

Economic Analysis of Nature-Based Adaptation to Climate Change
Ventura County, California

Prepared for:
The Nature Conservancy
201 Mission Street
San Francisco, CA 94105

Prepared by:
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, CA 94945
www.environcorp.com

and
ESA PWA
550 Kearny Street, Suite 800
San Francisco, CA 94108

Date:
February 13, 2015

Project Number:
30-32524A

ENVIRON

Contents

List of Appendices

Acronyms and Abbreviations

BCA	Benefit Cost Analysis
BCR	benefit to cost ratio
BWA	Beach Width Analysis
CAA	Coastal Armoring Alternative
CCSM	Community Climate System Model
CNRM	Centre National de Recherches Météorologiques
CRV:	Coastal Resilience Ventura
DIVA	Dynamic Interactive Vulnerability Assessment
DOF	Department of Finance
dSAY	Discounted Service Acre Year
EBA:	Engineering Based Adaptation
EIA	Economic Impact Analysis
EMHW	Extreme Monthly High Water
EPA	US Environmental Protection Agency
FEMA	Federal Emergency Management Agency
F-RAM	Flood Rapid Assessment Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluids Dynamics Laboratory
GIS	Geographic Information Systems
HEA	Habitat Equivalency Analysis
HSIs	Habitat Suitability Indices
IPCC	Intergovernmental Panel on Climate Change
NBA:	Nature Based Adaptation
NBVC:	Naval Base Ventura County
NCAR	National Center for Atmospheric Research
NESA	Net Ecosystem Services Analysis
NOAA	National Oceanic Atmospheric Administration
NPV	Net Present Value
NRC	National Research Council
PCM	Parallel Climate Model
SAYs	Service Acre Years

SLAMM: Sea Level Affecting Marshes Model

SLR: Sea Level Rise

TNC: The Nature Conservancy

USACE US Army Corps of Engineers

USFWS United States Fish and Wildlife Service

VWRF Ventura Water Reclamation Facility

Executive Summary

Communities facing climate change threats must identify cost effective responses to these threats. Proposed responses to climate change-induced sea level rise (SLR) are often focused on defensive engineering or coastal armoring approaches such as building dams, levees, seawalls, and channels to control flooding and provide storm protection. Such engineered responses may be necessary in some instances but can also cause their own adverse impacts to natural systems. The Nature Conservancy (TNC) has developed a decision-support network, Coastal Resilience, which provides tools and information to better inform stakeholders on climate change and disaster risk reduction, while emphasizing the important role of ecosystems in this process. ENVIRON and ESA PWA were retained by TNC to explore the question of whether nature-based interventions that capitalize on existing natural processes (e.g. wetland and dune restoration) could reduce risk from SLR effectively while still protecting the natural ecosystem functions.

This report is an economic analysis of two different responses to SLR in Ventura County, California. One response favors engineered solutions, and is referred to as the Coastal Armoring Adaptation strategy, or CAA, while the other is called the Nature Based Adaptation strategy, or NBA. The two strategies are evaluated for the major benefits and costs through time, including financial costs and benefits as well as ecosystem service gains and losses. This study is part of TNC's Coastal Resilience Ventura (CRV) project (http://coastalresilience.org/project-areas/ventura-county-introduction). The work builds on the prior forecasting and mapping of climate change-induced hazards that have been developed through this cooperative effort.

The two alternative adaptation approaches for the Ventura coastline were developed with input from local stakeholders. Neither strategy is composed strictly of one approach or the other, with both involving some coastal armoring elements as well as some wetland restoration and other natural elements. Still, each strategy favors one approach over the other, with the CAA alternative favoring an engineered approach, and the NBA favoring natural elements and 'managed retreat'. Managed retreat involves removing or elevating structures and infrastructure at risk from SLR while allowing the shoreline to advance. Details of each strategy are found in Appendix B.

Results

The results of the analysis show that both the CAA alternative and the NBA alternative will yield more benefits than costs in terms of mitigating the SLR damages to buildings, infrastructure, agriculture, and recreation that would otherwise occur. The figure below shows how each adaptation alternative performs (See Figure ES-1). Results are shown in net present value terms, using a three percent discount rate. Reduced damages are measured against a baseline, with anticipated damages totaling $1.7 billion net present value over the 86 year period between 2014 and 2100. The annual damages under the baseline rise to more than $42 million per year by 2030, and to an expected $209 million per year by 2100. The damages are losses in property values, harm to buildings and infrastructure, lost agricultural product, and lost value of recreation.

