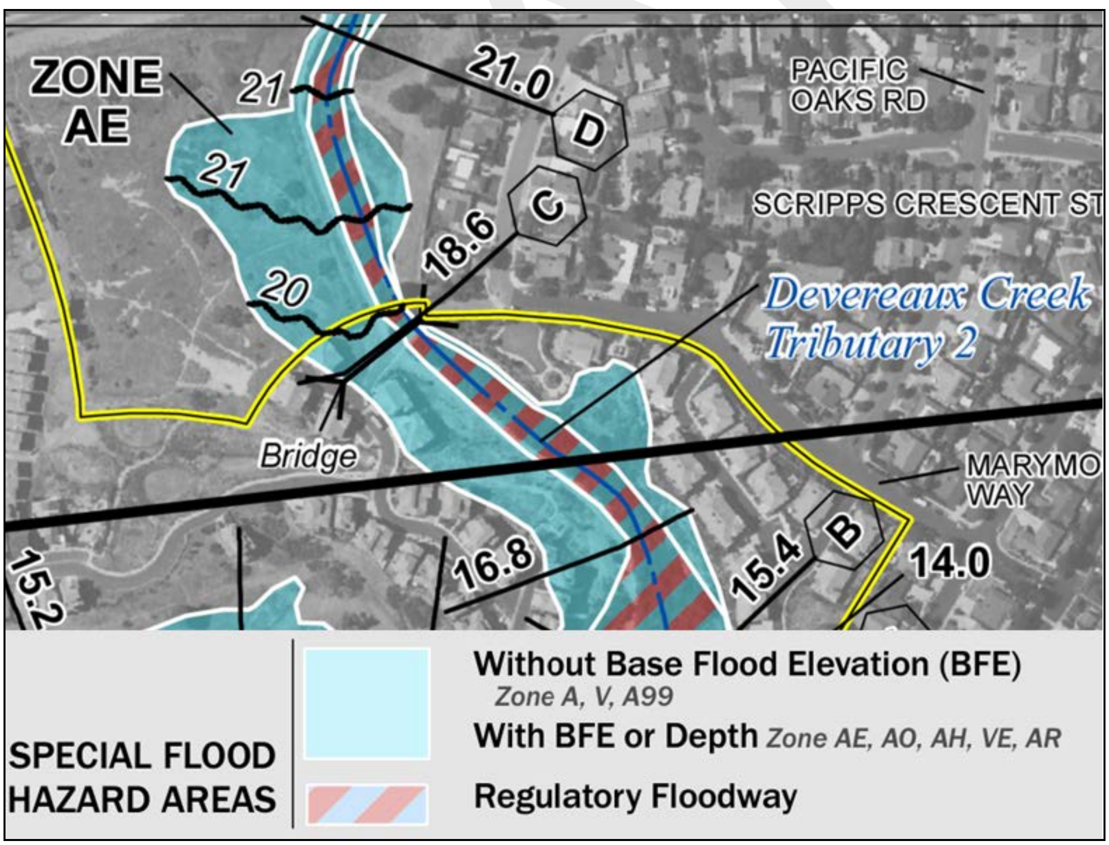

Figure 4.9. Revised FEMA flood map zoom, Upper Devereux, Ocean Walk.

Finally, recently updated tsunami maps (see Chapter 3) show some flooding into upper Devereux Slough, and onto the Devereux greenhouse site in the lower south slough finger, with a maximum water level of 23 feet above mean sea level (Figure 4.10). With sea level rise over the long run, this maximum would be around 29 feet, and could encroach on campus residential sites at the inland edge of Devereux and in the finger. This long-run possibility should be addressed through campus emergency services planning.

Figure 4.10. Maximum tsunami elevations at Devereux.

4.1.3. Area 1 SLR Adaptation Strategy

The Area 1 adaptation strategy includes monitoring, future planning and studies and specific retreat actions over the long run to address sea level rise vulnerabilities. The primary objectives of these adaptation pathways are to maximize protection of beach habitat and public access and recreation, protect and enhance wetland resources and functions in the Devereux Slough, minimize flood hazard risk to the built environment along the perimeter of the Slough, and maintain the important research and educational opportunities provided by the COPR and the NCOS. This strategy addresses various LRDP requirements, and the underlying Coastal Act requirements, such as LRDP Policy OS-10 and Coastal Act 30240, which require protection of environmentally-sensitive plover habitat.

4.1.3.1 Monitoring

Monitoring is already an important activity in both the COPR and the NCOS, including for protection of snowy plover and other sensitive habitat protection, and in relation to wetland change with the recent restoration in Devereux Slough. COPR has longitudinal data for various measures of plover success, and public access. NCOS is currently monitoring such things as water stage, carbon sequestration and sediment accretion in the wetlands. Importantly, both the COPR and NCOS provide significant research and educational opportunities for the UCSB community.

With sea level rise, it will become increasingly important to keep track of both physical changes in water level and flooding, and ecological changes in the now expanded Slough habitat-system. This is particularly true with respect to the potential regression of the shoreline and related movements or migrations of specific species habitats. For example, if the snowy plover population is to continue thriving, it will be important to monitor how habitat and species survival rates are changing, including to inform potential management interventions to address emerging threats and vulnerabilities. The behavior of the shoreline is a bellwether for the evolution of the physical system as a whole. The USGS has been monitoring the UCSB shoreline (Goleta Pier to Ellwood) with high-resolution topographic mapping on a semi-annual frequency since October 2005 to support coastal management decision making across the region, and plans to continue this work indefinitely. Further, additional shoreline data are being collected via the satellite record (Landsat and Sentinel) to complement the in situ data collection.

As discussed in other area assessments below, UCSB is proposing to amend the LRDP with a comprehensive monitoring requirement, to include its design, funding strategies and implementation. This should include consolidating and updating already-existing monitoring programs and efforts as necessary.[89] Table 4.1 lists multiple monitoring activities and parameters that are already taking place at UCSB. The time frame for initiating implementation of this recommendation is 1-3 years. For Area 1, specific focus should be placed on developing a coordinated monitoring program between the COPR and NCOS, including identifying long-term funding sources for data collection and management, and support of the research community.[90]

[89] The LRDP already requires monitoring of various resource trends, including public access parking (PA-05), campus water quality (WQ-03) and restoration objectives on open space lands (OS-09). Policy ESH-47 requires that the water quality of the Devereux Slough be monitored by COPR, including salinity, nutrient loading and sedimentation, as well as periodic botanical, invertebrate, and vertebrate monitoring and analysis. Policy SH-05 also requires the University to participate in regional shoreline monitoring to identify sea level rise concerns. UCS-NOID-0003-16 specifically requires cliff edge monitoring along Lagoon Road in order to anticipate the need to relocate infrastructure along that corridor (see Area 4 discussion).

[90] This will also implement LRDP Policy LU-19, which states that the NCOC "shall be used for purposes of open space preservation, coastal wetland and wildlife habitat conservation and restoration, public access, passive recreation, research and environmental education."

Table 4.1. Examples of monitoring taking place at UCSB.

Target	Location(s)	Start Date & Frequency	Contact Website
Beach and nearshore profiles and elevations	East Campus Beach to Ellwood	2005, 2x/yr, Fall & Winter	USGS
Rocky intertidal invertebrate and algal cover	Coal Oil Point,	2000, 2x/yr, Fall & Spring	MARINe, https://marine.ucsc.edu/
Wetland birds	Campus Lagoon, NCOS/Devereux Slough	1998, Monthly, 2017 NCOS	CCBER, https://escholarship.org/uc/ccber
Wetlands water stage/ storm flows	North Campus Open Space	2017, Continuous and biweekly	CCBER, https://escholarship.org/uc/ccber
Wetland vegetation monitoring and weed monitoring (monthly)	North Campus Open Space	2017, Annual and monthly	CCBER, https://escholarship.org/uc/ccber
Wetland nutrient concentrations	North Campus Open Space	2017, Storm events	CCBER, https://escholarship.org/uc/ccber
Dunes vegetation and intermittent topography	East & West Depressions	2000, Annual	CCBER website, Lagoon Monitoring reports.
Sandy Beach Western snowy plover breeding & wintering	Sands	2001, Frequently	COPR, https://copr.nrs.ucsb.edu/about/programs/snowy-plover-conservation
Public Access Users	Sands	Annually	COPR
Kelp forest, invertebrates, fish, algae	Sands	Annual	COPR, https://copr.nrs.ucsb.edu/about/programs/subtidal-monitoring

Sandy beach birds, invertebrates & wrack	East Campus, West Isla Vista, & Sands	1996-2001, 2008, 2019-Monthly	SBC LTER & MPA OPC, https://sbclter.msi.ucsb.edu/data/catalog/, https://wildlife.ca.gov/Conservation/Marine/MPAs#40713287-mpas, https://search.dataone.org/portals/CaliforniaMPA
Surf zone fish	South Campus,	2019, 3x/yr	OPC MPA, https://wildlife.ca.gov/Conservation/Marine/MPAs#40713287-mpas, https://search.dataone.org/portals/CaliforniaMPA
Kelp, algae, invertebrates, fish,	Isla Vista Reef	2000, 1x/yr	SBC LTERhttps://sbclter.msi.ucsb.edu/data/catalog/
Coastal cliff edge position	East campus (lot 6 to Henley Gate)	2017, 1x/yr	UCSB Campus Planning

4.1.3.2 Adaptation Studies

In addition to monitoring, targeted follow-up study is needed to identify future specific adaptation actions in Area 1. First, it is important to update the COPR Management Plan to address anticipated changes in the shoreline and associated sensitive habitat. This recommendation is for the near-term, and an update is already under consideration by the COPR. The plan update will also need to consider changes to and impacts on existing public access and recreation as the competition between people and other species increases with shoreline regression. This should include consideration of implementation mechanisms to assure the protection of sensitive habitats while providing for continued access and recreation (e.g. the relative effectiveness of different enforcement mechanisms). It should also consider, in conjunction with beach change assessment in other areas (see below), the potential to redirect beach users from the more sensitive Sands Beach to other campus and area beaches.

Another area of potential study is assessment of wetland restoration, expansion and migration opportunities along the perimeter of lower Devereux Slough. This "sea level rise and wetland transgression" assessment should be done in conjunction with or anticipating the triggering of action to close Slough Road to vehicular traffic, and develop a new road connection through West Campus Drive, as is already contemplated by LRDP Policy TRANS-12. This is a longer run study need, though, and would only come into play at higher sea levels. It also relates to specific actions to restore the north and south fingers of the slough (see below). The purpose of this study would be to identify supplemental and phased management strategies, in addition to restoration of the slough fingers, that will maximize the opportunities for natural wetland transgression and persistence.[91]

4.1.3.3 Adaptation Actions

Future studies of Area 1 may identify specific management actions or interventions to help the ecological system adapt to rising seas. They may also identify specific strategies for better managing public access to protect habitats while still meeting recreational demands. Other actions have already been anticipated that could be strengthened through the LRDP amendment. In particular, the effective relocation of auto traffic from Slough Road to a higher interior location, as called for by Policy TRANS-12, will help with the transition of the wetland system along its lower edge. However, whether any continued use of the road will be possible or desirable will depend on the conclusions of the assessment of wetland transgression and expansion opportunities. Several adjustments to TRANS-12 are recommended to address the increased understanding of potential sea level rise and related impacts. First, currently the changes to Slough Road are triggered by redevelopment of the West Campus Mesa or North Knoll site. However, the timing of such redevelopment is unspecified. To assure that necessary retreat of uses along the perimeter of Devereux Slough occur regardless, TRANS-12(B) should be amended to indicate that this change occurs prior to redevelopment, as recommended by the wetland regression study, or as triggered by frequent nuisance flooding and road closures (Amendment 15).

4.2. Area 2 – West Campus Bluffs and Devereux Beach

The Area 2 shoreline planning area runs easterly approximately 0.6 miles along the bluff edge of West Campus from Coal Oil Point to the western edge of Isla Vista, (Figure 4-11). The primary Area 2 adaptation strategy addresses vulnerabilities to existing blufftop development and public access through a program of managed retreat. Protecting sandy beach resources is also a primary concern.

[91] The Santa Barbara Area CEVA notes that for Devereux Slough, modeling suggests plant distributions will shift higher into the surrounding natural area (p. 177).

Figure 4.11. Area 2 shoreline.

4.2.1. Shoreline Characterization

The Area 2 shoreline planning envelope encompasses (1) Coal Oil Point, including the Cliff House (Building 362), Docent Office (Building 362.1), and Dovecote (Building 362.2); (2) the West Campus Bluffs, and access trails; and (3) Devereux Beach, including the "Jail House" structure.

Coal Oil Point is a significant geographic feature – a flat mesa about 35 feet above sea level, extending into the Santa Barbara Channel. It is exposed to large winter waves and is actively eroding. It is bound to the south and east by sloping sea cliffs with grades of 30 percent to 100 percent.

The West Campus Bluffs is an elevated, nearly flat marine terrace typically 30 feet high with steep cliffs facing to the south and east. It is capped by about 10-15 feet of weakly consolidated terrace deposits. The bedrock beneath is known as the Sisquoc Formation, a weak and highly fractured and erodible shale. From west to east, the bluff face becomes steeper and increasingly south-facing, to the point that they become nearly vertical. In some areas, cliff faces have been incised by erosional gullies and undeveloped trails.

Devereux Beach, also known as West Campus Beach, is a bluff-backed sandy beach that is typically widest at the center of Area 2 and narrowest at its ends, just east of Coal-Oil Point and at the Camino Majorca stairwell (Figure 4.11). Depending on the specific location, season, tide, and other factors, beach width can range from near-zero to 45 meters. Devereux Beach is a popular recreational beach, including for surfing and tide-pooling. The "Jail House," a highly degraded and graffitied remnant of a concrete structure from the historic Campbell Ranch ownership in the 1920s, is located at the toe of bluff almost midway along Devereux Beach. In addition to its recreational value, the LRDP maps Devereux Beach as Western Snowy Plover habitat.

4.2.2. SLR Hazards and Vulnerability Assessment

The main sea level rise hazard in Area 2 is the potential for accelerated beach and bluff erosion. A 1968 study indicated that the sea cliffs in Isla Vista to the east of the West Campus Bluffs are retreating at a long-term rate of about 12 to 18 inches per year due to shoreline erosion (Norris, 1968). More recently, ESA (2015) estimated that erosion rate values ranged from 0.05-0.4 meter (2-16 inches) per year for the cliffs between Devereux Slough and the UCSB Lagoon. At the higher rate of 16 inches a year, the bluff edge could retreat approximately 100 feet by 2100. Sea level rise will accelerate bluff and cliff erosion in Area 2. As illustrated in Figure 4-12, CoSMoSs projections show the bluff edge retreating 100 feet or more in places with 2 meters (6.6 ft) of sea level rise along Devereux bluffs.

4.2.2.1 Existing Development and Public Access

Existing development at Coal Oil Point – the Cliff House (Building 362), Docent Office (Building 362.1), Dovecote (Building 362.2) – is already in danger from bluff erosion. The LRDP recognizes this by requiring its removal as necessary. It is anticipated that these buildings are the first among all five study areas that will require removal or relocation due to SLR and cliff erosion, likely within the next 5-10 years.[92] Abandoned utilities connected to the Cliff House include electrical, water, and sewer. Importantly, the docent building serves an essential function by providing shelter for docents to observe the beach during periods of bad weather (usually intense winds). This function will need to be replaced through a relocated structure when the existing building is no longer functional.

[92] The LRDP states that at Coal Oil Point, "the Cliff House conference facility will be removed from the edge of the bluff in the future to eliminate risk from erosion hazards."

Figure 4-12. CoSMoS projected cliff edge erosion, 0.5-2m SLR.

Figure 4-13. Cliff House at Coal Oil Point.

In addition to the structures at Coal Oil Point, there is a remnant concrete structure known as the "Jailhouse" at the toe of the bluff. The LRDP currently contemplates the potential development of an accessway at or near this location.[93] All things equal, given on-going and accelerated bluff erosion, this structure increasingly will function as a seawall, leading to accelerated loss of the beach in front of it, and flanking, potentially exacerbated erosion on either side.

Figure 4-14. The Jail House, Devereux Beach.[94]

Related to the access concept for the Jailhouse, the LDRP describes the West Campus bluffs and Coal Oil Point as the most heavily used open space on West Campus. The

[93] LRDP Policy OS-04.
[94] Aerial Photo: Santa Barbara County Surveyor Information System.

area along the top of the bluff between Coal Oil Point and Isla Vista is an open field with vernal pools and dirt and DG paths used for passive recreation. The coastal trail from Isla Vista to Sands Beach passes within 5 to 20 feet of the edge of the bluff in many areas, and uncontrolled runoff from the seaward-sloping mesa and the trail contribute to downcutting and headward erosion of gullies and erosion of the sea cliffs. There are several overlooks adjacent to the blufftop trails. Much of the access resource is vulnerable to on-going cliff erosion.

Figure 4-15. Area 2 Blufftop Trail and Overlooks.

4.2.2.2 Shoreline Ecology and Recreation

Like Sands Beach, Devereux Beach is a significant ecological and recreational resource at UCSB. As summarized by Dr. Jenny Dugan:

> *. . . studies have revealed that sandy beaches of the UCSB campus support the richest intertidal assemblages ever reported for these open coast ecosystems (Dugan et al. 2003). UCSB's campus beaches have also been shown to support globally high levels of diversity and abundance for wintering shorebirds (Hubbard and Dugan 2003) as well as nesting and wintering populations of the Western Snowy Plover, a threatened species. These results indicate that* ***the sandy beach ecosystems of the UCSB campus can be regarded as global biodiversity hotspots for intertidal invertebrates and as essential habitat for wildlife including threatened species that are worthy of careful consideration in***

both campus and regional adaptation and conservation planning [emphasis added].

As discussed in Chapter 3, the dynamic profiles of sandy beaches are determined by a range of factors including sediment supply, wave climate, sea levels, and various geologic and anthropogenic controls including the space available for the beach to move – the "accommodation space." Sea level rise will accelerate beach and bluff erosion, and the responses of beach ecosystems, including their function and resilience, will be strongly affected by the potential for the shoreline to migrate and retreat. Given the lack of shoreline protection along this stretch of coast, there is more potential for the beach to persist in relative equilibrium as the back beach continues to erode. But, the degree to which the beach survives continues to depend on the relative rates of sea level rise and bluff erosion, longshore or other sand supplies, and future wave conditions.

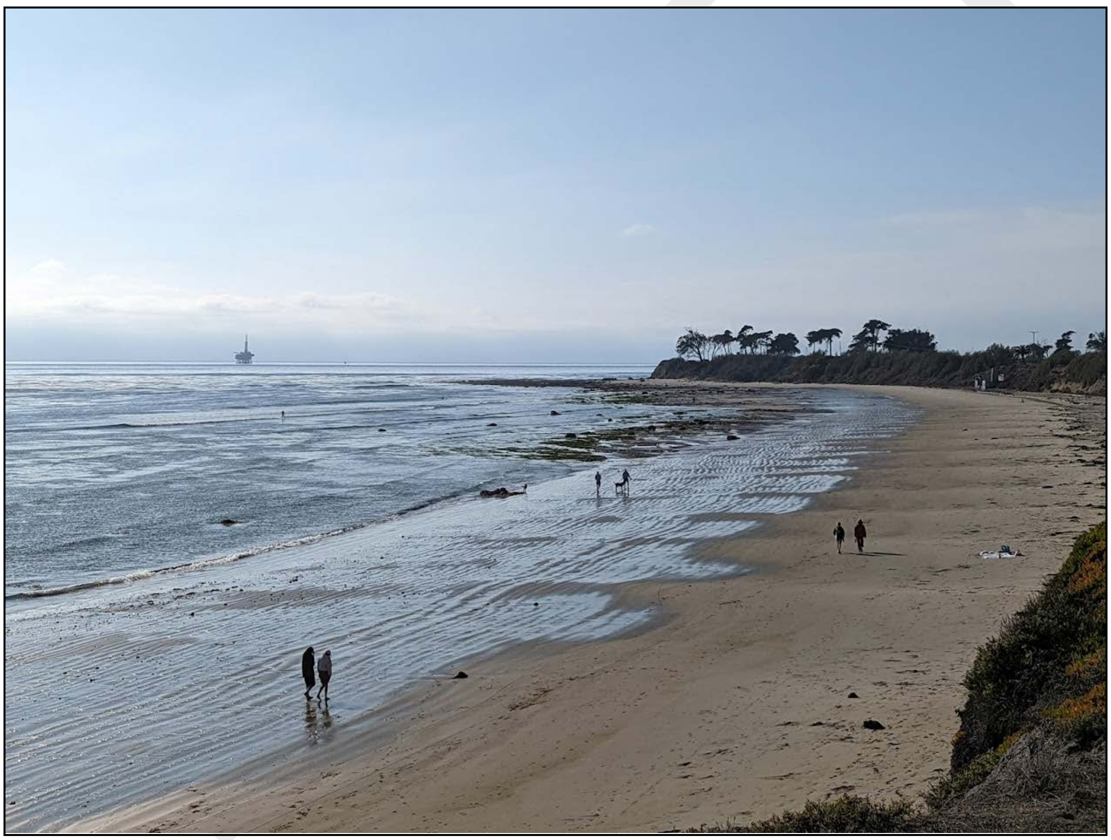

Figure 4-16. Devereux Beach at low tide, looking west to Coal Oil Point.

As for beach access and recreation, the LRDP calls for increased access amenities along this section. However, similar to beach ecology, the extent to which beach recreation continues to be viable will depend on the ability of beaches to persist with increased sea levels.

Finally, there are important biological resources along the blufftop as well, particularly the vernal pools just inland of existing trails (Figure 4-17). As bluff erosion requires the inland migration of public access trails, there will be an increasing need to assess potential impacts from human activity and options for protection of these vernal pools and other identified sensitive shoreline habitats.

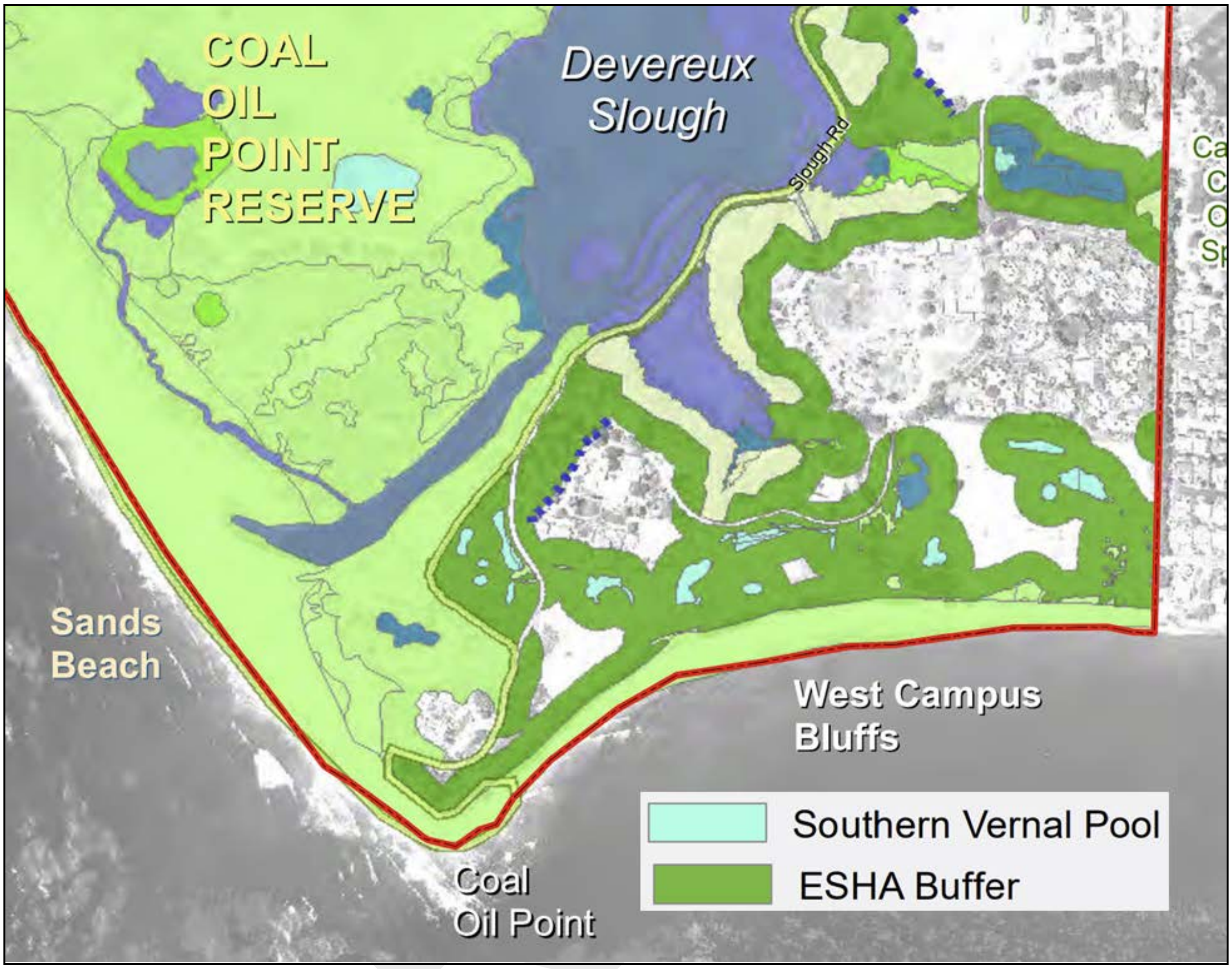

Figure 4-17. Vernal pools with habitat buffers on the West Campus Bluffs (LRDP).

4.2.3. Area 2 SLR Adaptation Strategy

The adaptation strategy for Area 2 consists of monitoring, potential research on beach and shoreline dynamics, development of enhanced access points resilient to sea level rise, and incremental retreat of existing development and access on the blufftop.

4.2.3.1 Monitoring

Monitoring is essential in Area 2, both for triggering removal or relocation of blufftop development, and for identifying the potential need for more proactive interventions to protect beach resources, including public access and recreation. As part of the comprehensive monitoring program recommended in Area 1, UCSB should closely monitor erosion risks to development at Coal Oil Point. A new action is recommended to require the removal or relocation of this development before it collapses or becomes a public hazard. Likewise, monitoring of the bluff edge and erosion of public access trails is required to trigger the relocation of access amenities as necessary to maintain safe public access along the bluff. In addition, the various features and dimensions of the beach should be monitored, in order to inform on-going evaluation of the need for more proactive interventions to protect the beach.

4.2.3.2 Adaptation Studies

Several specific assessments would benefit the capacity of UCSB to proactively adapt to erosion in Area 2. First, UCSB should initiate, in coordination with COPR management staff, the development of a building demolition, disposal and/or relocation management plan for the existing structures at Coal Oil Point that can be triggered before structures become hazards. Any required new beach accessways to Sands Beach should avoid more permanent, engineered structures.

Second, the LRDP should be amended to require development of a managed retreat plan for blufftop access and environmental resources. Anticipating the need to retreat access trails while protecting wetlands and other sensitive resources will enable UCSB to avoid emergency closures, or unanticipated conflicts with other important coastal resources, so as to maintain access. The plan should be developed in coordination with Santa Barbara County given the adjacency of Isla Vista, including resources like the stairway at the southern end of Camino Majorca, in the County's jurisdiction. In addition, planning should be coordinated with on-going monitoring and shoreline change in Area 1, to identify potential projects and programs directing public access from nearby parking to Devereux Beach and away from the sensitive Sands Beach, as may be required and if feasible.

4.2.3.3 Adaptation Actions

In addition to monitoring and further study, an LRDP amendment proposes to implement three adaptation actions for Area 2. Additional actions or pathways may be identified in the future through on-going monitoring and recommended studies.

1. Development at Coal Oil Point (Cliff House (Building 362), Docent Office (Building 362.1), Dovecote (Building 362.2) should be removed or relocated before falling to the beach below or otherwise becoming a public hazard. This is already required by the LRDP but further specification is now warranted. Detailed implementation measures may be identified in a managed retreat plan.

2. Public access trails and other amenities should be relocated as necessary. Safety measures, such as temporary fencing or signage should be used while minimizing visual impacts. Access should be maintained to the maximum extent while avoiding impacts to sensitive resources, such as blufftop vernal pools, to the maximum extent feasible. This program should be coordinated with existing LRDP requirements to consolidate informal trails to minimize erosion.[95]

[95] LRDP Policy OS-04, Paragraph 5: The University shall remediate and re-plant with appropriate native species eroded or compacted areas that have resulted from unauthorized trails . . . .

3. A new access stairway and supporting trails should be planned and developed in the vicinity of the Jail House.[96] This project should assess the viability and/or feasibility of maintaining the Jail House in its current location as an integrated feature of an accessway. If necessary, the plan should assess alternatives to allowing the structure to stay on the beach as sea level rises. Any accessway should be designed to be resilient for a reasonable structure life, considering its cost of development. In addition, this accessway could be evaluated as a point for redirected public access from parking lots on West Campus.

4.3. Area 3 – Depressions Beach to Campus Lagoon

The Area 3 shoreline planning area is on the Main Campus, running easterly from the eastern edge of Isla Vista, to and around Campus Point, northerly to the edge of the Campus Lagoon (adjacent to the southern tip of the Marine Science Institute (MSI) facilities (Marine Operations, Biotechnology Laboratory, and the REEF) and including the interior of the lagoon (Figure 4-17). It includes approximately 0.8 miles of open ocean shoreline and 1.6 miles of interior lagoon shoreline. The primary adaptation strategy addresses vulnerabilities around the edge of the Campus Lagoon and whether to allow or facilitate the opening of the lagoon to increased tidal action, or attempt to stabilize and maintain its current condition. Protection of beach resources is also a significant concern.

[96] LRDP Policy OS-04, Paragraph 3: The University shall implement . . . improvements . . . includ[ing] . . . development of a public coastal access trail system on . . . West Campus . . . including parking, three beach access improvements, restrooms at Coal Oil Point, beach access improvement at "Jail House". . ..

Figure 4-18. Area 3 shoreline planning area.

4.3.1. Shoreline Characterization

As shown in Figure 4-18, the shoreline within Area 3 consists of (1) Depressions Beach (between east and west depressions), fronting the mesas consisting of Manzanita Village, Lagoon Island and Campus Point); (2) Campus Point Beach, including a public bathroom (Building 502) and the pump house for UCSB's seawater system (Building 550); and (3) the Campus Lagoon and the surrounding natural and built environs, including the Lagoon Berm, the eastern weir, and the western weir.

Depressions Beach is an approximate half-mile long bluff-backed sandy beach, ranging in width from 20 to 50 meters, bookended by "west" and "east" depressions. The mesa along Depressions Beach has a nearly vertical ocean-fronting bluff face, and steep vegetated slopes descending into the lagoon. Manzanita Village, which houses 1,100 undergraduate students, is located on the mesa adjacent to Isla Vista. A series of public trails traverse and connect the mesas, including the UCSB labyrinth (a 0.6-mile trail constructed in 2011) located on Lagoon Island.

Figure 4-19. Depressions Beach, looking west to the beach weir and Isla Vista.

Campus Point Beach in Area 3 is a short, north-south trending beach segment, similar though somewhat narrower in width than Depressions. It is separated from Depressions at Campus Point by an intertidal bedrock platform extending approximately 300 feet from the base of the cliff into the surf zone. Though it is also generally a bluff-backed beach, the toe of the bluff is armored with an approximate 540 foot-long revetment wrapping around the point. At the lagoon mouth, there is an artificial berm constructed by the Marine Corps in the 1940s, consisting of miscellaneous construction debris, with a service road and public access. The eastern weir drains in pipes that run under the berm.

The Campus Lagoon began to convert to a perched freshwater lagoon[97] when a berm was constructed at the western mouth (West depression) in 1942, prior to the establishment of the UCSB campus.[98] The lagoon's water level is maintained with two weirs. The western "overflow" weir, constructed in 1954, is located on the beach separating Lagoon Island from the mesa that includes Manzanita Village. A 18-inch pipe runs from the lagoon inlet under the beach to the outflow box (Figure 4-19). The

[97] As described, the Lagoon does receive significant quantities of sea water from marine science laboratories.

[98] Management Plan for the Campus Lagoon at the University of California, Santa Barbara, Jones and Stokes (1999).

eastern weir is located north of Campus Point near the pump house for the campus seawater system. The surface elevation is generally stable, at about 6.35 feet about mean sea level. The Lagoon receives water inputs from 16 storm drains, surface flows, and seawater from the marine science laboratories and aquaria. There are also various utility lines in and around the development footprints adjacent to the lagoon and bluffs. However, most of the significant built environment surrounding the lagoon is about 30-40 feet above the surface of the water. There are some lower-lying areas, including the Commencement Green and Pearl Chase Park. A Lagoon Management Plan was incorporated into the LRDP in 1999 and amended in 2010 to include restoration opportunities. Area 3 also includes multiple areas, including the entire Lagoon Management Area, managed by the Cheadle Center for Biodiversity and Ecological Restoration (Cheadle Center) for ecological function.[99]

There is a known cultural resource at Goleta Point: a dense shell midden approximately 50 feet in diameter and partially covered by asphalt pavement on the mesa. Much of the midden was removed in 1948 when the area was paved, but subsurface deposits remain undisturbed.

4.3.2. SLR Hazards and Vulnerability Assessment

The primary sea level rise vulnerabilities in Area 3 concern potential loss of sandy beach environments at Depressions and Campus Point Beach; loss of ecosystem, recreational access, and aesthetic values around the Campus Lagoon; and risks to certain campus infrastructure, including the lagoon's weir system and eastern berm, and the sea-water intake system and public bathroom at Campus Point Beach.

4.3.2.1. Depressions Beach

Along Depressions Beach, bluff erosion rates historically have ranged from approximately 2 to 16 inches/year.[100] Existing public access nature trails, associated amenities and designated bluff habitat (ESHA) areas have been and will continue to be incrementally endangered by bluff erosion. Existing and potential cultural resources may also be exposed and affected by erosion. But even at the highest documented erosion rates along Depressions, no significant structural development other than the western weir structure (see below) would be in danger from erosion for at least 100 years. For example, the Manzanita housing complex is approximately 140 feet inland of the cliff edge at its closest point, which would lend approximately 100 years of safety at an erosion rate of 16 inches/year.[101]

[99] Additional information on current activities in these management areas can be found at the CCBER website: https://www.ccber.ucsb.edu/ecosystem/management-areas.
[100] ESA (2015) estimated that erosion rate values ranged from 0.05-0.4 meter (2-16 inches) per year for the cliffs between Devereux Slough and the UCSB Lagoon.
[101] As originally approved, the Manzanita development was set back at least 150 feet from the bluff edge, as required by the LRDP. CCC, NOID 1-98 (1999), https://documents.coastal.ca.gov/reports/1999/6/M9a-6-1999.pdf.

Similar to Areas 1 and 2, sea level rise will likely accelerate shoreline erosion in Area 3 as wave energy increasingly attacks the toe of the bluff and cliffs that back the UCSB beaches. CoSMoS projections of the bluff edge location under different sea level rise scenarios show the incremental retreat of the bluff edge along Depressions Beach. However, even assuming as much as 2 meters of sea level rise, no buildings in the Manzanita development would be at risk (Figure 4-20). Applying the state guidance for the UCSB region to these projections suggests that the Manzanita development "likely" will be safe well into the next century. There is only a very small chance that the buildings would be threatened late in this century under a high emissions or H++ scenario.[102] And even with the uncertainty surrounding the CoSMoS projections, there is little likelihood of this development being in danger in this century (Figure 4-20).

Figure 4-20. CoSMoS cliff edge projections at Manzanita Village – 0.5 to 2 meters of SLR.

A similar assessment holds for the Lagoon Island and Campus Point Mesas, which suggest that only the public trail network, including the Lagoon Island Labyrinth, and surrounding ESHA habitat and potential cultural resource areas will be in danger from accelerated bluff erosion due to sea level rise (Figure 4-21).[103] Miscellaneous utility lines and pathways adjacent to building envelopes will also be endangered over the long

[102] Recent projections from NOAA suggest this scenario is implausible for 2100. See Chapter 3.
[103] UCSB's Cheadle Center for Biodiversity and Ecological Restoration (Cheadle Center) will be restoring native bluff habitat with recent grant funding that will support the removal of the asphalt pad and the replacement of invasive plants with native flora. The Cheadle Center also will work with the Barbareño Band of Chumash Indians to protect the site's cultural resources.

run, but no more so than the development envelopes themselves. As discussed below, though far from immediate, it will be important to address these on-going erosion threats through periodic monitoring and adaptive action.

Figure 4-21. CoSMoS cliff edge projections at Lagoon Island and Campus Point Bluffs, for 0.5 to 2 meters of SLR.

There are two locations along Depressions Beach where the bluff drops down to essentially beach level (west and east depressions) – the original western outlets of the lagoon that are now blocked by both historic road and path development and dune habitat. At these points, vulnerability is better understood by looking at best available projections for the future shoreline location under different sea level rise scenarios. As shown in Figure 4.22, CoSMoS modeling projects the regression of the shoreline (mean high tide line) into the lagoon at the western depression with a little less than 2 meters of projected sea level rise, assuming that no effort is made to stop or slow natural erosion of the shoreline through armoring or sand replenishment. Using the OPC state projections, this may be likely to occur some time in the next century (after 2100) under a high emissions scenario, though there is very small probability (1 in 200) that it could occur late this century (2075-2100).

Figure 4.22. CoSMoS shoreline projections at historic Campus Lagoon western outlets, for 0.5 to 2 meters of SLR.

This future change at the lagoon's western low points is consistent with CoSMoS flood predictions also. As shown in Figure 4.23, typical (annual) flooding does not begin to overtop the existing lagoon barriers until more than 1 meter of sea level rise, although the maximum extent of flooding given the uncertainty of these projections, could overtop the low point at the some time after a half-meter of sea level rise. Under 100-year storm conditions, flooding could overtop the western-most existing barrier with as little as 0.25 meters or approximately 10 inches of sea level rise.[104]

[104] Field observations show that there has been overtopping at the West Depression with significant wrack deposition at least three times in association with big wave events. Lisa Stratton, personal communication.