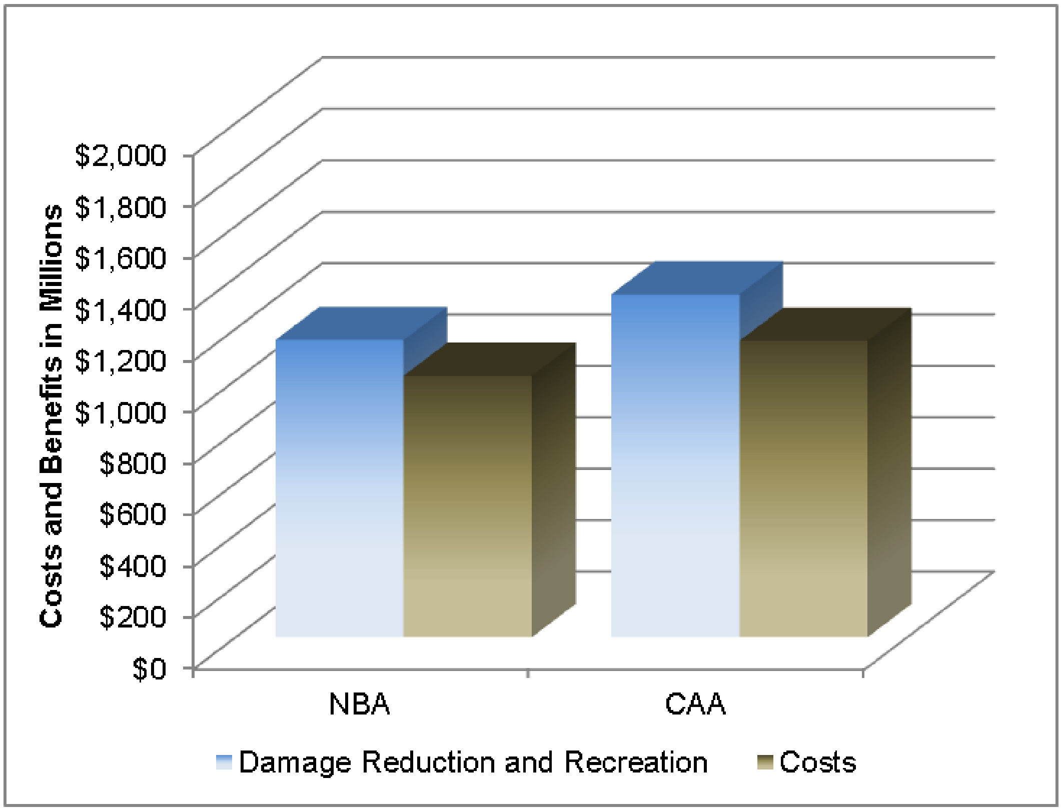


Figure ES-1: Net Present Value of Costs and Benefits of CAA and NBA Scenarios from 2014 to 2100 (Assuming a 3% discount rate, and Storm = 1% Chance per Year)

The two adaptation scenarios reduce these damages by 66 percent and 76 percent respectively for the NBA, and the CAA. However, the NBA approach provides ecosystem service benefits in terms of preserving or restoring the natural functions of the ecosystem such as water storage and treatment, production and protection of wildlife, prevention of beach erosion, and other natural ecosystem services. The analysis suggests that compared with the CAA, the NBA produces and additional 44,000 service-acre years (SAY) of ecosystem services, where one SAY is equivalent to the services from one acre of salt water wetland for one year.

The question of which adaptation strategy is preferred is complex and will depend on a number of site-specific variables. This research demonstrates that an NBA alternative may be economically preferred, depending on the value assigned to the ecosystem services. Under the example assumptions described above, if the value of one SAY was equal to about $3,000, then the NBA alternative would provide a greater level of net benefit than the CAA.