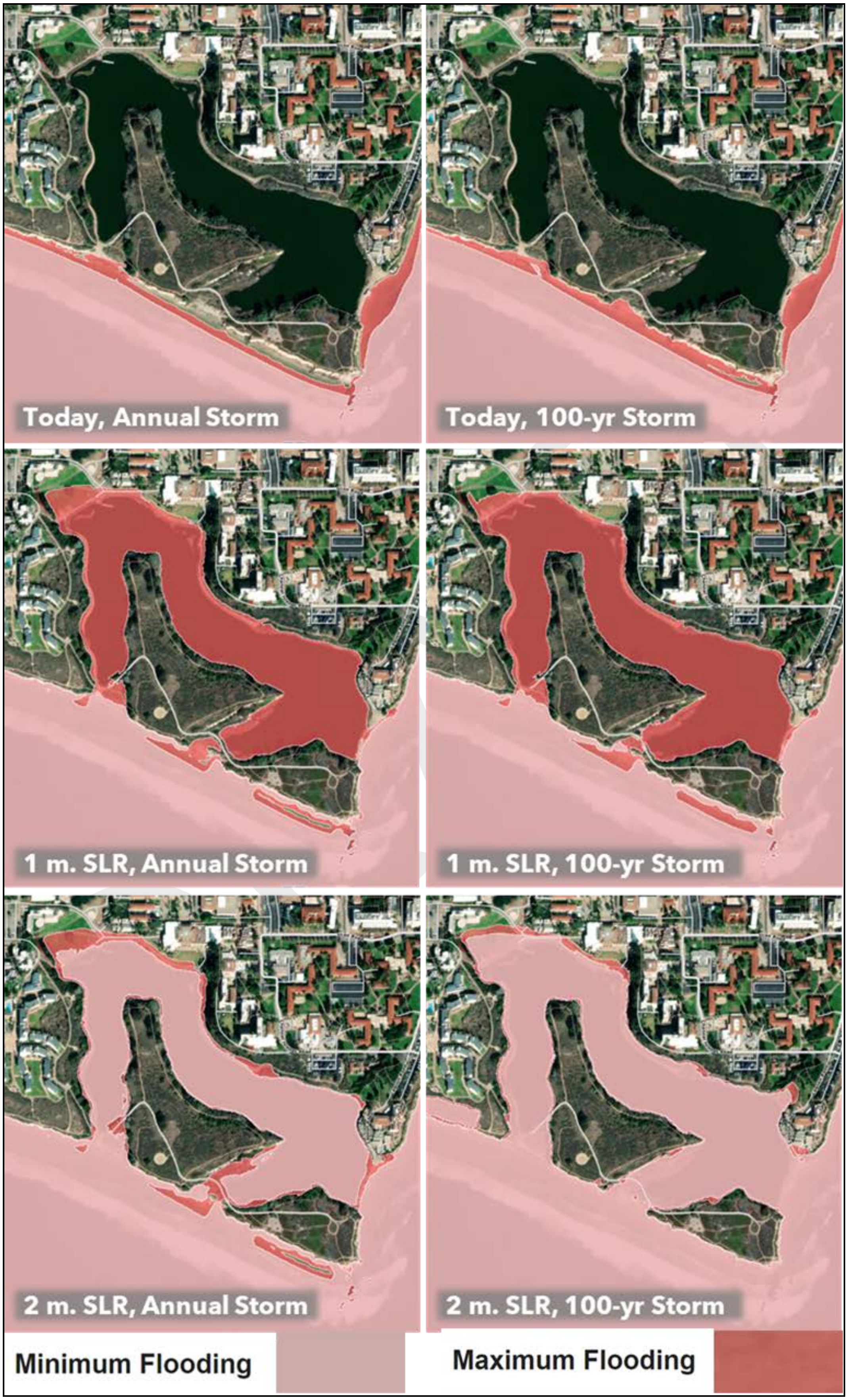

Figure 4.23. Projected Flooding at Campus Lagoon.

Although more permanent flooding and breaching of the lagoon is unlikely until the next century, the overflow western weir structure is vulnerable to high tides, storm conditions and wave attack under current conditions (see Figure 4-24, showing wrack line inland of weir beach outfall box (King Tide, December, 2021). The outfall/weir has long required regular maintenance to clear sand, boulder, and debris clogging the outfall pipe and reducing its capacity. CoSMoS also shows the mean high tide shoreline retreating inland of the beach outlet with only 0.25 meters of sea level rise. Given the importance of this overflow outlet to maintaining current lagoon conditions, this vulnerability should be addressed through more detailed assessment sooner rather than later (see below).

Figure 4-24. Western weir outfall box and lagoon intake.

Finally, similar to Areas 1 and 2, one of the most significant vulnerabilities in Area 3 may be the potential loss of sandy beach resources along Depressions Beach, including ecosystem functions and recreational and aesthetic values. If UCSB were to contemplate armoring or seawall development to fix the backshore, the inevitable loss of sandy beach at Depressions would be greatly accelerated due to the coastal squeeze.[105] However, such armoring of the Depressions Beach shoreline would not be consistent with the UCSB adaptation vision of allowing natural shoreline erosion to continue wherever possible. Assuming this path is followed, the degree of future beach loss at Depressions (and other beach areas) generally will be determined by the relative rates of sea level rise and erosion of the back shore, and the sand supply to this stretch of coast.

4.3.2.2 Campus Point Beach

Similar to Depressions, the primary vulnerability at Campus Point Beach is potential loss of shoreline access trails, upper bluff habitats and cultural resources, and sandy beaches. The lagoon berm, seawater intake system and beach restroom are addressed

[105] See Chapter 3.

in section 4.3.2.3 (Campus Lagoon). As shown in Figure 4-26, the shoreline position is projected to move steadily inland with increasing sea level rise. Again, assuming that natural erosion is allowed to continue, the extent of sandy beach and upper bluff resource loss generally will be a function of the relative rates of sea level rise, erosional trends, sand supply inputs or beach width, and hydrological changes at the lagoon mouth. However, in this sub-area there is an historic, pre-1972 rock revetment at the toe of the bluff generally running northerly from Campus Point to the Lagoon Road Berm. If this revetment is maintained or left in place, more significant beach loss can be anticipated due to the coastal squeeze. Continuing degradation of the revetment can also be anticipated absent any maintenance or augmentation.

Previous proposals to increase shoreline protection at this location have not gone forward, and the LRDP currently prohibits new armoring at the lagoon.[106] In the context of projected sea level rise, existing shoreline resources and vulnerabilities and the UCSB vision for shoreline adaptation, the revetment does not serve a meaningful purpose along the bluff. Removal of the revetment would increase natural erosion at Campus beach. However, any changes in the current configuration of the revetment should be considered in relation to potential changes at the eastern lagoon mouth (see next section).

[106] LRDP Policy MAR-03 states:

> *Lagoon Berm Road may be maintained in the approved road prism consistent with typical repair and maintenance practices such as replenishing the fill and recompacting the fill slopes. Lagoon Berm Road shall not utilize rock revetments or seawalls to maintain the road prism. The road may be removed to adapt to rising sea level. Placement of sandbags or other temporary stability measures shall require a NOID or Emergency Permit.*

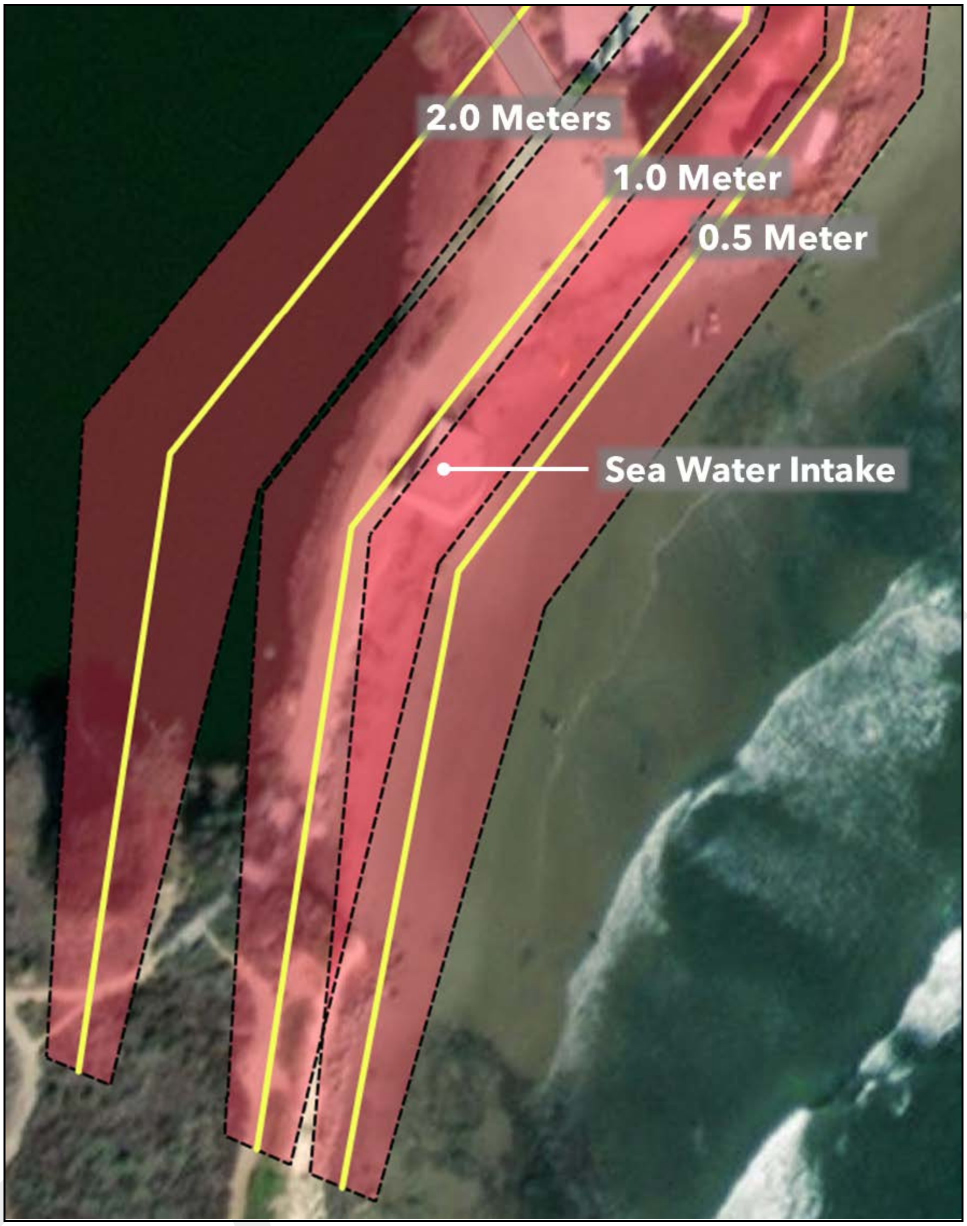

Figure 4-26. Shoreline Projections for Campus Point Beach/Lagoon Mouth

Figure 4-27. Historic, Degrading Revetment along Campus Point Beach.

4.3.2.3 Campus Lagoon

Potential changes to the Campus Lagoon and mouth at Campus Beach raise significant vulnerabilities in Area 3. As discussed, the Campus Lagoon is currently a 31-acre, approximately 6-8 foot-deep, non-tidal lake. It receives saline water from the sea water system and seasonal runoff from about 187 acres of campus watershed that together maintain its elevation at approximately 9.5 feet (NAVD88). Water levels can rise to approximately 11 to 12 feet following more extreme runoff events due to the limited capacity of the three 18-inch drain pipes that make up the outflow system at the east and west depressions.

One key vulnerability of immediate concern is the possibility that the eastern berm, currently constructed with concrete rubble, is breached by high water levels during storms (i.e., storm surge and wave-driven run-up).[107] The berm erodes each year with storms and UCSB maintains it by backfilling with sandy materials, consistent with LRDP policy MAR-03 (see note 100 above). Also the Campus Point Stairs at this location are vulnerable to current and future erosion (see below). If the berm breaches, the water

[107] As described in the Lagoon Management Plan: :A combination of beach sand depletion and severe winter storms in 1982-1983 caused damage to, and a near-breach of, the revetment." p. 2-11.

level in the lagoon could decline by 3-5 feet, and the lagoon could become intermittently tidal with periods of low water levels if the berm was not repaired.[108] Since the bathymetry of the majority of the lagoon's shoreline is mostly steep (shore edges at the islands are more gradual), a lower water level would leave a ring of steep shoreline. *This would change the ecology, water quality and aesthetics of the lagoon, especially along its edges, impact public access to the Campus Point Stairs, and have an effect on the recreational use of Campus Point Beach, raising new management concerns.* As identified below, further study is needed to understand the implications of different adaptation options for the lagoon.

Other potential vulnerabilities in the lagoon area concern potential impacts to the built environment on the interior perimeter of the lagoon from flooding. However, best projections suggest these are unlikely to be a concern over short- and medium-term horizons. The current water level within the Campus Lagoon is higher than the ocean due to existing berms. As sea level rises, and assuming the berm is breached, water levels in the lagoon will initially fall. However, there could be more significant changes over the longer run. As shown in Figure 4.23, Lagoon Island and Campus Point both become individual islands with 2 meters of SLR and a 100-year storm event. Under this scenario, the Commencement Green is also flooded and Pearl Chase Park is partially flooded, though this does not appear to be an issue with 1.5m of SLR, even with a 100-year storm.

Finally, concerning the lagoon berm itself and other physical development at the lagoon mouth, the existing berm supports an important link in the public access network at Campus Point that probably would be lost if sea level rise and erosion is allowed to convert to a more natural sand berm and intermittently tidally-influenced system. In addition, the sea level rise intake structure is located in the center of the mouth area. This is an important component of the UCSB coastal-dependent research and education program. This structure was built with a deep foundation structure, and would likely be resistant to erosion and ocean waves.[109] Similarly, the restroom

[108] The bathymetry of the lagoon would put the bottom of the lagoon at about 3 - 4 feet elevation, so above current low tide levels and thus, there could be small depressional pools in the lagoon in a tidally-influence regime.

[109] When the seawater system was upgraded in the late 1990s, the Coastal Commission, noting the University's confirmation, concluded:

> *. . . a shoreline protective device is not necessary to·protect the expanded pumphouse structure which will be constructed on 16 grade beam driven piles not including the wet well structure which also serves as an independent support for the structure. The University has also confirmed by letter dated May 22, 1998, that the construction and integrity of the proposed seawater renewal system pump house and associated utility lines are not dependent upon the construction of a rock revetment (Exhibit 8).*

California Coastal Commission, Revised Findings for Major Amendment (2-97) to the University of California Santa Barbara, August 20, 1998. https://documents.coastal.ca.gov/reports/1998/9/Th12a-9-1998.pdf.

structure is an important resource for beach goers at this location and also houses a sewer pump station underneath.

As shown above in Figure 4-26, both the sea water intake and restroom structures would be overtaken by the inland regression of the shoreline as sea level rises. If hard armoring is maintained around them, there will be increasing loss of beach resources on the seaward and lateral sides. In addition, access to the structures would gradually be compromised absent some strategies to maintain physical access (such as bridging or otherwise maintaining roads/paths).[110]

4.3.3. Area 3 SLR Adaptation Strategy

The Area 3 adaptation strategy broadly consists of LRDP updates to implement shoreline monitoring, conduct several focused studies, and anticipate specific phased, managed retreat and shoreline and lagoon restoration pathways. The objective of these pathways is to maximize beach preservation and assure public access and recreation and coastal resource protection, while continuing to provide coastal-dependent seawater to the University's various marine science research programs.

4.3.3.1 Monitoring

Shoreline monitoring in Area 3 will be important for effective implementation of adaptation actions. In addition to broad oceanographic trends, this monitoring should include observation of beach and cliff change, as well as tracking of changes to the environmental conditions of the lagoon, including as may be further specified in a future update to the Campus Lagoon Management Plan. Recommended LRDP Amendment SH-03(A) directs that UCSB design, fund and implement a comprehensive shoreline monitoring program. This should include consolidating and updating already-existing monitoring programs and efforts as necessary.[111] The time frame for initiating implementation of this recommendation is 1-3 years.

4.3.3.2 Adaptation Studies

In addition to monitoring, targeted follow-up study is needed to identify future specific adaptation actions in Area 3. Most important, there are several approaches for lagoon and berm management that could range from attempting to maintain current conditions to letting it evolve to a more natural system with intermittent wave and tidal influence. The vision of this shoreline management plan, and the general consensus of

[110] Groundwater table rise in this location could also be a significant issue for the low lying areas between the lagoon berm and the beach, for example, for any underground utilities in this corridor.
[111] The LRDP already requires monitoring of various resource trends, including public access parking (PA-05), campus water quality (WQ-03) and restoration objectives on open space lands (OS-09). Policy SH-05 also requires the University to participate in regional shoreline monitoring to identify sea level rise concerns. NOID UCS-NOID-0003-16 specifically requires cliff edge monitoring along Lagoon Road in order to anticipate the need to relocate infrastructure along that corridor (see Area 4 discussion).

the scientific advisory group, supports moving towards a more natural system to better adapt to long-term sea level rise. In addition, as discussed above, the LRDP prohibits hardening strategies at the east berm location, although maintenance and the placement of sandbags or other temporary stability measures is allowed with a NOID pursuant to the LRDP or through a Coastal Commission emergency permit (see note 100).

However, determining the most effective adaptation pathway at the lagoon berm (the sequence of moves to get to this more natural system) will likely require evaluation using a quantified model similar to that created for NCOS and Devereux Slough that would consider the inputs (pumped in sea water, storm water runoff, wave overtopping), wave energy, sand bar build up, sea level rise and tidal influence; as well as potential landscape changes (e.g., wetland restoration) in and along the interior edge of the lagoon.

By understanding the potential water stage patterns and hydrology, UCSB could begin to assess the aesthetic and ecological function that the wetland might provide under different hydrological and other physical and management conditions. This might include increased habitat for migratory shorebirds and an either more or less eutrophic condition depending on the degree of flushing. The current wetland condition is one that is fairly eutrophic with low dissolved oxygen levels and thick organic and anoxic muck at the bottom, and relatively high nutrient levels in the incoming run-off from irrigated landscapes and storm water runoff. Intermediate treatment wetlands like the Manzanita development bioswales significantly reduce nutrient inputs into the lagoon and increase the water quality.

The best mechanism for identifying detailed adaptation actions at the lagoon is to update the Campus Lagoon Management Plan. This would include the assessment described above, as well as consideration of alternative lagoon berm and edge management strategies that will address the changing hydrology, as well as the risks and reconfiguration options for existing public access, the seawater intake system and public restroom facility near the lagoon mouth. The recommended pathway would potentially use temporary protection measures, while a "phase 1" assessment of the different lagoon scenarios is completed (from status quo to opening and conversion/restoration of the lagoon to tidally-influenced). This assessment would identify the optimum feasible pathway for initiating implementation in a phase 2 in the 5 to 15-year or longer time frame. This would be followed by monitoring and evaluation, and potential adaptive management actions depending on the performance of the restoration. This phased strategy would be incorporated into the LRDP with the shoreline plan amendment.

This assessment and updating should occur in coordination with adaptation strategies for Area 4 (see below). Further amendment of the LRDP may be required based on this update work.

In addition to addressing lagoon management, based on on-going monitoring of beaches, any opportunity to provide more accommodation space for campus beaches, especially in locations such as dune-backed beaches at the lagoon boundaries, should be identified and explored. It is possible that over the longer-run, it may be beneficial to consider sand replenishment in conjunction with sand retention as a mechanism for maintaining beach width in Areas 3 and 4 (see below).

4.3.3.3 Adaptation Actions

In addition to monitoring and further study, the LRDP should be amended to implement several adaptation actions in Area 3. Most important, the Campus Lagoon Management Plan should be updated within five years to address the following:

- Alternatives for natural shoreline recession and implications for hydrology, habitat, cultural resources, public access, and aesthetics at the lagoon.
- Options for replacing and ultimately removing the eastern and western weirs and transition strategies in relation to lagoon management strategies;
- Protection and enhancement of public access by replacing the eastern lagoon berm with a pedestrian bridge as may be required and consistent with the Lagoon transition plan.
- Maintenance and protection of the seawater intake system consistent with the lagoon transition strategy, including potential reconfigurations in conjunction with other adaptation strategies in Area 4.
- Potential adaptation strategies for the beach restroom facility in conjunction with adaptation strategy development in Area 4.
- Removal of debris and other hard armoring to the maximum extent feasible, consistent with the lagoon transition plan and protection of the seawater intake system.
- To address internal consistency within the LRDP, Policy MAR-03 should also be updated to support the direction of the Sea Level Rise Adaptation Strategy for the Campus Lagoon:

> <u>Transition the lagoon mouth to a more open connection with ocean waters, as specified through the updated Lagoon Management Plan.</u> Lagoon Berm Road may be maintained in the approved road prism consistent with typical repair and maintenance practices such as replenishing the fill and recompacting the fill slopes <u>until such time as transition actions are identified and funded for implementation</u>. Lagoon Berm Road shall not utilize rock revetments or seawalls to maintain the road prism. The road may be removed to adapt to rising sea level. Placement of sandbags or other temporary stability measures shall require a NOID or Emergency Permit.

- Maintain and retreat public access pathways as necessary. Monitor access trails and assure public safety along the bluff edge. Consider realignment strategies that result in path stability for at least 5 years, to minimize disruption of habitat and other coastal resources over time. Enhance interpretive signage as needed.
- Engage local tribal representatives to advise on recognition and protection of cultural heritage and resources. Monitor for and protect cultural resources, consistent with the LRDP, as they may become exposed due to cliff erosion.
- Remove the existing revetment between Campus Point and eastern lagoon mouth and restore the shoreline as may be required. Evaluate and pursue as appropriate opportunities to finance implementation of this removal with mitigation monies from shoreline protection projects in the region.
- Incrementally remove and relocate as necessary any existing infrastructure that may become exposed or potentially exposed in the immediate future.

4.4. Area 4 – East Bluffs and Lagoon Road

The Area 4 shoreline is on the eastern edge of Main Campus, running northerly about 0.8 miles from the downcoast edge the Campus Lagoon mouth to the western edge of Goleta Beach Park (Figure 4.28). It includes the developed corridor along Lagoon Road and the East Bluffs. The adaptation strategy addresses shoreline erosion vulnerabilities to the developed blufftop and beach. In addition to monitoring, the strategy calls for further assessment of retreat strategies for the built environment, and eventual relocation of vulnerable development.

Figure 4.28. Area 4

4.4.1. Shoreline Characterization

The Area 4 shoreline encompasses the Marine Science Institute (MSI) facilities Marine Operations, Biotechnology Laboratory and Reef Aquarium; East Bluffs and beach; Lagoon Road, Steck Circle and the southern portion of Highway 217; Sewer Pump

Station #529, and the residential and academic buildings, parking and other infrastructure along this corridor.

The MSI facilities at the lagoon were first established in 1969 and expanded in the 1970s and 80s. The buildings sit on a 20-35 foot high terrace, which is protected by approximately 550 linear feet of riprap placed before 1972 (Figure 4.29). In contrast to the unprotected and nearly vertical cliff face further down-coast, the bluff face behind the riprap is vegetated and lays back at a less steep angle (Figure 4.30).

Figure 4.29. EEMB marine Facilities at the Lagoon with Revetment, 1972.

Figure 4.30. East Bluffs with and without rock rip-rap .[112]

To the north of the MSI facilities and rip-rap, the East Bluffs marine terrace gently rises from around 30 feet above MSL to approximately 45 feet above MSL at Steck Circle. The bluff face is nearly vertical and is generally barren, except for vegetation growing where groundwater emerges at or above the top of the Sisquoc formation.

The natural and geological characteristics of the bluffs in Area 4 are similar to Area 2 . The beach along the East Bluffs is narrow, typically ranging in width from 0 to approximately 30 meters. Historically, the beach width has changed rapidly as a result of a large storm or months of sand build-up.[113] For example, before the 1982-83 El Niño storm season, the beach below the East Bluffs and north of Parking Lot 6 was wide and thickly vegetated. The 1982-83 El Niño storm season decimated the beach and the area has not recovered (Figure 4.33), though the shoreline position does fluctuate considerably on inter-annual time scales. Nonetheless, the beach remains an important ecological and recreational asset of the campus.

In addition to the heavily-used transportation corridor from the base of Highway 217, through Steck Circle, and to and along Lagoon Road, the Area 4 built environs includes two residential halls and seven academic and research buildings (including the MSI facilities). Utilities serving the entire campus are also located within and on both sides of this transportation corridor. For example, sewage from the Main, and parts of Storke campuses eventually flows through the Main Sewage Pump Station at the northeastern corner of Area 4. This pump station also receives sewage from the restaurant and restroom at Goleta Beach located within the County of Santa Barbara. Rip rap that was placed in front of the sewer pump station in April 2020 to provide protection was

[112] Photo, December 3, 2021; Aerial from Santa Barbara County Surveyor Information System 2, Accessed 04/04/2022.

[113] As an example, Google Earth aerial imagery from December 2005 shows the ocean at the base of the bluff nearest to Anacapa Hall. The next aerial image of the area, from November 2006 (11 months later) at the same location shows a beach that is approximately 55 meters wide.

removed in August 2022. The area is being restored by seeding the bluff, layering jute netting, and planting Lemonade berry bushes along the top. (Figures 4.31, 4.32).

Figure 4.31. Rip-rap (left) now removed, fronting the Sewer Pump Station (right).

The blufftop along Lagoon Road is also a significant public access corridor, and includes a popular blufftop trail, scenic views, and a major public access parking area with a stairway down to the beach in the vicinity of Anacapa Hall. In addition, The Cheadle Center manages a 2-acre portion of the bluffs near the sewage lift station, currently undergoing habitat restoration.[114] The Cheadle Center has restored three other areas near the sewer pump station, one at the the entrance to the East Gate, an area immediately adjacent and to the west of the pump station, and the bluff face just below the pump station.

Figure 4.32. Area of removed rip-rap being restored.

[114] See, https://www.ccber.ucsb.edu/ecosystem/management-areas/eastbluff.

Figure 4.32. Beach Stairs at Parking Lot 6.

Figure 4.33. East Bluffs Beach, 1975 and 1983.

4.4.2. SLR Hazards and Vulnerability Assessment

Area 4 has significant campus development and coastal resources vulnerable to erosion, both in the near term and in the longer-term as sea level rise accelerates erosion. This includes continued upper bluff erosion at the MSI facilities, and on-going and likely accelerated erosion along the Lagoon Road corridor, including the iconic East Bluffs Beach below.

4.4.2.1. Lagoon Road Corridor

The MSI facilities and a portion of Parking Lot 6 are currently behind the existing, pre-Coastal Act revetment. Nonetheless, though not immediately threatened, they could be vulnerable to upper bluff erosion over the long run as the bluff continues to erode.

Facilities located within or east of Lagoon Road and CA-217 north of Parking Lot 6 and that are not protected by existing revetment include:

- Sewer pump station, with high-voltage electric lines, potable water lines, and multiple sewer lines.
- Bike path
- Pedestrian paths and scenic overlooks
- Beach access stairs adjacent to Parking Lot 6
- Utilities, including:
    - Sewer lines
    - Storm drains and stormwater outfalls
    - High voltage electric lines
    - Electrical lighting, including light poles
    - Natural gas lines
    - Potable water lines
    - Sea water lines
    - Reclaimed water lines
    - Lines that have been abandoned in place.

The erosion of the East Bluffs has been studied extensively. In 2015, Environmental Science Associates (ESA) estimated that average erosion rate values ranged from 0.05-0.2 meter (2-8 inches) per year for the stretch of cliffs between the UCSB Lagoon and Goleta Slough. Based on measurements of the bluff top taken from 121 fence posts from 2000 through 2018, and supplemented by data collected from photographs taken of the area since 1972, the minimum rate of sea cliff retreat in Area 4 is 5 inches per year, although the observed range is from 3 to 9 inches per year. At five inches per year, the edge of the sea cliff will be at the east edge of Lagoon Road opposite Anacapa Hall in 36 years, or at the edge of a 12 foot wide roadside shoulder in seven years (see below).

Cliff erosion will likely accelerate with sea level rise. Figures 4.34 and 4.35 show the projected cliff edge along Lagoon Road with increasing sea level rise and no armoring or beach widening . Significant portions of the blufftop, including public access areas, parking, Lagoon Road and underlying utilities may be vulnerable with 0.5 meters of sea level rise. With 1.0 and 2.0 meters, significantly more development potentially will be endangered, including buildings and additional utility lines. In a 2016 review of a UCSB project to install new stormwater and seawater pipelines under Lagoon Road, the Coastal Commission summarized that the estimated bluff erosion rate with sea level rise was between approximately 12 and 16 inches a year. This would put the new pipelines potentially in danger from cliff erosion within 20 to 25 years.[115] Therefore, the Commission conditioned the project to require monitoring and the removal of the infrastructure when necessary, consistent with existing LRDP Policy (GEO-3, GEO-4).

In April 2020, the campus placed a rock revetment below the sewer pump station at the east entrance to the University. The rock revetment was not ultimately permitted by the Coastal Commission and was removed. Further analysis of the vulnerability of the pump station is now needed in the near term, including identification of alternatives to address any vulnerabilities identified. For example, it may be better to protect the structure with a sheet pile wall or similar concept closer to the pump station. The potential for accelerated erosion fronting the station, and the possibility of extreme storm wave runup and inundation should also be evaluated. Any strategy should be coordinated with a current assessment of longer-term adaptation strategies for Goleta Beach and surrounding infrastructure that are being considered by Santa Barbara County Parks, and with the evaluation of this critical campus support system that is being conducted by facilities management. This would include consideration of relocation alternatives for the sewer pump station and existing sewer lines that connect the campus through the pump station to the Goleta Sanitary District.

[115] https://documents.coastal.ca.gov/reports/2016/10/th24b-10-2016.pdf.

Figure 4.34. CoSMoS projected Cliff Edge with 0.5, 1.0 and 2.0 meters of SLR.

Figure 4.35. CoSMoS Projected Cliff Edge with 0.5, 1.0 and 2.0 meters of SLR.

Figure 4.36. The “pinch-point” at Anacapa Hall on Lagoon Road.

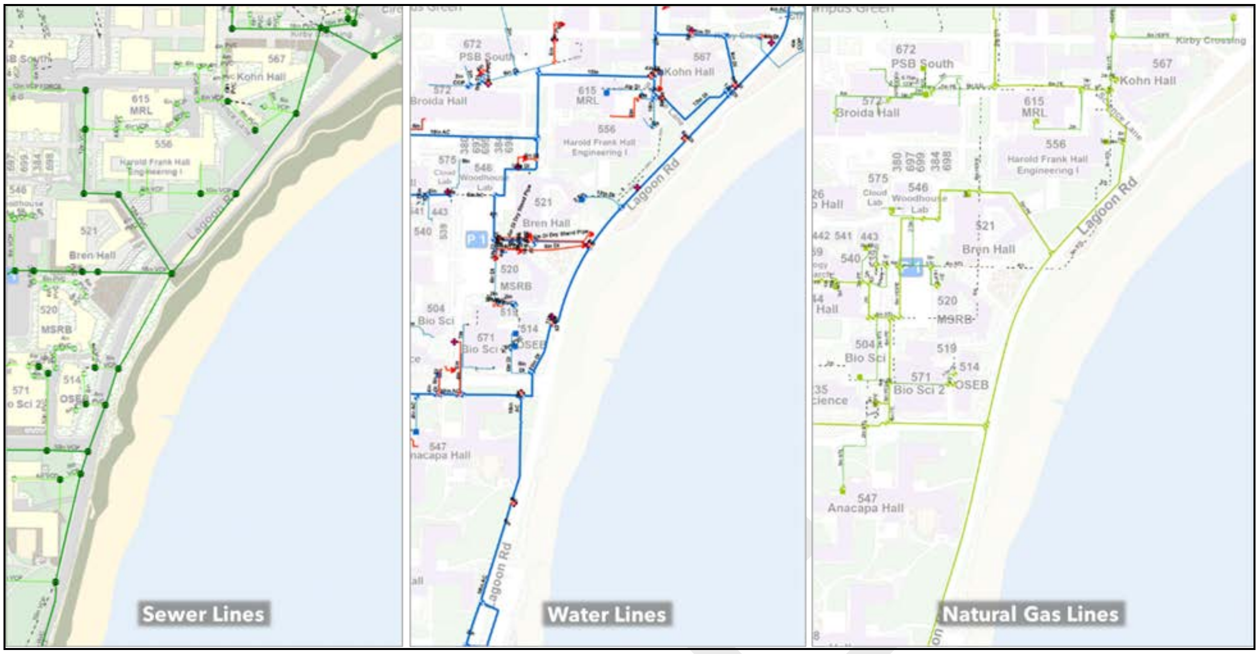

Figure 4.37. Illustrative Utility Lines along Lagoon Road.

There is a short term erosion concern in Area 4 yet unaddressed. Figure 4.36 shows the narrowest point along Lagoon Road where development is most threatened by erosion. This also is the location where a bluff protection project has been preliminarily considered to protect Lagoon Road. In 2017, the cliff edge was observed to be approximately 14 feet from the Lagoon Road curbline, and 60 feet from Anacapa Hall. [116] In 2020, UCSB prepared a draft CEQA analysis of a proposed shotcrete wall on the surface of the bluff to slow the erosion.[117] Part of that analysis concluded that the bluff was potentially subject to failure well into the road corridor, with an estimated static factor of safety of 1.2. or less. The document concludes, therefore, that Lagoon Road is "at imminent risk of failure."[118] This is a significant vulnerability, as "Lagoon Road is a primary traffic corridor servicing the eastside of the UCSB campus, . . . [and] provides primary access for emergency vehicles, including fire trucks, to this portion of the campus."

[116] TerraCosta, July, 2017. Coastal Bluff Evaluation And Geotechnical Basis Of Design Emergency Upper Bluff Stabilization Anacapa Hall, Uc Santa Barbara, Santa Barbara, California.

[117] https://files.ceqanet.opr.ca.gov/259903-2/attachment/SZlp_nSWEFSQJbf1vhSfTgZAhLMZJgmT1FpKLYjtCwVVV6280b5z-FznORNJ0E8_cGx_gG0SVyKP1SkZ0.

[118] Draft Initial Study Mitigated Negative Declaration, East Bluff Stabilization Project, February 2020, p. 2-2.

Figure 4.38. Slope Failure Projections for Lagoon Road, 2017.[119]

4.4.2.2. East Bluffs Beach

The beach along the Lagoon Road corridor is also vulnerable to sea level rise, particularly if protective strategies were to be pursued for the built environment along the corridor. Without armoring or significantly accelerated sea level rise, one might expect a beach to remain in general equilibrium with the ocean and cliff. However, as sea level rises, erosion would occur more frequently and at progressively higher elevations along the shoreline. And as the bluff or back beach erodes, more space, and sediment, is created to nourish the beach. As discussed in Chapter 3, sand inputs from along the shoreline system are also critical to maintaining this beach zone. However, if the rate of sea level rise outpaces the ability of the back-beach environment to erode, and thus regress inland, the beach would be overtaken in a process termed "passive erosion"-- also known as the "coastal squeeze." There is a little doubt that the beach along the East Bluffs, including all of its ecological, recreational and aesthetic values, would be lost to rising seas over the long run if the bluffs were armored with seawalls or revetments. However, if the bluffs are allowed to continue to erode, there may continue to be a beach. This will depend on continued sand supply, the rates of sea

[119] Terracosta Id.

level rise, and the rates of bluff erosion – a function of the underlying geology (see Areas 1 and 2 discussions).

Sand replenishment also is a countervailing strategy that can compensate for beach erosion, but it comes with considerable uncertainty as to effectiveness, and can be quite expensive and short-lived.[120] Similar to Area 3, it may be that further study identifies strategies of replenishment in conjunction with retention structures that might help offset beach loss. Such studies would need to consider the larger subregional and regional sand supply trends and dynamics.

4.4.3. Area 4 SLR Adaptation Strategy

Area 4 presents the most challenging sea level rise vulnerabilities for UCSB. There are significant campus resources along the Lagoon Road corridor, including buildings, infrastructure, public access and the road itself. Given the high, eroding bluffs, and the important beach resource below, the University faces difficult choices when considering how to adapt to sea level rise. Consistent with the University vision, though, a variety of monitoring, study and immediate and long-term actions are recommended that would facilitate a phased retreat of the built environment to maximize natural shoreline dynamics and resource values.

4.4.3.1 Monitoring

Significant monitoring of the East Bluffs and adjacent beach is on-going, both as required by the Coastal Commission and as part of on-going scientific research by UCSB and USGS. This monitoring will be critical to adaptive management in Area 4. Knowing the location of the bluff edge, and the possible failure planes of the bluff is necessary to anticipate when development will need to be relocated or potentially protected in emergency conditions (see below). Monitoring is also important to keep track of beach trends, including changes to shoreline position, beach ecology and recreational opportunities. Consistent with other Areas, the LRDP should be amended to develop and implement a comprehensive shoreline monitoring program.

4.4.3.2 Adaptation Studies

Multiple studies or additional planning is also needed in Area 4. First, an assessment of EEMB's marine facilities and other development, and the possibilities for redevelopment or incremental retreat at that location should be conducted. This examination should consider the connected shoreline segment from the beach restroom structure along the length of the existing revetment. Any recommendations should also be developed in conjunction with planning for the adjacent down-coast Lagoon Road corridor.

[120] Griggs, et al. 2020.

Second, a managed retreat/shoreline management plan should be developed for the corridor that considers the details for implementing managed retreat along Lagoon Road, or that explains why this is not feasible and justifies another strategy (such as bluff armoring, e.g.).[121] Such a plan should consider the alternatives for infrastructure and public access, such as phased realignment, redesign and ultimately relocation of utilities, road and public access developments. The goal of such a plan should be to have the menu of adaptation "moves" identified and ready for implementation based on relevant triggers tied to monitoring bluff conditions.

The managed retreat plan should also be considered in conjunction with a third research prong, which is to consider options for maintaining a buffering beach through replenishment and retention interventions, particularly if bluff protection is needed at some point. As summarized by the Advisory Committee:

> *The potential for emulating or enhancing natural features that could slow the rate of longshore transport to enhance the retention of sand and the width of campus beaches should be explored as a possible adaptation approach that can both protect vulnerable infrastructure and conserve their replaceable ecological and recreational resources of UCSB campus beaches. The design and implementation of low relief permeable sand retention structures could provide a means to increase sand residence time on campus beaches while reducing potential impacts to downcast beaches.*

Finally, further assessment is needed to determine if the sewer pump station needs to be protected from erosion in the near-term and if so, the best way to do this so as to maximize beach access and ecological resources. This assessment should also consider potential relocation over the longer-run, and be coordinated with other agencies, including Santa Barbara County and perhaps BEACON. Relocation of the sewer lines to the existing pump station would be included in the assessment.

4.4.3.3. Adaptation Actions

There are several adaptation actions that should be initiated as soon as possible to facilitate the vision of managed retreat in Area 4.

1. An assessment and identification of preferred action should be completed for the immediately vulnerable development at the Anacapa Hall "pinch point." This should be done in close coordination with the Coastal Commission and other interested parties. Emergency shoreline protection should only be considered if absolutely necessary to avoid public endangerment or closure of the Lagoon Road corridor in the near term. Temporary closure or realignment of Lagoon Road, including lane narrowing, should be considered.

[121] LRDP Policy GEO-10 states that "[t]he east-facing bluffs will be protected from future erosion only if campus development becomes immediately threatened, consistent with Policy SH-06."

2. Campus planning should coordinate with Campus facility managers to identify and assess all anticipated capital improvements projects, both buildings and infrastructure. This assessment should be integrated into strategies for shoreline management to avoid unnecessary investments in development that may create future vulnerabilities.
3. Any actions identified in the corridor managed retreat/shoreline management plan should be funded and implemented as may be recommended.

4.5 Area 5 – North Bluffs and Storke Campus

Area 5 encompasses lands adjacent to the northern boundary of Main Campus, running approximately 2.5 miles along Goleta Slough and the Storke Campus. In contrast to Areas 2, 3 and 4, where shoreline erosion is a major concern, Area 5 adaptation strategies address the primary vulnerability of risks caused by flooding and elevated groundwater and wetland change due to sea level rise exacerbated by storm surges and large runoff over the longer term. Recommended strategies include monitoring, collaboration with adjacent management partners, and accelerated strategy development and implementation for continued restoration in the Storke/Goleta Slough wetland system.