The value of a SAY has been estimated by many different researchers, with results ranging from a few hundred dollars to more than $35,000. Estimates will vary by community, by features of the wetland, services provided, and the availability of similar wetland sites in the study area. While estimating a monetary value for a SAY for saltwater wetlands in Ventura County is outside the scope of this work, the effort might also produce a result that would be satisfactory to some, but controversial to others. For both reasons, an alternative approach is employed for this research. This approach quantifies the level of service provided under the NBA and CAA strategies, and allows decision makers to explore how the preferred strategy would differ depending on the value of the ecosystem services.

Figures ES-2 and ES-3 show how the addition of the ecosystem service values can be brought into the decision making process. In Figure ES-2, the net benefits are shown in the reddish color. Net benefits are the difference between the benefits and costs shown in Figure ES-1. The value of a SAY (using $3,500 as the value of the service acre year of wetland) are shown in the green column. Figure ES-3 shows the comparison between approaches when ecosystem services are added into the total net benefit calculations.

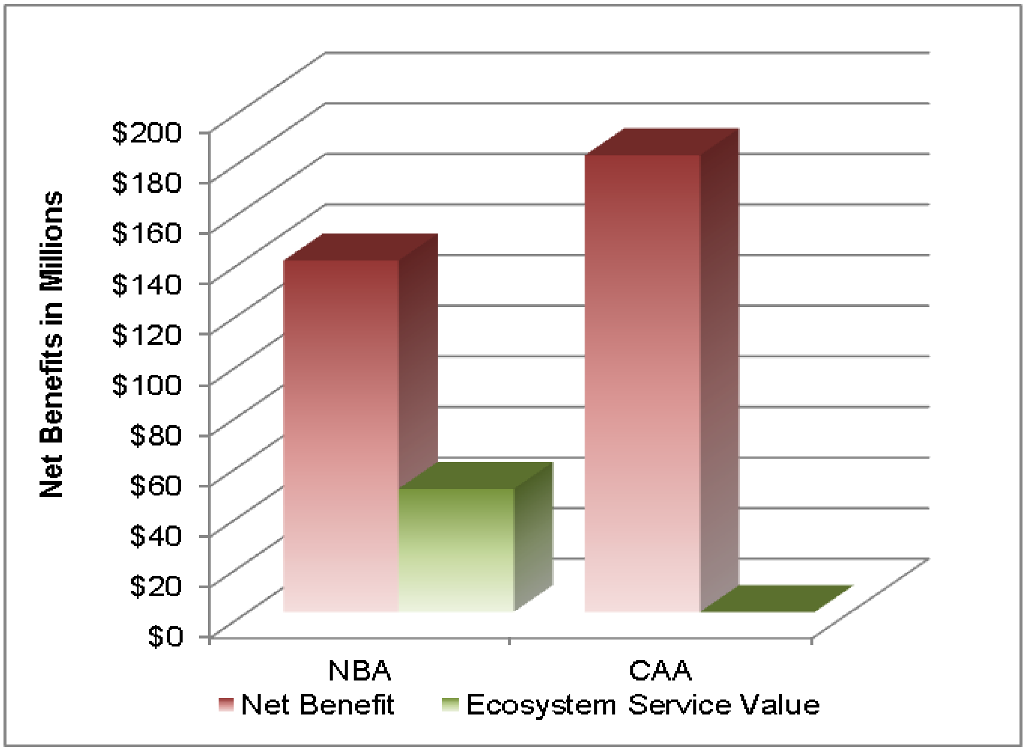


Figure ES-2: Net Present Value of Net Benefits of CAA and NBA Scenarios from 2014 to 2100 (Assuming a 3% discount rate, and Storm = 1% Chance per Year) and Value of Ecosystem Services Assuming $3,500 for the Ecosystem Services Provided by One Acre of Saltwater Wetland for One Year