4.5.1 Shoreline Characterization

The Area 5 shoreline runs approximately parallel to Mesa Road, including the higher elevation "upper Mesa" north bluffs, down to a lower elevation portion of Mesa Road, and then along the Storke Campus perimeter to its intersection with the restored upper Devereux Slough in North Campus (Figure 4.39). On the UCSB campus, this shoreline extent includes the North Bluff, all Storke Campus wetlands and adjacent uplands, the Public Safety facilities (Santa Barbara Fire Station 17 and UC Santa Barbara Police Department), Communication Services, Mesa Road, the Facilities Management offices and yard, Los Carneros Road, Storke Family Housing, Santa Ynez Apartments, and the San Joaquin Villages development. More broadly, Area 5 is the interface with significant potentially vulnerable resources in other jurisdictions, including the Goleta West Sanitary District Office, Storke Ranch (within the City of Goleta), the Goleta Slough itself, Highway 217, the Santa Barbara airport, and the portions of Hollister Avenue and Fairview Avenue that are respectively located north and east of the Santa Barbara Airport.

Figure 4.39. Area 5 Shoreline – Goleta Slough and Storke Campus

North Bluffs

The North Bluff terrace is a generally flat surface that gently descends along Mesa Road to the northwest from about 54 feet (NAVD) near the roundabout to about 34 feet just before the facilities management (FM) site. The bluff face down to Goleta Slough is vegetated with coast live oak woodland – a unique occurrence on the UCSB main campus. Managed by CCBER, the area is a remnant of a much larger historical oak woodland.[122]

[122] See: https://www.ccber.ucsb.edu/ecosystem/management-areas/north-bluff.

Figure 4.40. Oak Woodland below the North Bluffs

The entire North Bluff area within UCSB's boundary is also located within the Goleta Slough Ecosystem Management Plan Boundary and adjacent to the Goleta Slough Ecological Reserve.[123] The Goleta Slough Ecosystem covers over 2,200 acres of sensitive wetland habitat area between the Santa Barbara Airport and UC Santa Barbara (including all wetlands on the Storke Campus discussed below) on the west and More Mesa on the east. A number of agencies have regulatory authority in the area and are part of the Goleta Slough Management Committee (GSMC). These include the City of Santa Barbara, the City of Goleta, the County of Santa Barbara, UCSB, several special districts, and several state and federal resource protection agencies.

[123] See Part 2, Background, of the 2015 Goleta Slough Management Plan, https://www.goletaslough.org/committee/2016-goleta-slough-management-plan/.

Figure 4.41. A View Over Goleta Slough from the North Bluffs.

Stroke Campus and Wetlands

The Storke Campus Wetlands and adjacent uplands create a large, 76.5-acre regional greenbelt that spans from the east edge of San Joaquin Villages (West Storke Wetlands) to the west side of Harder Stadium (East Storke Wetlands) (Figure 4.42). The area around West Storke Wetlands includes significant residential development. Storke Family Housing consists of 1- to 3-story apartments and houses over 300 residents. The Santa Ynez Apartments are two stories and house 800 third- and fourth-year undergraduate students. San Joaquin Villages and Santa Catalina, houses over 2,300 third- and fourth-year undergraduate students. Historically subject to tidal influence, the Storke wetlands have undergone numerous restoration efforts, including the San Joaquin Wetland Restoration, the San Clemente Restoration, the Lot 38 Restoration Site and Lot 38 Bioswale, and the Greenwaste Area Restoration site . The CCBER Greenhouse and Nursery is also located in this area, adjacent to the Greenwaste Area restoration site.[124]

[124] See CCBER, https://www.ccber.ucsb.edu/ecosystem/management-areas.

Figure 4.42. CCBER Storke Wetlands Management Area.[125]

4.5.2. SLR Hazards and Vulnerability Assessment

Most of Area 5 along the North Bluffs is not significantly threatened by sea level rise. However, the lower elevations along Mesa Road and on Storke Campus already are exposed to flooding during extreme events, and will be exposed to increased flooding due to sea level rise over the long run. Potential tsunami risk also exists for this area. Further, elevated groundwater tables driven by sea level rise may threaten underground utilities in the region before overland flooding becomes prominent. Goleta Slough, too, faces significant changes with long-term sea level rise.

4.5.2.1. Upper North Bluffs

Most of the North Bluffs section of Area 5 is at an elevation well-above mean sea level and any reasonably foreseeable sea level rise over the next 80 years. So, although this sub area includes significant infrastructure for campus, particularly the major transportation corridor of Mesa Road, rising waters will not impact most of this development, even in the most extreme scenarios. As shown in Figure 4.43, Mesa Road runs from about elevation 55 feet NAVD at the roundabout northwest to approximately 35 feet near the Facilities Management (FM) site, at which point the slope steepens down to about 19 feet at the entrance to the FM site. The mean high high water elevation of Goleta Slough is 5.25 feet (NAVD).

[125] CCBER, *Id.*

Figure 4.43. Elevations Along Mesa Road and Interface with Goleta Slough.

In addition to Mesa Road, this segment includes pedestrian trails and a scenic overlook (Figure 4.44). Several major utilities, including potable water, reclaimed water, and high-voltage electric lines, are located in and along various portions of the Mesa road corridor. Ten stormwater system outfalls also are located along the north side of the road/bluff and east of the Public Safety site.[126] At the top of Mesa Road, north of the Steck Circle roundabout, there is an approximately one-acre property, formerly an easement for SoCal Gas, currently in an Open Space land use designation.[127] Further down the slope of Mesa Road, the Police, Fire, and Communications buildings are across from the FM site on the Slough side of Mesa Road, discussed in more detail below. Central Stores and Mail Services are located along Mesa Road west of FM. In addition, there is an access road coming off of Mesa Road down into the Slough area (Figure 4.45 and 4.46), that serves Goleta West Sanitary District. Further west, the planning segment continues as a developed boundary, on both sides, connecting up with Area 1 (the Coal Oil Point Reserve segment near the top of the restored Devereux Lagoon); see Figure 4.2.

[126] The Main Campus is served by over 70,000 linear feet of mostly underground storm drains, with pipes ranging in size from 4-36 inches. All storm water is discharged into the lower-lying Goleta Slough, Campus Lagoon, Storke Campus wetlands, Devereux Slough, and, ultimately, to the Pacific Ocean.
[127] SoCal Gas is in the process of decommissioning the site, after which the easement will be quitclaimed back to the University.

Figure 4.44. Mesa Road View above Goleta Slough & from the Slough up to Mesa Road.

Figure 4.45. Goleta West Sanitary District, on lower Mesa Road.

Figure 4.46. Access Road into Goleta Slough, below Mesa Road.

Given the elevation of the North Bluff, there appears to be little direct campus resource vulnerability to sea level rise along this stretch. CoSMoS modeling shows the extent of flooding stopping at the base of the bluff, only elevating gradually up the slope with increased projections and storm conditions (Figure 4.47). Even with 2 meters of projected sea level rise and the 100-year storm, there is no projected flooding of physical structures other than possibly the end of the utility road below the bluff (Figure 4.47).[128] This assessment is consistent with the conclusions of the City of Goleta vulnerability assessment from 2015.[129] With respect to the stormwater outfalls along this segment, any impact in the immediate term is unlikely, and monitoring will be part of the plan (see below). However, future groundwater elevations and impacts to campus drainage should be assessed over the longer run, as 1 meter (3.3 feet of SLR will potentially result in adverse impacts from higher groundwater (Figure 4.48). Finally, there will no doubt be significant changes to the Goleta Slough wetland system with sea level rise, as increased water levels, salinity, and finite accommodation space influence ecosystem evolution and health. The interaction of wetland change and flooding is discussed in more detail below.

[128] LRDP Policy ESH-37 both requires that the Goleta Slough bluffs remain in, or be restored to, natural conditions, and prohibits the construction of retaining walls or other remediation on the bluff face.
[129] City of Goleta, 2015. City of Goleta Coastal Hazards Vulnerability Assessment and Fiscal Impact Report.

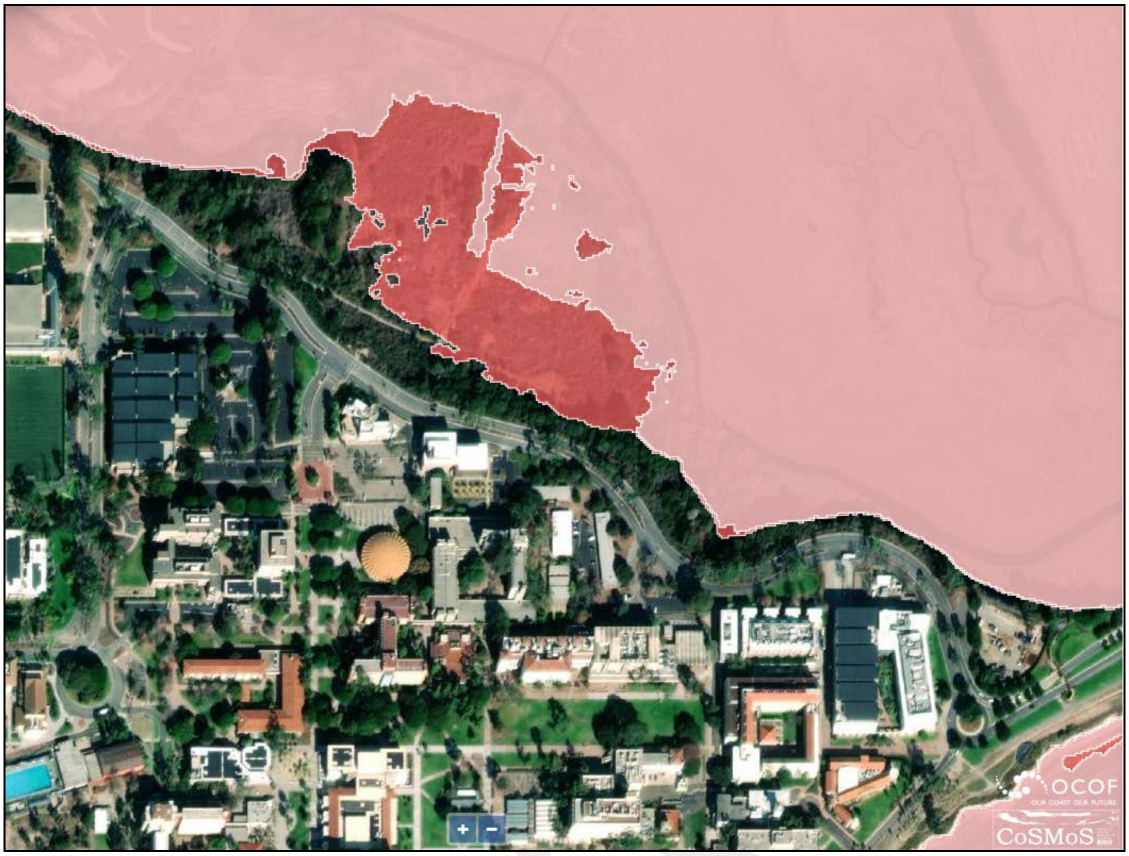

Figure 4.47. North Bluffs, maximum flooding with 2 Meters of SLR and 100-yr Storm.

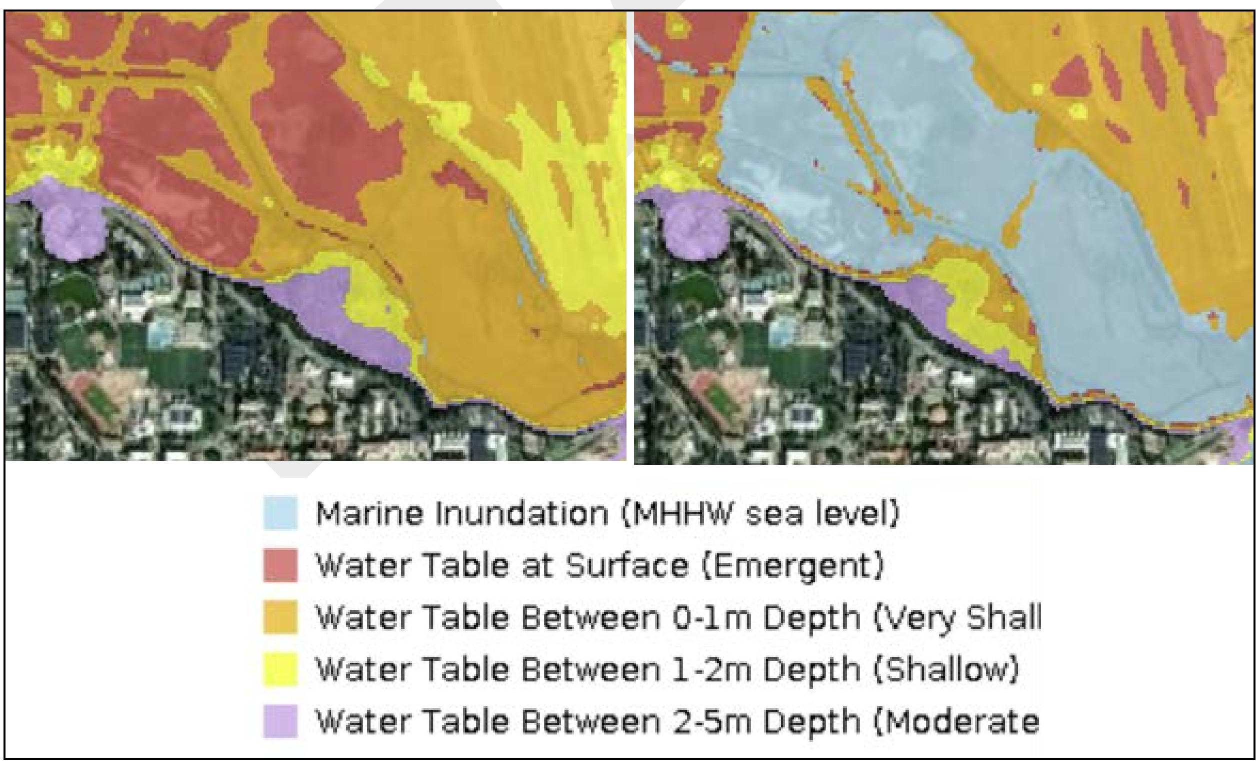

Figure 4.48. Groundwater change below Mesa Road, CoSMoS, 0-3.3 feet SLR.

4.5.2.2. Lower Mesa Road

Lower Mesa Road presents more significant vulnerabilities to flooding of UCSB and other facilities. Campus facilities here include Public Safety facilities (Santa Barbara Fire Station 17 and UC Santa Barbara Police Department) and Communications Services on the Slough side of Mesa Road, and the Facilities Management (FM) offices and yard on the inland side (Figure 4.48 and 4.49). The FM site is designated in the LRDP for student housing. The Goleta West Sanitary District office is immediately adjacent to the Public Safety site.

Figure 4.48. Developed Sites along Lower Mesa Road.

Figure 4.49. UCSB Police and Fire Station on Lower Mesa Road

Both the Public Safety and Communication Services site are currently vulnerable to extreme flooding events, as illustrated by the CoSMoS modeling of the annual storm event in these locations (Figure 4.52). They are also shown in the FEMA-mapped 100 year flood zone, though based on an examination of Lidar elevations, the FEMA map does appear to be slightly misaligned with the aerial photography for the area (Figure 4.50 see below).

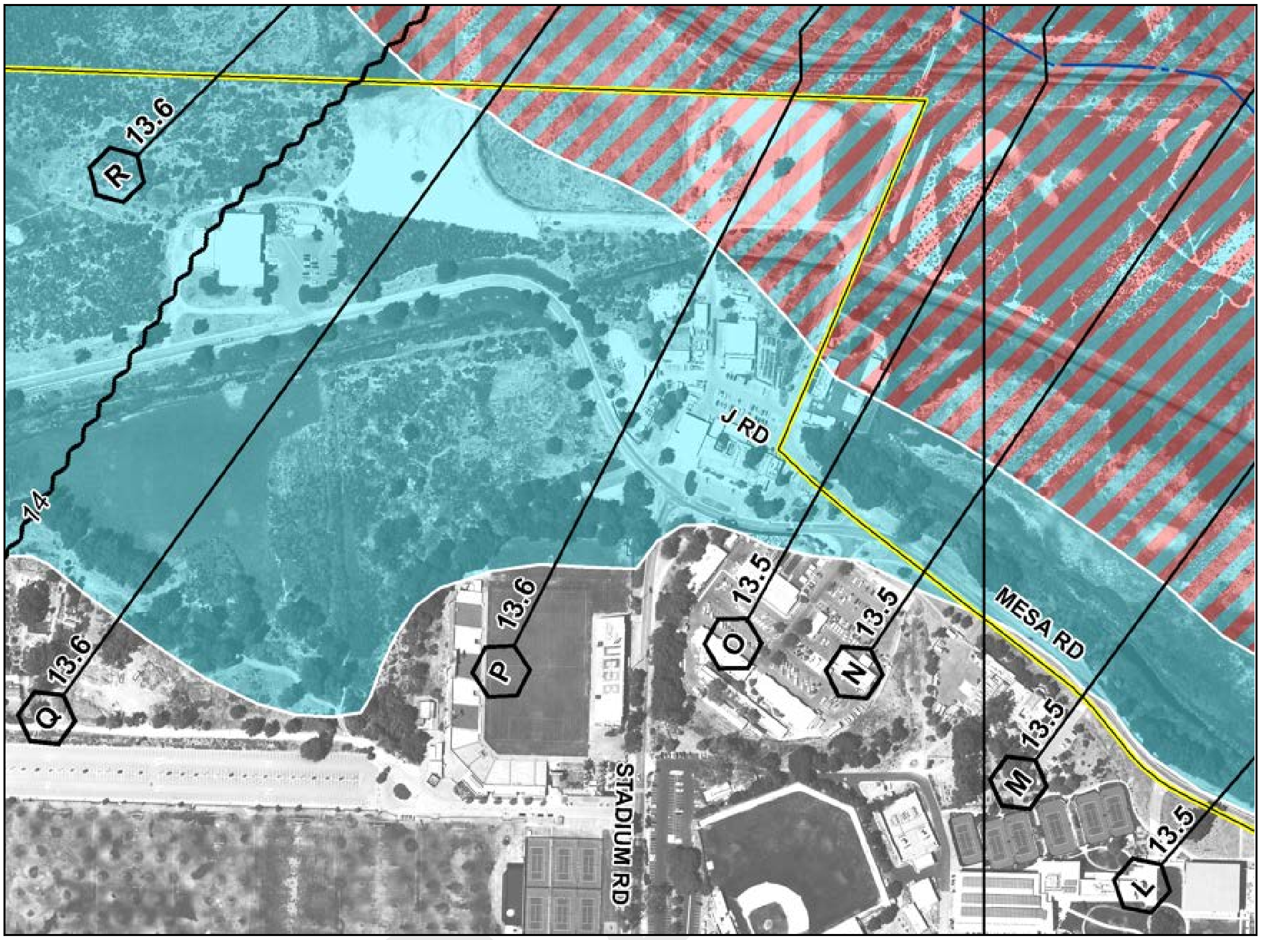

Figure 4.50. FEMA Flood Map, Lower Mesa Road.

As discussed below, the development of both these nodes could be removed providing for wetland restoration. On the other hand, though not part of the campus, it is significant that the Goleta West Sanitary District is just completing the construction of a floodwall around its perimeter, designed to keep the site safe from flooding up to elevation 15' NAVD (Figure 4.51). According to the CEQA analysis for the project, this would accommodate a sea level rise of approximately 10 feet from the mean high elevation of Goleta Slough for the life of the project, though there is little discussion of combined future conditions of a 100-year flood with that amount of sea level rise. However, the City of Santa Barbara did condition the coastal development permit for the project to require on-going monitoring and coordination with surrounding jurisdictions, including future consideration of relocation.[130] It is also unclear if rising groundwater levels would be a concern at this site.

Figure 4.51. Goleta West Sanitary District Flood Wall

There would appear to be no significant flooding risk to the FM site, even with projected 2 meters of sea level rise and the 100-year storm. However, the site for a possible new retention basin associated with proposed residential development at the FM site is currently subject to potential flooding (Figure 4.52), and certainly would be increasingly inundated during storm events with higher sea levels (Figure 4.54). CoSMoS projections also show the potential for increasingly shallow groundwater along the lower Mesa Road corridor, which could undermine road foundations and threaten underground utilities where water tables depths are shallower than 2 meters though even with 2 meters of sea level rise, locations south of Mesa Road maintain depths to groundwater of mostly 2-5 meters (Figure 4.55). More detailed hydrological assessment is underway for potential development at the FM site.

[130] City of Santa Barbara CDP, Condition D(11):

> *Future Sea Level Rise and Flood Protection Assessment. Sea level rise conditions at the Goleta Slough shall be reassessed by the Goleta West Sanitary District as new information becomes available to ensure proper sea level rise and flooding protection is maintained for the life of the facility. Research and technologies using the best available science, studies, and building codes shall be used. The district shall continue to participate in the inter-jurisdictional planning efforts with the Goleta Slough Management Committee and explore all feasible management options, including relocation, protect in place, dredging, levees, Goleta Slough mouth management or additional floodwalls (MM-HYD-1).*

There will be long-term flooding risks, particularly from extreme events, along the primary access routes of Carneros and Mesa Roads. This flooding potential should be incorporated into monitoring in this area, so that appropriate flood contingencies can be put in place. Over the very long run, alternative transportation strategies, such as elevating the roads, may be necessary.

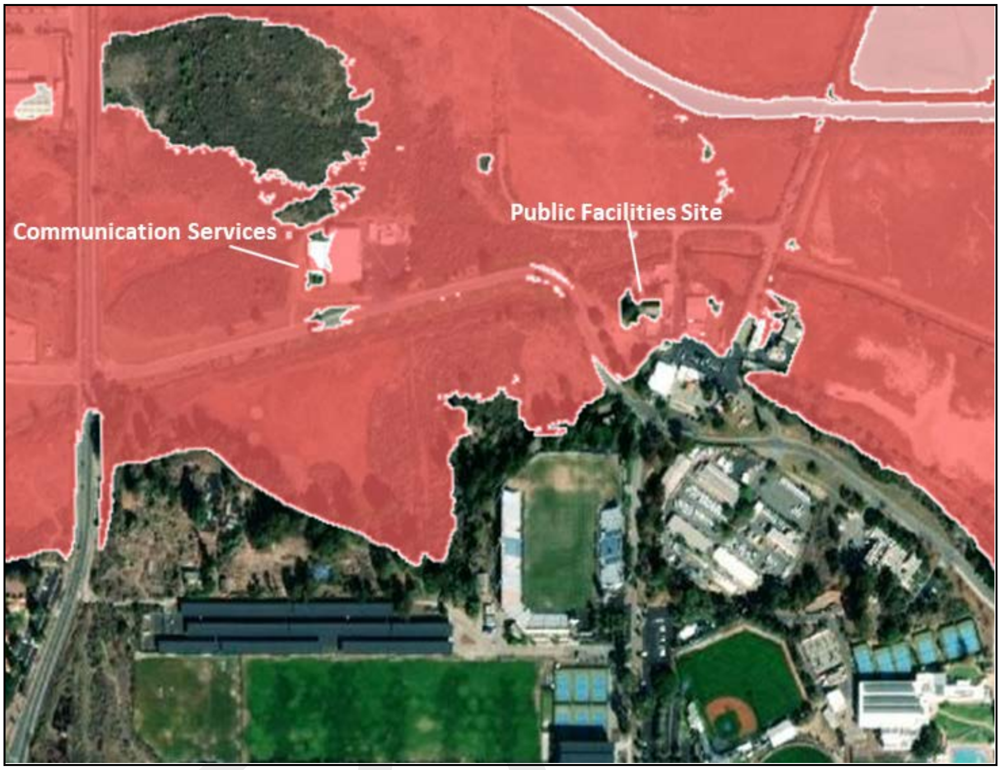

Figure 4.52. Annual Maximum Potential Storm Flooding Today.

Figure 4.53. Facilities Management Site Entrance at elevations 18-20 feet NAVD.

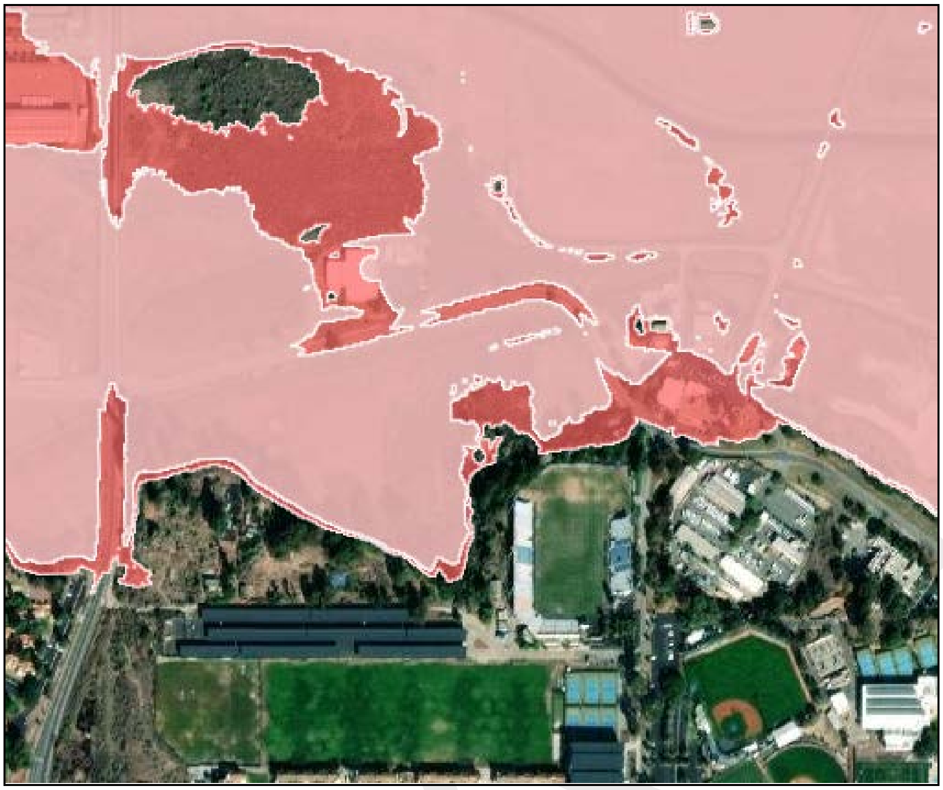

Figure 4.54. CoSMoS Potential Flooding, 2 meters SLR, 100-yr Storm.

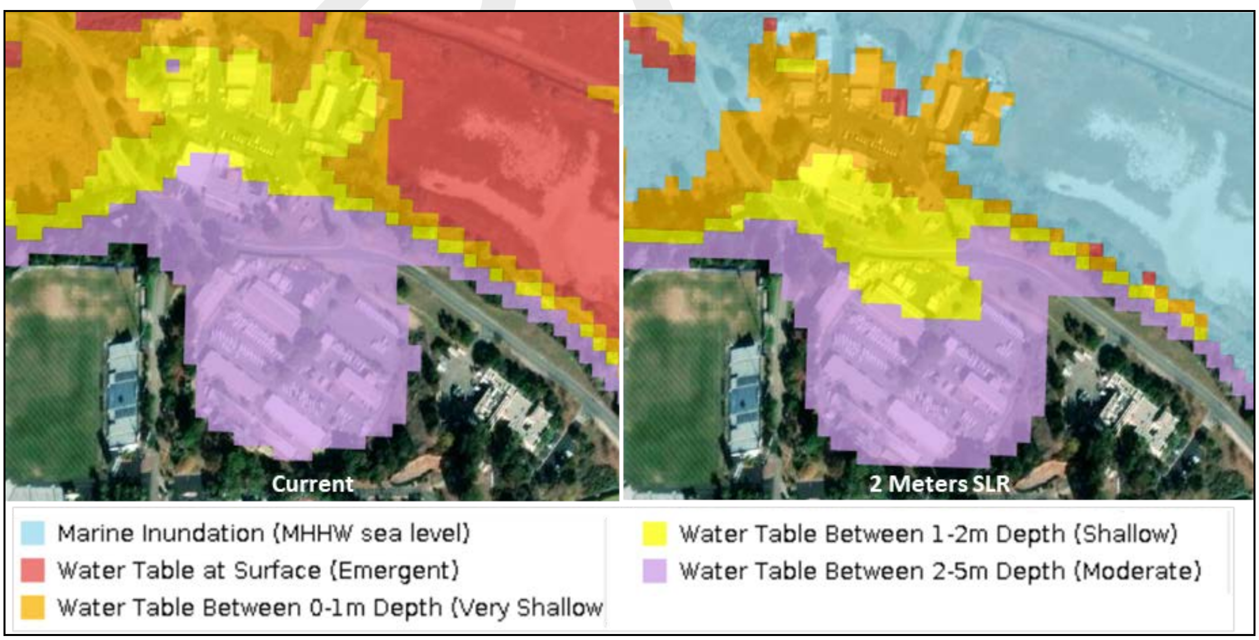

Figure 4.55. Depth to Groundwater Change at FM site, current to 2 meters of SLR.

Finally, recently updated tsunami flood maps show some risk to lower elevations along Mesa Road (and to the Airport, e.g.) at maximum tsunami water level scenarios of 16 feet above mean sea level today. With projected sea level rise over the long run, this potential extreme event could begin to encroach on campus development sites, such as sites north of Mesa Road, and potentially across Mesa to the Facilities Management site. For example, with six feet of sea level rise, the maximum event would be ~22 feet above mean sea level, which is a little higher than the current elevation at the FM site entrance along Mesa Road. This possibility, as well as flooding along Carneros Road, should be addressed through campus emergency services planning.[131]

Figure 4.56. Maximum Tsunami Inundation at Goleta Slough.

4.5.2.3. Storke Campus

The primary development vulnerability in the Storke Campus section of Area 5 is potential flooding in the vicinity of Storke Family Housing, the Santa Ynez Apartments, the San Joaquin Villages, and portions of Los Carneros Road. As with Mesa Road, Los Carneros is an important transportation corridor into the campus. Again, various utilities along the roads in the area include, but are not necessarily limited to, potable water, electric street lights, storm drains, sewer, natural gas, and high-voltage electricity. Similar to the lower elevations along Mesa Road, the Storke Family Housing complex and Los Carneros Road are subject to potential extreme storm flooding now, according to FEMA Flood Hazard mapping and CoSMoS modeling of maximum flooding, taking into account uncertainty in the modeling,[132] and certainly with 2 meters

[131] https://www.emergency.ucsb.edu/emergency-response-procedures/tsunami.
[132] CoSMos Modeling uncertainty is plus or minus 50 cm. See, https://data.pointblue.org/apps/ocof2_flood_map/images/infographics/min_max_flooding.png.

of sea level rise (Figures 4.57, 4.58, 4.59). Further, rising water tables may pose a significant problem in the mid to longer-term to roads and utilities.

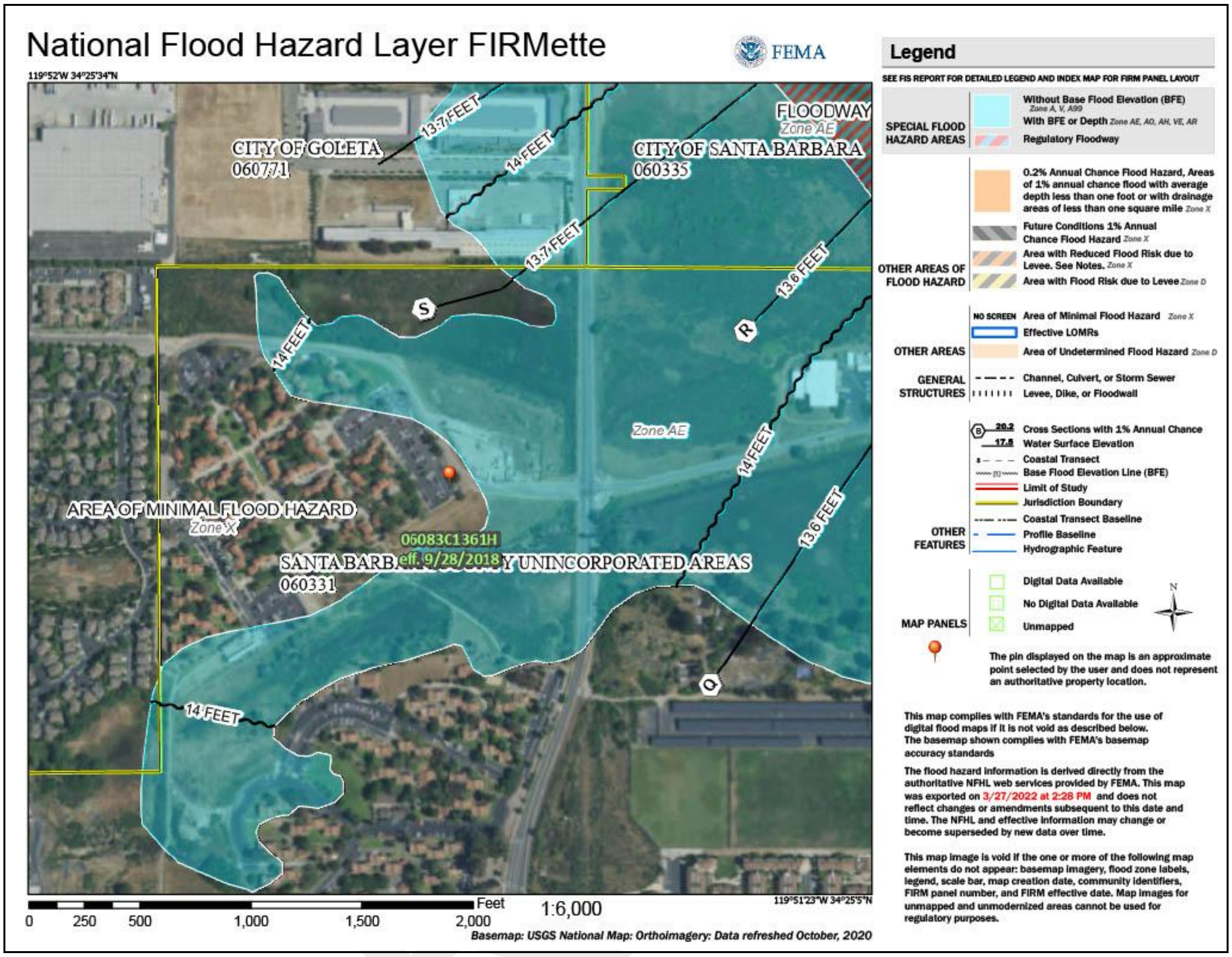

Figure 4.57. FEMA 100-year Flood Mapping at Storke Apartments.

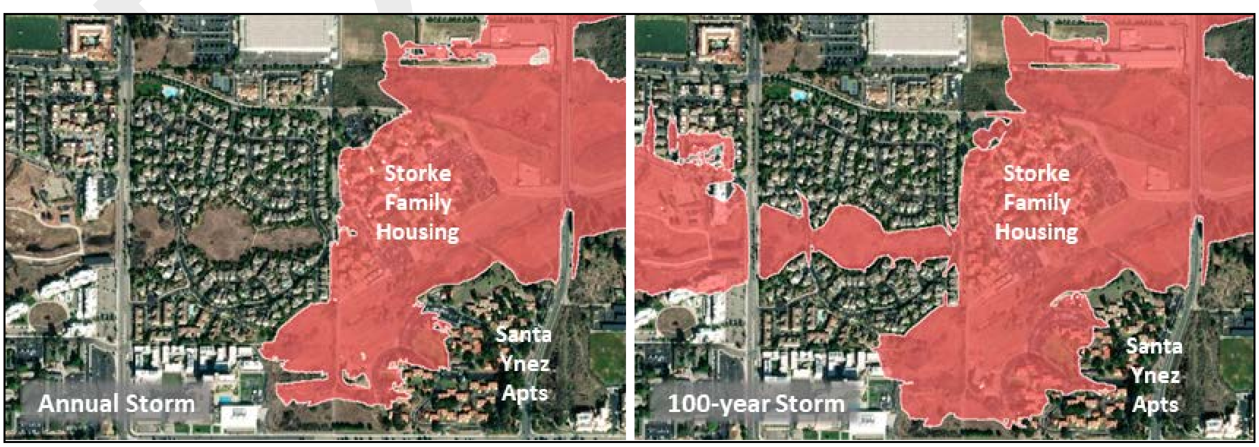

Figure 4.58. Current Maximum Flooding with Annual and 100-year Storm (CoSMoS).

Figure 4.59. Min-Max Flooding with 2 meters of SLR and 100-year Storm (CoSMoS).

Given the current potential flooding and the incremental increases possible with both larger storms and increasing sea levels, the nature of the flood hazard for the Storke and Santa Ynez housing in this vicinity is characterized by an increasing frequency of extreme event flooding, not necessarily concern for permanent inundation. As shown in Figure 4.60, even with 2 meters of sea level rise, daily ebbing and flowing of tidal inundation does not reach University housing, though certainly the airport and low-lying surrounding areas will have a concern with more regular flooding. In terms of campus vulnerabilities, the functioning of utilities such as wastewater, water supply and storm drainage infrastructure could be increasingly at risk with rising sea levels, shallower water tables, and more regular flooding.

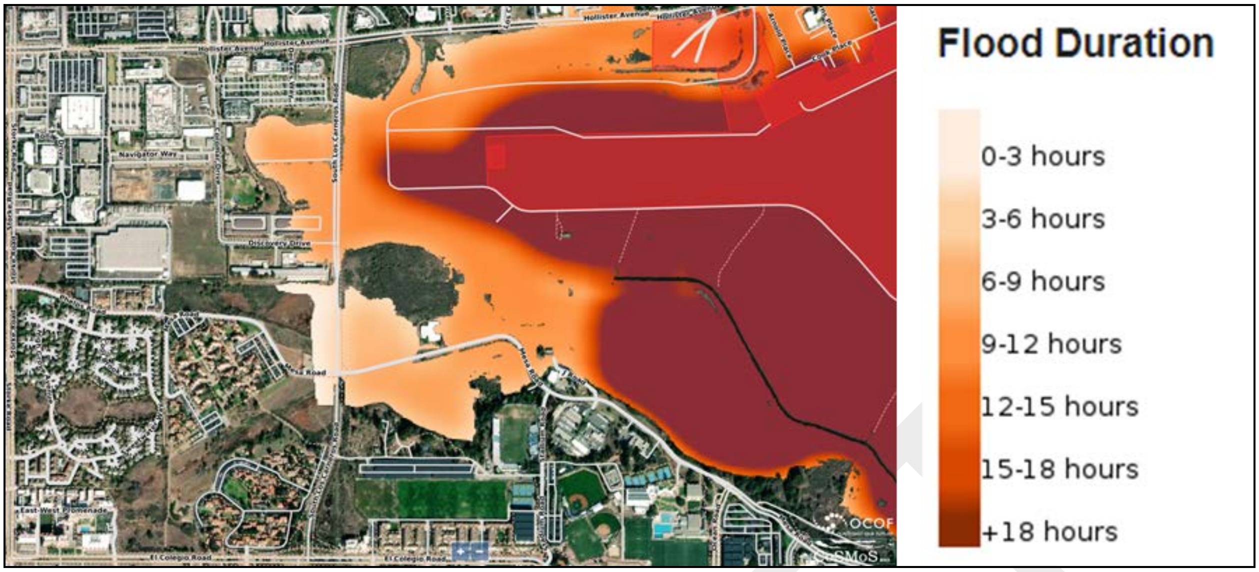

Figure 4.60. Flood Duration with 2 meters of Sea Level Rise (CoSMoS).