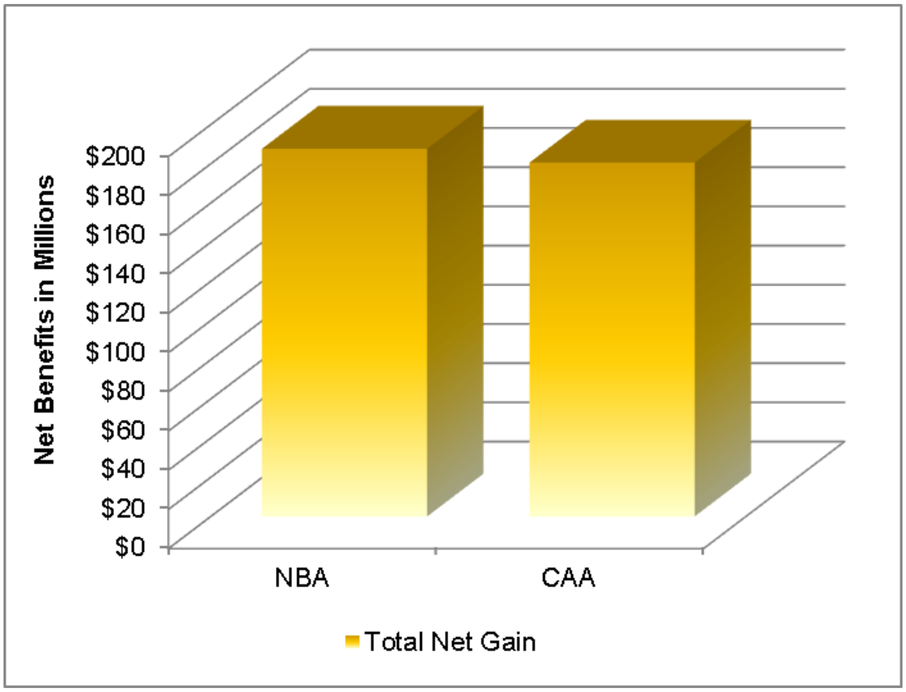


Figure ES-3: Total Net Benefits of CAA and NBA Scenarios from 2014 to 2100 (Assuming a 3% discount rate, Storm = 1% Chance per Year, and $3,500 per Service Acre Year)

Conclusions

This research shows an effective way to make climate change adaptation decisions by blending environmental gains and losses with traditional monetary metrics in a theoretically consistent manner. The results also suggest that nature-based approaches to climate change adaptation can provide benefits in terms of damages reduced that are comparable to coastal armoring approaches. Conclusions include:

- The benefits are expected to exceed the cost using a three percent discount rate for the coastal armoring adaptation (CAA) strategy.
- The benefits are also expected to exceed the costs under the same assumptions for the nature-based strategy (NBA).
- If the value of the services of a saltwater wetland for one year is assumed to be greater than $3,000 per acre per year, then the NBA approach produces greater net benefits than the CAA approach.

This research has been developed in conjunction with stakeholders, and is intended to inform municipal decision makers about climate change adaptation choices. To this end, the research product has been structured to allow local decision makers to explore which alternatives perform the best across a variety of flexible assumptions. In particular, results should be explored using different assumptions about

- the future frequency of large storm events,

- the discount rate used in the analysis, and
- the monetary value of a SAY.

The analysis includes estimates for wave damages, which has not been extensively studied before in economic terms. The work does not include damages associated with storms at frequencies other than the one percent chance storm which was modeled in prior research for Ventura County. As such, these results may be considered a low estimate of damages and a low estimate of the benefits from adaptation.

1 Introduction

Annual global emissions of greenhouse gases have already exceeded the worst case scenarios modeled by the Intergovernmental Panel on Climate Change. California's communities are beginning to develop plans to respond to impacts being generated by the degree of climate change to which we have already committed ourselves.

Among the many potential impacts from climate change, a particularly worrisome component for coastal areas is the issue of sea level rise (SLR). Global indicators suggest that sea levels, which had been stable for over 2,300 years, began to rise in the 19th century. Satellite imagery suggests that since 1993, sea levels have been rising at a rate of about 3 mm per year (http://www.climate.org/topics/sea-level/#sealevelrise). While there is debate as to the magnitude and rate of increase in specific locations, the risk and the potential for loss of habitat, physical property, infrastructure and other assets is clear.

Currently, proposed responses to climate change-induced SLR are often focused on defensive engineering or 'hard responses' such as building dams, levees and channels to control flooding, and building or reinforcing seawalls to protect from SLR. Such engineered responses may be necessary in some instances, but they will not be sufficient to address the full scope of climate change impacts and can cause their own impacts to natural systems.