Goleta Slough/Storke Wetlands

The most significant vulnerability in Area 5 may be the potential changes to the Goleta Slough wetland system itself. Though more study is needed, significant studies of potential changes to the wetland system with sea level rise have been completed in recent years. The Goleta Slough Management Committee's 2015 study of sea level rise vulnerabilities shows significant changes to wetland habitats depending on changes in sea level rise and sedimentation into the Slough (Figure 4.61). And as summarized by the recently convened UCSB scientific advisory committee, "there will need to be discussion on the desired mix of future wetland habitats and how to develop and manage for those habitats in the face of sea level rise and coastal flooding." Another important aspect of this consideration will be the potential role of expanded restoration into the Storke wetland complex, and how this might affect not only flood risk, but the nature of wetland change itself.This will be an important area of further study and collaboration with adjacent jurisdictions, also, given the significant flood risks to the airport and parts of Goleta, such as Old Town. Chapter 3 includes a discussion of the general dynamics and considerations for future adaptation in Goleta Slough.

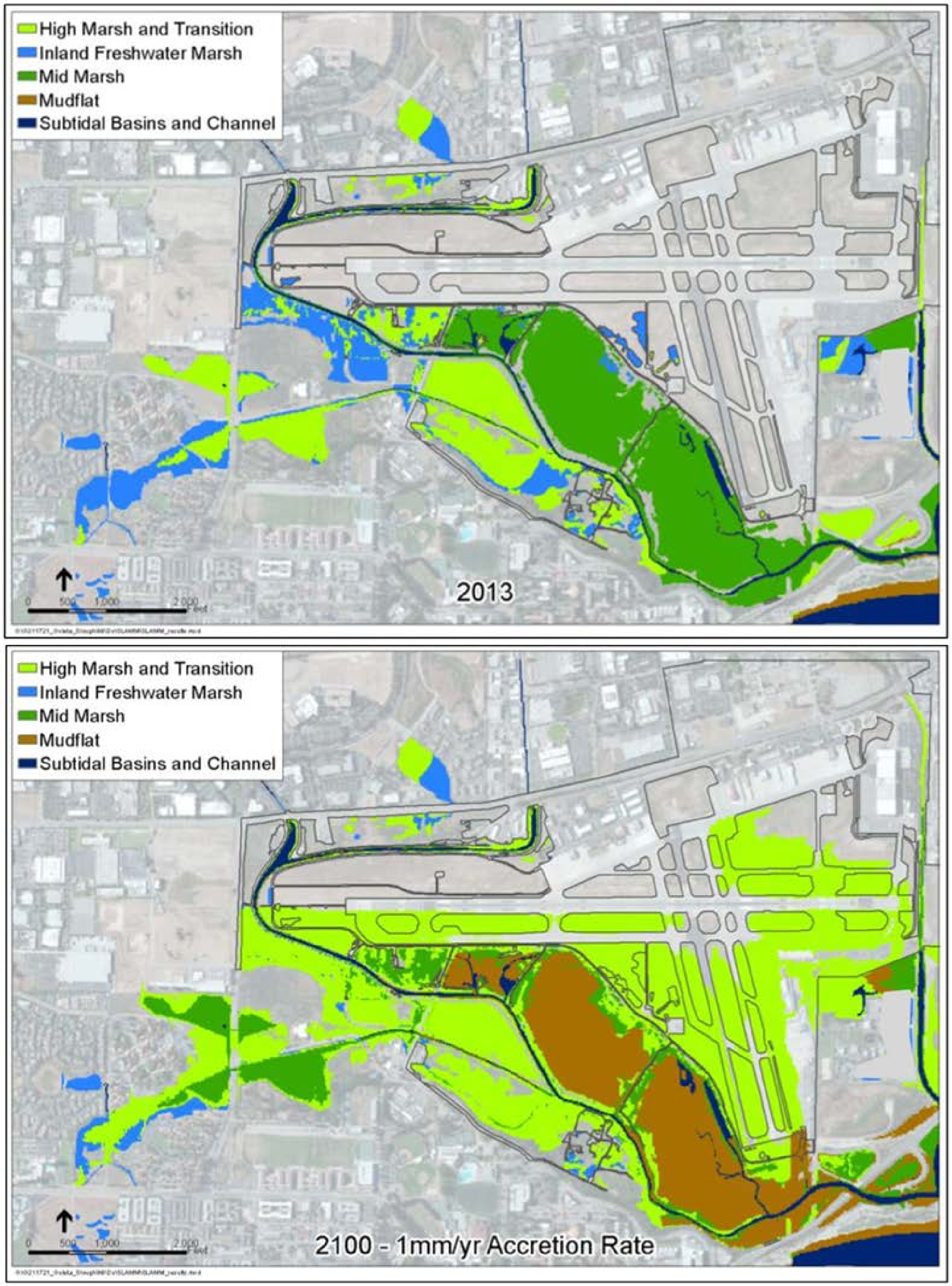

Figure 4.61. Potential Habitat Changes in Goleta Slough system with sea level rise (ESA 2015).

4.5.3. Area 5 SLR Adaptation Strategy

The Area 5 adaptation strategy broadly consists of LRDP updates to implement wetland, flooding and infrastructure monitoring, collaborate with adjacent jurisdictions and the Goleta Slough Management Committee, conduct several focused studies, and anticipate specific phased, managed retreat of development nodes north of Mesa Road and potentially parts of Storke Campus, in conjunction with wetland restoration. The objective of these pathways is to maximize wetland resource values and flood mitigation for the campus and adjacent areas, and assure continued access to and along the Storke and Main campus areas.

4.3.3.1 Monitoring

Monitoring of extreme flood events in Area 5 will be important for potentially triggering flood mitigation measures or relocation strategies over the long-term. In addition, monitoring of public services in potential flooding zones, such as storm drain outfalls, wastewater and water supply lines will assure timely replacement or relocation of these as necessary. Scientific monitoring and assessment of changing wetland conditions will also contribute to long-term management of Goleta Slough, including future restoration strategies to protect habitat/slough functions and expand flood mitigation capacity (see below). As discussed for other areas, Recommended LRDP Amendment SH-03(A) directs that UCSB design, fund and implement a comprehensive shoreline monitoring program. This should include consolidating and updating already-existing monitoring programs and efforts as necessary.[133] The time frame for initiating implementation of this recommendation is 1-3 years.

4.3.3.2 Adaptation Studies

As with other areas, targeted follow-up study or planning is needed to identify future specific adaptation actions in Area 5. With respect to vulnerable development nodes north of lower Mesa Road, plans will be needed for the relocation of police, fire and other UCSB support facilities in consideration of both overland flooding hazards and shallower groundwater. LRDP Amendment SH-08(j) directs that these plans be completed within 5 years of certification of this Amendment. Another proposed policy also provides for the interim use of flood walls as may be necessary until such time as relocation is completed.

Concerning Goleta Slough, there is a need to assess the desired mix of future wetland habitats in relation to future sea level rise, flooding and restoration scenarios. This is consistent with existing LRDP policy SH-03.[134] Ideally, planning will target a mix of

[133] The LRDP already requires monitoring of various resource trends, including public access parking (PA-05), campus water quality (WQ-03) and restoration objectives on open space lands (OS-09). Policy SH-05 also requires the University to participate in regional shoreline monitoring to identify sea level rise concerns. NOID USC-NOID-0003-16 specifically requires cliff edge monitoring along Lagoon Road in order to anticipate the need to relocate infrastructure along that corridor (see Area 4 discussion).
[134] Policy SH-03 - After completing the Comprehensive Sea Level Rise Hazards Assessment required pursuant to Policy SH-01, the University shall continue to research and respond to the impacts of sea

different habitat types to preserve native biodiversity and ecosystem functioning. Priority should be given to those habitats that support state and/or federally-listed endangered and threatened species and species of conservation concern, while maximizing flood capacity and mitigation of potential impacts to surrounding development. This study should evaluate the feasibility of: allowing wetland transgression through available suitable habitat; topographic modification such as through the manipulation of sediment supply; manipulation of hydrology to protect specific habitat types; and regional mitigation opportunities for unavoidable wetland loss. To support this work, more information is needed about the tidal dynamics and hydrology of Goleta Slough; water quality; sediment accretion (or erosion, subsidence); biological resources, including gaps on ecological functions of wetlands adjacent to UCSB, and mapping of non-native species.[135]

The study and planning for Goleta Slough should focus on certain critical questions, including:

- the criteria for, and target mix of habitats desired under SLR scenarios;
- the triggers or thresholds to initiate adaptation measures (e.g., water level, time);
- whether and when to reconnect the Storke and CDFW wetlands to Goleta Slough;
- the availability of restoration opportunities to mitigate for unavoidable loss of habitat available on or around UCSB;

4.3.3.3 Adaptation Actions

The most important actions to address sea level rise in Area 5 are in the longer-term future, as water levels and the potential for extreme flooding increase, though groundwater hazards should be evaluated more thoroughly. However, in the short term, it is important for UCSB to continue implementing existing LRDP Policy SH-05 by collaborating with the Goleta Slough Management Committee and participating jurisdictions about actions in and around the slough that will affect water management

level rise on the campus along the Goleta Slough and Pacific Ocean shoreline. On-going efforts to respond to SLR-related hazards may include: A. Continue to gather information on the effects of sea level rise on the shoreline, particularly the most vulnerable areas identified in the Comprehensive Sea Level Rise Hazards Analysis. Participate, as possible, in regional assessments of sea level rise vulnerability, risk and adaptation planning efforts to ensure compatible treatment for sea level rise across jurisdictional boundaries; B. Updating the Best Available Science, consistent with regional policy efforts, as new, peer-reviewed studies on sea level rise become available and as agencies such as the OPC or the CCC issue updates to their guidance reports; and C. Amending the LRDP to add policies and provisions that address the impacts of sea level rise based on information gathered over time. Modifications to address SLR may include: relocating proposed development envelopes, changes to land use designations, relocating utilities, updates to the public access plan to ensure long-term protection of the function and connectivity of existing public access and recreation resources.

[135] Notably, LRDP Policy MAR-02 states: "The University shall work with the City of Santa Barbara and other interested parties to evaluate the benefits and feasibility of reestablishing tidal influx from Goleta Slough into the Storke Wetlands through the City of Santa Barbara's tidal gates. Where feasible and beneficial, restore the tidal connection."

and flood mitigation strategies in the future.[136] In particular, the City of Santa Barbara and the Airport are embarking on a three-year project consisting of a vulnerability assessment, adaptation plan and LCP update for the Santa Barbara Airport that will have direct implications for SLR adaptation in Area 5.

It is also important for UCSB to support and ideally initiate the additional study required, to position the campus for investing in and taking actions to restore wetland resources and retreat development nodes north of Mesa Road. This should include implementation of a utility and flood monitoring program to anticipate any necessary mitigation of utility and transportation impacts. Depending on the progression of sea level rise and extreme events, it may also be necessary to implement an interim floodwall protection plan for lower Mesa Road and Storke Campus. Wetland restoration could also begin in the next decade.

In the long run, adaptation actions include relocating and restoration of development nodes north of Mesa Road, continuing restoration of wetlands adjacent to Goleta Slough, and potential redevelopment of housing areas in the Storke Campus.[137] UCSB should also work with the City of Goleta, the Airport and other interested parties on assessment of long-term adaptation actions to protect Carneros Road from flooding in extreme events.

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[136] Policy SH-05 - The University will coordinate vulnerability assessments and adaptation planning with other regional jurisdictions that face common threats from sea-level rise, including the Goleta Slough management planning efforts, and will participate in regional studies of sea level rise vulnerability and adaptation, and in shoreline monitoring to identify sea level rise concerns.

[137] The LRDP notes: "Storke Family housing has rapidly deteriorated due to problems with its initial construction. All 342 existing units must therefore be removed and will be replaced with up to 390 additional units (730 site total)"; and "[Santa Ynez Apartments] would be redeveloped to ultimately provide a total of 580 apartments. The existing 180 units would be removed and replaced along with an additional 400 units . . . ." Policy LU-22 already requires a specific sea level rise assessment of redevelopment of Storke Family housing.

4.6 Regional Vulnerabilities and Adaptation Strategies

As discussed in Chapter 3, UCSB is an important asset in and relies on, the Santa Barbara coastal region. The LRDP should be amended as necessary to address such regional connections.

For example, the rivers and creeks are major sources driving regional/subregional (littoral cell) shoreline dynamics. It is important, therefore, that UCSB support and participate in planning for adaptation to regional trends with other actors in the UCSB region, such as BEACON and local governments.

One subregional dynamic that is important are the connections between Isla Vista shoreline and development trends and the surrounding campus. It may behoove UCSB to explore opportunities to integrate managed retreat and housing strategies in Isla Vista with the long run adaptation strategies for the campus, particularly in Areas 2 and 3.

Similarly, UCSB should continue to coordinate closely with the City of Santa Barbara and the Airport, both because of the shared interest in planning for Goleta Slough, and because of the economic significance of the airport to the University and the region. The recently initiated vulnerability and LCP planning for the airport will be an important opportunity for such coordination.

Likewise, UCSB should continue to coordinate with adjacent jurisdictions and Caltrans concerning long-term planning for the transportation network. Currently, small portions of Hollister Avenue, Los Carneros and South Fairview Avenue flood, and are vulnerable to 1 meter of sea level rise, even without an annual storm. Similarly, an off-campus portion of Highway 217 may flood in the longer term, though this risk is currently being assessed. Figure 4.62 shows 2m SLR with 100-year storm.

Figure 4.62. Flooding with 2 meters SLR at Highway 217.

5.0 LRDP Amendments to Address Sea Level Rise Adaptation

This Chapter identifies the LRDP amendments necessary to implement the UCSB Shoreline Adaptation Strategy. Changes to the LRDP are shown with underline for proposed new or additional text, and ~~strike-out~~ for proposed deletions of existing text.

1. Amend LRDP (Pg. A-3) to incorporate shoreline management vision

INTEGRATE SUSTAINABLE PRACTICES

As environmental stewards, the campus will minimize its impact on the environment by:

- Reducing automobile use by increasing housing on or near campus
- Defining and protecting environmentally sensitive areas of the campus, including coastal resources
- Continuing implementation of environmentally friendly transportation programs including bicycling, carshare, vanpools, and public transit
- Continuing to expand enhancement programs for the surrounding natural environment: the sloughs, lagoon, and shoreline, including through shoreline restoration and proactive, phased, managed adaptation to climate change-driven shoreline change.
- Working toward becoming a more "carbon-neutral" campus
- Managing resources sustainably through increased conservation programs and by incorporating state-of-the-art efficiency measures into campus development.

2. Amend Sustainability text (pg. C-12) to address climate adaptation.

. . .

BUILT ENVIRONMENT

Create superior places to study, work, and live that enhance the health and performance of building occupants through sustainable planning, design, construction, operations, retrofits, and bio-mimicry. Site and design new buildings and other development to avoid shoreline hazards for their economic life and to avoid the need for shoreline protection. Relocate and remove development as necessary to maximize a natural shoreline at UCSB.

. . .

LANDSCAPE/BIOTIC ENVIRONMENT

Protect and maintain the natural environment through restoration, preservation, and education while enhancing the role of campus as classroom. This includes open space areas, recreational areas, building landscapes, and native habitat. Adapt the built environment to natural shoreline features and processes to the maximum extent feasible.

3. Amend LRDP (pg. F-40) to incorporate SLR Adaptation Strategy

LRDP Policies

Given the evolving nature of climate change science as well as the site-specific considerations, UCSB adopted a Sea Level Rise Adaptation Strategy that has been incorporated into the LRDP. T~~t~~he policies below, and other policies of the LRDP as amended to reflect the Adaptation Strategy, rely heavily on research, best available science, vulnerability studies, coastal hazards assessments, and the incorporation of feedback loops and adaptation measures. The campus currently has three areas where shoreline devices protect existing facilities. Large rocks or revetment at the base of the bluff protect the east bluffs from erosion and extend to the south to protect the seawater pump station, the Marine Sciences Laboratory, and the Campus Lagoon. Berms have been constructed on the east and west ends of the Lagoon to prevent the lagoon from draining into the ocean. While some maintenance is necessary to protect the berm between the lagoon and the beach, no other protective devices are anticipated in the LRDP. As reflected in the Adaptation Strategy, the LRDP supports a vision to maximize campus resilience and protect and restore natural shorelines, through proactive, phased, managed adaptation to sea level rise and shoreline change.

4. Amend Implementation Policy 1-4 to Address Monitoring

1.4 MONITORING OF DEVELOPMENT PROJECTS, ENVIRONMENTAL CONDITIONS, AND SEA LEVEL RISE ADAPTATION STRATEGY

The University shall be responsible for ensuring that all terms, and conditions, and mitigation measures associated with authorized development projects, including but not limited to mitigation measures and CEQA/NEPA requirements, are fulfilled. Project managers and other UC personnel assigned responsibility to implement and/or monitor authorized development projects or environmental conditions shall contact the Director of Campus Planning and Design annually by the end of each calendar year to provide information regarding compliance with the terms and conditions of each LRDP authorization that year and continuing obligations from authorizations in previous years, as well as implementation of the UCSB Sea Level Rise Adaptation Strategy.

5. Amend Open Space Policies to Incorporate Sea Level Rise Strategy

Policy OS-04: The University shall provide for the comprehensive planning, tracking, management, and monitoring of the OS-designated lands, consistent with the UCSB Sea Level Rise Adaptation Strategy and in accordance with the following: . . .

Policy OS-09: Within three years after certification of the 2010 LRDP Update, the University shall prepare and submit an LRDP Open Space Management Plan for certification as an LRDP amendment. . . .

> 10. The Plan shall include monitoring and adaptive management provisions sufficient to ensure that the restoration goals and success

criteria are ultimately achieved and to ensure consistency with the Sea Level Rise Adaptation Strategy. Individual restoration projects shall be monitored for a minimum of five consecutive years and until the restoration has been demonstrated to be a success.

6. Amend Policy SH-01 to Address Sea Level Rise Adaptation

Policy SH-01 - Implement and update every ten years the UCSB Sea Level Rise Adaptation Strategy. Updates shall consider as may be necessary and indicated by environmental monitoring, revised vulnerability assessments using the best available science, adaptation strategies to achieve the University's shoreline adaptation vision, and necessary implementing LRDP amendments. ~~Within five years of certification of the 2010 LRDP, the University shall prepare a Comprehensive Sea Level Rise Hazards Assessment for submittal to the Coastal Commission as an Amendment to the LRDP that addresses the anticipated impacts of sea level rise on the campus along the Goleta Slough and Pacific Ocean shoreline. The Plan shall be available prior to submitting a NOID for development or redevelopment that is located along the north boundary of the Storke Campus~~
~~or at the Facilities Management site. The Plan shall:~~
~~A. Identify the most vulnerable areas, structures, facilities, and resources; specifically areas with priority uses such as beaches, public access and recreation resources, ESHA and wetlands, wetland restoration areas, open space areas where future wetland or habitat migration would be possible, and existing and planned sites for critical infrastructure.~~
~~B. Include a detailed sea level rise vulnerability and risk assessment, either as an independent effort, or in conjunction with other assessments, such as the Goleta Slough multi-jurisdictional planning effort, that includes a specific analysis of the vulnerable areas and coastal resources in subsection "a" above. The vulnerability and risk assessment shall use best available science and multiple scenarios including best available scientific projections of expected sea level rise, such as by the Ocean Protection Council [e.g. 2013 OPC Guidance on Sea Level Rise], National Research~~
~~Council, Intergovernmental Panel on Climate Change, and the West Coast Governors Alliance.~~
~~C. Based on the vulnerability analysis, identify campus areas that are potentially subject to the effects of sea level rise for the purpose of determining whether a detailed site-specific coastal hazards analysis will be required consistent with Policy SH-02 and Policy SH-04.~~
~~D. Recommend adaptation management strategies that would minimize risks to coastal resources and development due to hazards associated with sea level rise. Adaptation management strategies may include:~~
~~• Relocating existing development to safer locations~~
~~• Siting new development to avoid areas vulnerable to flooding, inundation, and erosion;~~
~~• Modifying land use designations and individual campus uses, and developing siting and design standards for new development, to avoid and minimize risks;~~
~~• Establishing conservation areas to allow wetland and habitat migration;~~

~~• Creating an adaptive public access plan that maximizes access to and along the shore as the effects of sea level rise are realized.~~
~~E. Analyze sea-level rise impacts at both the site-specific and regional scales. The Plan must evaluate how sea-level rise impacts from the littoral cell or watershed (such as expected changes in sediment supply, increases or reductions in stream flows, post-fire sediment pulses, etc.) could affect the campus. Additionally, the Plan must evaluate how options to adapt to sea-level rise could result in cumulative impacts to other areas in the littoral cell or watershed, and should recommend actions to minimize any impacts.~~
~~F. The Assessment shall identify the recommendations that will require processing through an LRDP Amendment to be effectuated.~~

7. Amend Policy SH-02 to Address Sea Level Rise Adaptation

Policy SH-02 - New development shall be sited to avoid potential flooding, inundation, and erosion hazards created or exacerbated by long-range SLR, and as may be required by the Sea Level Rise Adaptation Strategy. New development that is potentially subject to the effects of sea level rise shall require a current (prepared within the past 2 years) coastal hazards assessment as described in Policy SH-04. Based on the coastal hazards assessment, new development and redevelopment shall be sited to avoid any hazards anticipated during the life of the structure and to avoid the need for bluff retaining or shoreline protection devices. Hazard avoidance efforts shall not result in impacts to coastal resources or encroachment into coastal habitats and shall not undermine broader ecosystem sustainability; for example, siting and design of new development must not only avoid sea-level rise hazards, but also ensure that the development does not have unintended adverse consequences that impact sensitive habitats or species in the area. The assessment must also consider the potential need for larger setbacks near ESHA and natural open spaces to allow for habitat sustainability and migration.

8. Amend Policy SH-03(A) to Require Comprehensive Monitoring

Policy SH-03 - To implement ~~After completing~~ the Comprehensive Sea Level Rise Hazards Assessment required pursuant to Policy SH-01, the University shall continue to research, monitor and respond to the impacts of sea level rise on the campus along the Goleta Slough and Pacific Ocean shoreline. On-going efforts to respond to SLR-related hazards shall ~~may~~ include:

A. A comprehensive monitoring program ~~Continue~~ to gather and report, to the maximum extent feasible, information on the effects of sea level rise on the shoreline for purposes of triggering adaptation action, particularly concerning the most vulnerable areas identified in the UCSB Sea Level Rise Adaptation Strategy, ~~Comprehensive Sea Level Rise Hazards Analysis.~~ including but not limited to: sea level rise trends in the Santa Barbara region as may be available; shoreline and bluff erosion and potential impacts to the built environment, public access and other coastal resources, at regular intervals no less frequent than every 3 years; flooding events as necessary but at least every 3 years; water table levels continuously and monthly if feasible; indicators for sensitive species and habitat, hydrology, erosion and other ecological health measures for the COPR and NCOS system and Campus Lagoon; and beach ecology and recreational use on all campus beaches. The monitoring program shall integrate existing LRDP monitoring requirements as necessary, identify thresholds or triggers for adaptive action consistent with the Adaptation Strategy, and include an implementation component that addresses funding needs and sources and an administrative structure. UCSB shall support coordination between campus programs as required, and development of specific monitoring protocols in coordination with campus programs such as COPR and NCOS. COPR and NCOS shall coordinate to maximize extent feasible to facilitate adaptation of the ecological system to climate change. The program shall be prepared within 3 years of certification of this amended policy. Participate, as possible, in regional assessments of sea level rise vulnerability, risk and adaptation planning efforts to ensure compatible treatment for sea level rise across jurisdictional boundaries;

9. Amend Policy SH-04 to Address Sea Level Rise Adaptation

Policy SH-04 - A site-specific coastal hazards study shall be prepared by technical experts (e.g., geologic, geo-technical, hydrologic, and engineering professionals, as appropriate) in combination with planning professionals to address the potential hazards from erosion, flooding, wave attack, scour and other conditions created or exacerbated by SLR. The study shall use the best available science, consistent with the UCSB Sea Level Rise Adaptation Strategy, and consider multiple SLR scenarios including best available scientific projections of SLR such as by the Ocean Protection Council, NOAA Inter-agency Working Group on Sea Level Rise and Coastal Flood Hazard Scenarios and Tools, and the ~~National Research Council,~~ Intergovernmental Panel on Climate Change~~, and the West Coast Governors Alliance~~. All input parameters for hazard analysis shall be clearly described in the analysis and, if judgment was used to choose between a range of values, the basis for the selection should be provided. The study shall identify the anticipated economic life of the structure(s), assess the ease of removal or adaptation, and recommend applicable adaptation management strategies, including siting and design measures, that eliminate or reduce hazards and that are consistent with all policies and provisions of the certified LRDP.

10. Amend Policy SH-05 to Address Regional Adaptation Needs

Policy SH-05 - The University will coordinate implementation of the UCSB Sea Level Rise Adaptation Strategy and any future vulnerability assessments and adaptation planning with other regional jurisdictions that face common threats from sea-level rise, including the Goleta Slough management planning efforts, and will participate in regional studies of sea level rise vulnerability and adaptation, and in shoreline monitoring to identify sea level rise concerns.

11. Amend Policy SH-06 to Address Sea Level Rise Adaptation

Policy SH-06 - Shoreline structures, including revetments, seawalls, cliff retaining walls, or other such construction that alters natural shoreline processes shall be prohibited except as may be consistent with the Sea Level Rise Adaptation Strategy and where there is no less environmentally-damaging alternative for the protection of existing development or to serve coastal- dependent uses, or to protect public beaches in danger from erosion. Any such structures shall be sited to avoid sensitive resources and designed to minimize, to the maximum extent feasible, the alteration of natural land forms, and eliminate or mitigate adverse impacts on public access and on local shoreline sand supply. Visual impacts shall be minimized through siting the structures as far inland as possible, using a narrow profile or small footprint structure if possible, inclusion of living shoreline or bioengineering techniques, and the use of appropriate colors and materials. Structures shall be removed at such time as the structure is no longer needed for its permitted purpose.

12. Add New Policy SH-08 to Direct Future Sea Level Rise Studies

SH-08. The University shall, as necessary, anticipate and conduct the following studies to identify and trigger future sea level rise adaptation actions, consistent with the Sea Level Rise Adaptation Strategy:

a. Wetland Transgression Assessment – Lower Devereux Slough, to assess wetland restoration, expansion and migration opportunities, in addition to restoration of the north and south slough fingers, along the perimeter of lower Devereux Slough, to maximize opportunities for natural wetland transgression and persistence. The assessment shall be conducted in conjunction with or anticipating the triggering of action to close Slough Road to vehicular traffic, and develop a new road connection through West Campus Drive, as contemplated by LRDP Policy TRANS-12.
b. Coal Oil Point Building Demolition, Disposal, and Removal Plan, to trigger managed removal or relocation of existing structures at Coal Oil Point. The plan should specify the monitoring protocol for triggering removal to assure public safety.
c. West Campus Bluffs Coastal Resource Retreat Plan, to anticipate the need to retreat access trails and avoid emergency closures or impacts to sensitive wetlands and habitats. The plan should be developed in coordination with Santa Barbara County to address adjacent resources like the stairway at the southern end of Camino Majorca.
d. Campus Lagoon Management Study, as described in the Sea Level Rise Adaptation Strategy, to evaluate alternatives for natural shoreline recession and implications for hydrology, habitat, cultural resources, public access, and aesthetics at the lagoon; and assess alternative lagoon berm and edge management strategies to address the changing

hydrology and erosion, including options for removing the eastern and western weirs, the risks and reconfiguration options for existing public access, the seawater intake system and public restroom facility near the lagoon mouth. The update should recommend short term actions, such as temporary protection measures, during a "phase 1" assessment of the different lagoon scenarios; and phase 2 actions followed by monitoring and evaluation, to facilitate transition of the lagoon to a more open, tidally-influenced system. This phased strategy should be developed in coordination with adaptation strategies for Area 4 (Lagoon Road), and incorporated into the LRDP as an amendment to the Lagoon Management Plan.

e. Beach Transgression and Protection Study, to identify opportunities to provide more accommodation space for campus beaches, especially in locations such as dune-backed beaches at the lagoon boundaries, while maximizing protection of sensitive habitat such as plover areas at Sands Beach.
f. Campus Lagoon Marine Science Facilities Assessment, to explore redevelopment or incremental retreat of facilities at that location. This examination should consider the connected shoreline segment from the beach restroom structure along the length of the existing revetment. Any recommendations should be developed in conjunction with planning for the adjacent Lagoon Road corridor.
g. Lagoon Road Managed Retreat/Shoreline Management Plan to identify implementation triggers and actions for retreat of development along Lagoon Road, or that explains why this is not feasible and justifies another strategy (such as bluff armoring, e.g.). Such a plan should consider the alternatives for infrastructure and public access, such as phased realignment, redesign and ultimately relocation of utilities, road and public access developments. The goal of such a plan should be to have the menu of adaptation "moves" identified and ready for implementation based on relevant triggers tied to monitoring bluff conditions.
h. Beach Sand Replenishment and Retention Study, to consider options for maintaining a buffering beach along East Bluffs through replenishment and retention interventions,
i. Sewer Pump Station Assessment, to determine if the sewer pump station (Building 529) needs to be protected from erosion, groundwater or saltwater intrusion in the near-term and if so, the best way to do so considering maximum protection of beach access and ecological resources. This assessment should be coordinated with other agencies, including Santa Barbara County and perhaps BEACON.

j. Relocation Plan for Lower Mesa Road Development, within five years, to specify actions for the relocation of police, fire and other UCSB support facilities.
k. Goleta Slough wetland habitat study, consistent with the Sea Level Rise Adaptation Strategy and in coordination with adjacent partners, to assess the desired mix of future wetland habitats in relation to future sea level rise, flooding and restoration scenarios. This study should evaluate the feasibility of: allowing wetland transgression through available suitable habitat; topographic modification such as through the manipulation of sediment supply; manipulation of hydrology to protect specific habitat types; and regional mitigation opportunities for unavoidable wetland loss.

13. Add New Policy SH-09 to Direct Sea Level Rise Adaptation Actions

SH-09. The University shall plan for and implement the following shoreline adaptation actions as required, based on monitoring of environmental conditions and consistent with the Sea Level Rise Adaptation Strategy.

a. Development at Coal Oil Point (Cliff House (Building 362), Docent Office (Building 362.1), Dovecote (Building 362.2) shall be removed or relocated, consistent with a removal plan, before falling to the beach below or otherwise becoming a public hazard.
b. Public access trails and supporting amenities to and along the shoreline shall be maintained and relocated as necessary to avoid erosion threats. Monitor access trails and assure public safety along the bluff edge. Public safety measures, such as temporary fencing or signage should be used as necessary, while minimizing visual impacts. Access should be maintained to the maximum extent while avoiding impacts to sensitive environmental resources, such as blufftop vernal pools, to the maximum extent feasible. Consider realignment strategies that result in path stability for at least 5 years, to minimize disruption of habitat and other coastal resources over time. Enhance interpretive signage as needed. This program should be coordinated with existing LRDP requirements, such as OS-04, to consolidate informal trails to minimize erosion.
c. A new access stairway and supporting trails should be planned and developed in the vicinity of the Jail House. This project should assess the viability and/or feasibility of maintaining the Jail House in its current location as an integrated feature of an accessway from West Campus parking and, if necessary, assess alternatives to allowing the structure to stay on the beach as sea level rises. Any accessway should be designed to be resilient for a reasonable structure life, considering its cost of development.

d. Within five years of certification of the Sea Level Rise Adaptation Strategy, update the Campus Lagoon Management Plan consistent with the assessment of lagoon management alternatives assessed under SH-08. Pursuant to the updated plan, the University shall:
    i. replace and ultimately remove the eastern and western weirs as necessary consistent with the transition strategy;
    ii. Protect and Enhance Public Access by replacing the lagoon berm with a pedestrian bridge as may be required and consistent with the Lagoon transition plan.
    iii. Maintain and protect the seawater intake system consistent with the lagoon transition strategy.
    iv. Evaluate and pursue potential reconfigurations of the beach restroom facility in conjunction with adaptation strategies for development in Area 4.
    v. Plan the removal of debris and other hard armoring to the maximum extent feasible, consistent with the lagoon transition plan and protection of the seawater intake system.

e. Engage local tribal representatives to advise on recognition and protection of cultural heritage and resources. Monitor for and protect cultural resources, consistent with the LRDP, as they may become exposed due to cliff erosion.

f. Remove the existing revetment between Campus Point and eastern lagoon mouth and restore the shoreline as may be required. Evaluate and pursue as appropriate opportunities to finance implementation of this removal with mitigation monies from shoreline protection projects in the region.

g. Incrementally remove and relocate as necessary any existing infrastructure that may become exposed or potentially exposed in the immediate future.

h. In coordination with the Coastal Commission and other interested parties, identify and implement the preferred action to address immediately vulnerable development along Lagoon Road near Anacapa Hall Emergency shoreline protection should only be considered if absolutely necessary to avoid public endangerment or closure of the Lagoon Road corridor in the near term. Temporary closure or realignment of Lagoon Road, including lane narrowing, should be considered.

i. Campus planning shall coordinate with Campus facility managers to identify and assess all anticipated capital improvements projects (buildings and infrastructure) for consistency with the Sea Level Rise Adaptation Strategy. This assessment should be integrated into strategies for shoreline management to avoid unnecessary investments in development that may create future vulnerabilities.

j. Actions identified in the Lagoon Road Corridor managed retreat/shoreline management plan should be funded and implemented as may be recommended.
k. Conduct studies necessary to support restoration of wetland resources and retreat of development nodes north of Mesa Road. This should include implementation of a utility and flood monitoring program to anticipate any necessary mitigation of utility and transportation impacts.
l. As may be required, implement an interim floodwall protection plan for lower Mesa Road and Storke Campus, until such time as relocation of development is completed.
m. Coordinate the relocation and restoration of development nodes north of Mesa Road
n. Consider and implement restoration of wetlands adjacent to Goleta Slough in conjunction with potential redevelopment of housing areas in the Storke Campus.
o. Work with the City of Goleta, the Airport and other interested parties on assessment of long-term adaptation actions to protect Carneros Road from flooding in extreme events.

14. Amend Coal Oil Point Policy to address Climate Change

Policy ESH-50 – The University shall continue to implement the Commission-approved Beach Access and Snowy Plover Management Plan for the term authorized in the applicable Coastal Development Permit. An updated Plan shall be prepared by a qualified biologist or environmental resource specialist to address climate change and renew authorization of the program through the coastal development permit process.

Policy LU-33 – The Coal Oil Point Reserve shall be used and adapted for purposes of open space preservation, coastal wetland and wildlife habitat conservation, ~~and~~ restoration, and university-level teaching, ecological research, and public education to contribute to the understanding and wise stewardship of the Earth and its natural systems in the face of climate change. Development on the Coal Oil Point Reserve site shall be consistent with the following standards:

a. Development at the COPR shall include the enhancement, maintenance, and restoration of the natural resources on the site. Areas that provide or support endangered, threatened, or valuable species or habitats (because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments) shall continue to be protected and adapted to changing conditions, such as increasing sea level rise.

b. The Reserve shall continue to protect Western Snowy Plover at the Reserve with the goal to facilitate adaptation to climate change and reduce disturbance by beach users by increasing public awareness of snowy plover issues by maintaining a rope fence around the beach roost and nesting area to keep foot traffic away from sensitive snowy plover habitat, consistent with Policy ESH-50. The rope must be aligned in a manner in which public access would be maintained at all times, including, at a minimum, maintaining access through and along the wet sand area.

. . .

f. The Reserve Director shall work with the City of Goleta, the County of Santa Barbara, and other interested parties to ensure that the Reserve is managed within the larger context of its watershed and climate change, and to ensure that potential impacts to COPR from surrounding new development are mitigated appropriately.

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15. Update LRDP Policy TRANS-12 to Facilitate Wetland Adaptation.

Policy TRANS-12 - In order to prevent adverse effects to the Coal Oil Point Natural Reserve and Devereux Slough, the following roadway and circulation measures shall apply on West Campus:

A. Vehicular access to West Campus shall be from the intersection of Storke and El Colegio Roads. The Campus shall coordinate and contribute to the installation of traffic control devices and other improvements at that intersection;
B. Slough Road shall be converted exclusively to use by pedestrians, bicyclists, and essential emergency vehicles or further limited as may be required by sea level rise analysis pursuant to Policy SH-08, and shall not be expanded beyond its existing footprint. All West Campus development shall utilize West Campus Point Lane for vehicular access. Vehicular access to Coal Oil Point Reserve (the Reserve) and the ADA coastal access parking spaces at Coal Oil Point shall utilize West Campus Point Lane, but shall be allowed to merge onto Slough Road through the Devereux South Knoll site in order to reach the applicable destination. The conversion of Slough Road shall be completed (1) prior to occupancy of the first redevelopment project or other significant construction of 10,000 GSF or greater on West Campus at either the West Campus Mesa or North Knoll site; (2) as may be recommended b the sea level rise and wetland transgression assessment required by Policy SH-08; or (3) if nuisance flooding causes interim road closures more than 3 times a year or 10 total days a year.
C. The existing West Campus Point Lane crossing of the North Finger of Devereux Slough, from West Campus Mesa to North Knoll, shall be

replaced with a bridge, or alternative crossing that retains a natural open connection, to maximize wetland connectivity and avoid fill of wetlands. The construction of the new bridge or crossing shall be completed no later than prior to occupancy of the new residential construction on the North Knoll of the Devereux property or as may be recommended by the sea level rise and wetland transgression assessment. However, the bridge, or crossing, shall be installed earlier if significant structural changes or roadway modifications are necessary to accommodate traffic in the area of the Slough crossing prior to North Knoll development;

D. Emergency vehicle, bicycle and pedestrian access may be provided from the existing Isla Vista streets of Fortuna or Pasado Roads; and;

E. ~~Where~~ Unless deemed to be biologically detrimental ~~beneficial~~, the University will replace the wetland crossings on Slough Road with crossings that are designed to restore the connection between the North and South Fingers to Devereux Slough and to avoid fill of existing and historic boundaries of the wetland to the maximum extent feasible. The replacement will occur as funding is available or as may be recommended by the sea level rise and wetland transgression assessment. The University will pursue potential University and non-University funding options to implement this project.

16. Amend Policy MAR-03 to Address Campus Lagoon Adaptation

Policy MAR-03. Transition the lagoon mouth to a more open connection with ocean waters, as specified through the updated Lagoon Management Plan. Lagoon Berm Road may be maintained in the approved road prism consistent with typical repair and maintenance practices such as replenishing the fill and recompacting the fill slopes until such time as transition actions are identified and funded for implementation. Lagoon Berm Road shall not utilize rock revetments or seawalls to maintain the road prism. The road may be removed to adapt to rising sea level. Placement of sandbags or other temporary stability measures shall require a NOID or Emergency Permit.