Alternatively there are methods that increase the capacity of the natural environment to respond to, and buffer the effects of climate change. These "green" methods may achieve the same goal as engineered responses, while improving overall service flows provided to the communities. For example, preserving, restoring, or constructing wetlands that attenuate a storm surge is one natural strategy to protect inland areas, while providing habitat and water treatment services at the same time. In addition, improving nature's ability to provide these services could potentially present a more cost-effective and long-term management response when compared with 'hard,' engineered, or "grey" responses.

As state and local planners begin to consider specific responses, The Nature Conservancy (TNC) is working to better understand when, where and under what circumstances nature-based adaptation strategies can be an effective alternative to coastal armoring. Activities like wetland conservation, flood plain restoration, and riparian reforestation can help human communities adapt to climate change while also helping to preserve the natural systems upon which we rely.

ENVIRON and ESA PWA were retained by TNC to explore the question of whether nature-based interventions (i.e. using nature's existing processes and services) could reduce risk to communities from climate change threats more cost-effectively than deploying additional "hard" or engineered responses.

1.1 Study Area

TNC has a long history of working with coastal communities in Ventura County and has developed a decision-support network, Coastal Resilience, which provides tools and information to better inform stakeholders on climate change and disaster risk reduction, while emphasizing the important role of ecosystems in this process. This approach has been adopted in a variety of geographies. This study is part of TNC's CRV project (http://coastalresilience.org/project-areas/ventura-county-introduction). The work builds on forecasting and mapping of climate change-induced hazards that has already been developed through this cooperative effort.

Ventura County is located in the southern part of California's Pacific coast. It is part of the Greater Los Angeles area. The County's diverse geography ranges from rugged mountain terrain to coastal plains. The County's ten cities lie in the southern portion of the County. The major cities in coastal Ventura County are Oxnard, Port Hueneme, and Ventura (San Buenaventura). The County has a total area of 2,208.20 square miles, of which 1,845.30 square miles (or 83.6 percent) is land and 362.90 square miles (or 16.4%) is water.

Ventura County has many natural assets that are valuable to Southern California. These assets include the Ventura River, Santa Clara River, and Ormond Beach. The Ventura River Watershed is the only major watershed in Southern California that does not rely on imported water. Climate change and land use changes could impact this water supply and the communities that depend on water from this source. Preserving the watershed and areas to the north intact as 'green capital' could allow the watershed to continue to function naturally and sustain valuable water sources that are continuously growing scarce in California. Similarly, the Santa Clara River is the one of the largest natural rivers remaining in Southern California stretching from its headwaters in San Gabriel Mountains until it meets the Pacific Ocean. The Ormond Beach region is considered by wetland experts to be the most important wetland restoration opportunity in southern California. The ongoing restoration of the Ormond Beach wetlands and associated habitat are capable of creating a self-sustaining biological system that could be the largest coastal wetland in Southern California. More information about the current conditions in Ventura County is presented in Appendix A. A map of the study area is shown in Figure 1.

1.2 Purpose and Objective

The purpose of this study is to provide economic information to coastal decision makers about nature-based climate change adaptation choices. Economic gains and losses of climate change adaptation decisions will be evaluated with attention to the value of several different classes of assets including built structures and infrastructures, agriculture, and ecosystem services. All of these asset classes are placed at risk as tides creep farther up coastlines, floods are deeper and more frequent, and storms become more severe with the changing climate. To protect these assets, decision makers need to have data on how alternative responses will affect each type of asset over time. The research builds on prior physical modeling of coastal climate change impacts and is a collaborative effort between TNC and Ventura County stakeholders.

The objective of this study is to identify the impacts associated with the two types of response strategies - a "nature based adaptation" (NBA) approach and a CAA approach – and to evaluate the costs and benefits of these alternatives in relation to the degree of risk reduction each will provide. These approaches represent a likely range of adaptation strategies that could occur. Actual adaptation strategies will most likely be a combination of coastal armoring and nature based strategies.

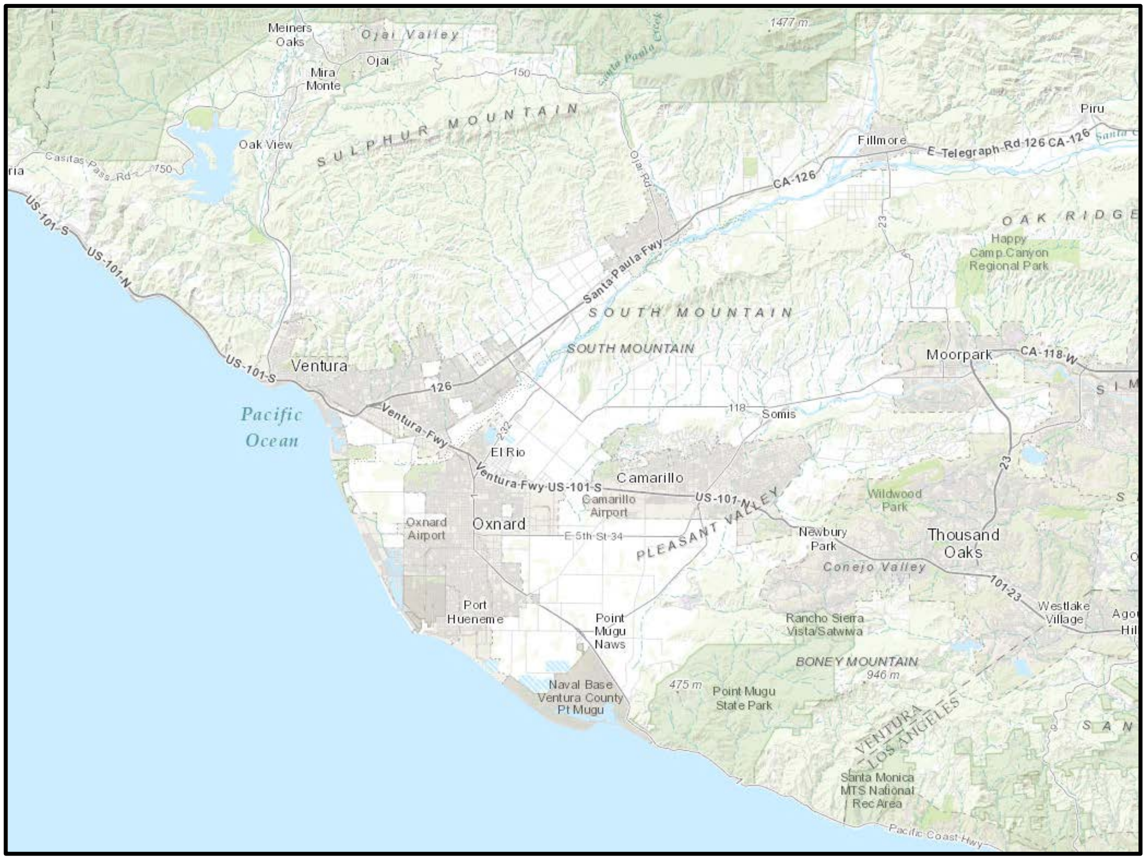


Figure 1 Map of Ventura County Study Area
Source: http://maps.coastalresilience.org/ventura/#

1.3 Layout of the Report

The remainder of this report comprises four chapters. Chapter 2 provides an overview of the previous physical modelling efforts that all of this analysis depends. The results presented in Chapter 2 form the basis for the scenarios that were developed and analyzed for this project. The process (including stakeholder engagement) of defining the baseline and identifying alternatives for analysis is presented in Chapter 3 along with methodological details of the benefit cost analysis, and ecosystem services analysis. Chapter 4 presents the results of the various analyses of the NBA and CAA alternatives. In Chapter 5 the results of the analyses are employed in a decision making framework, or formal benefit cost analysis that includes a Net Ecosystem Services Analysis (NESA). Chapter 6 concludes with a discussion of the outcomes and the development of recommendations for planners, local stakeholders, and decision makers. Appendices cover current conditions in Ventura County (Appendix A), detailed descriptions for the two management scenarios (Appendix B), and two technical memoranda regarding ecosystem service modeling and beach width analysis (Appendices C and D). A brief annotated bibliography about costs and benefits of adaptation makes up Appendix E.

2 Previous Modeling

ESA PWA modeled coastal hazard zones based on various climate scenarios for the Ventura County coastline. The model results are summarized below, followed by a list of datasets provided for each tool. Please refer to “Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping”[1] for more detailed information about the modeling approach and resulting SLR and hazard projection data sets. Examples of the previous modeling are provided below in Figures 2, 3, and 4, which show the combined storm hazard areas for 2030, 2060, and 2100 respectively. The shaded area in the figures shows combined storm hazard forecasts including a large storm flood inundation, wave impact, and river inundation under the “high” SLR scenario (see below).

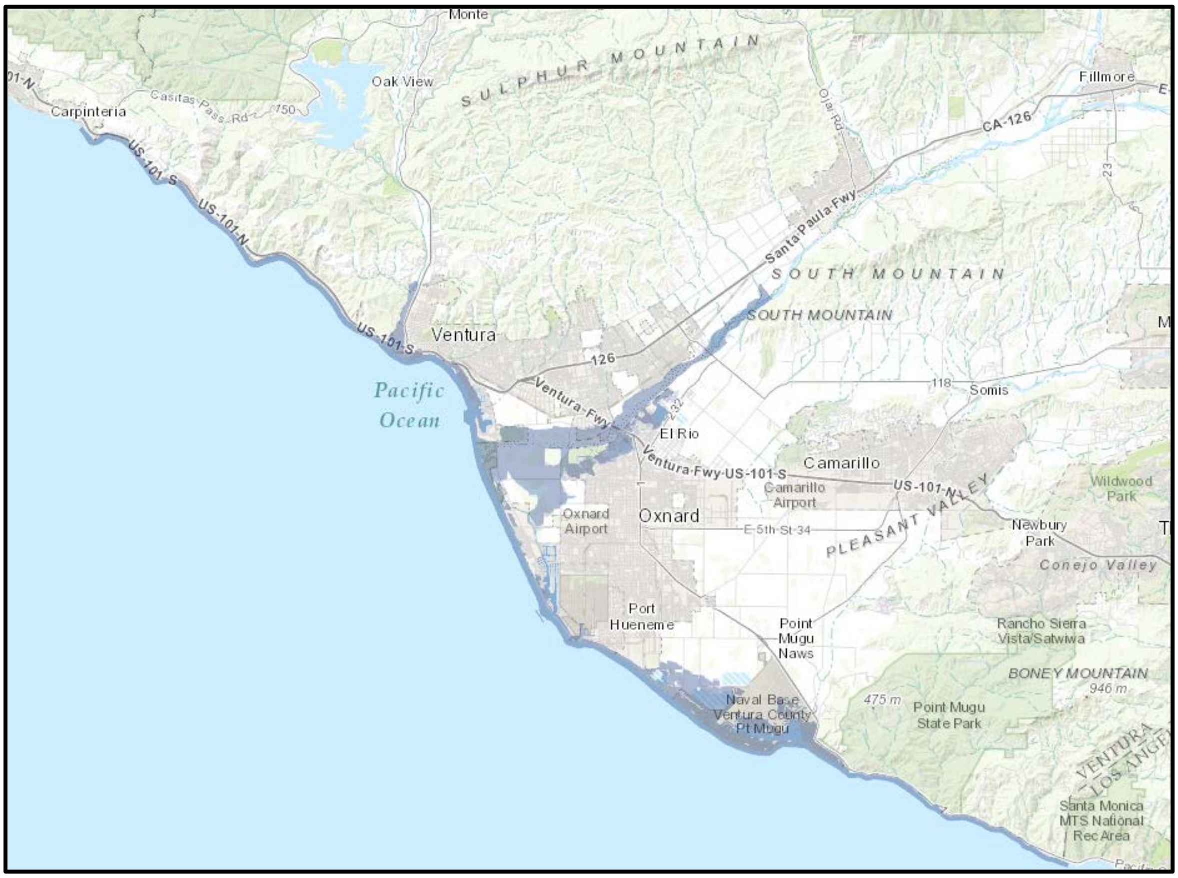


Figure 2 Combined Storm Hazard Forecast for 2030
Source: http://maps.coastalresilience.org/ventura/#

[1] See http://maps.coastalresilience.org/ventura/#

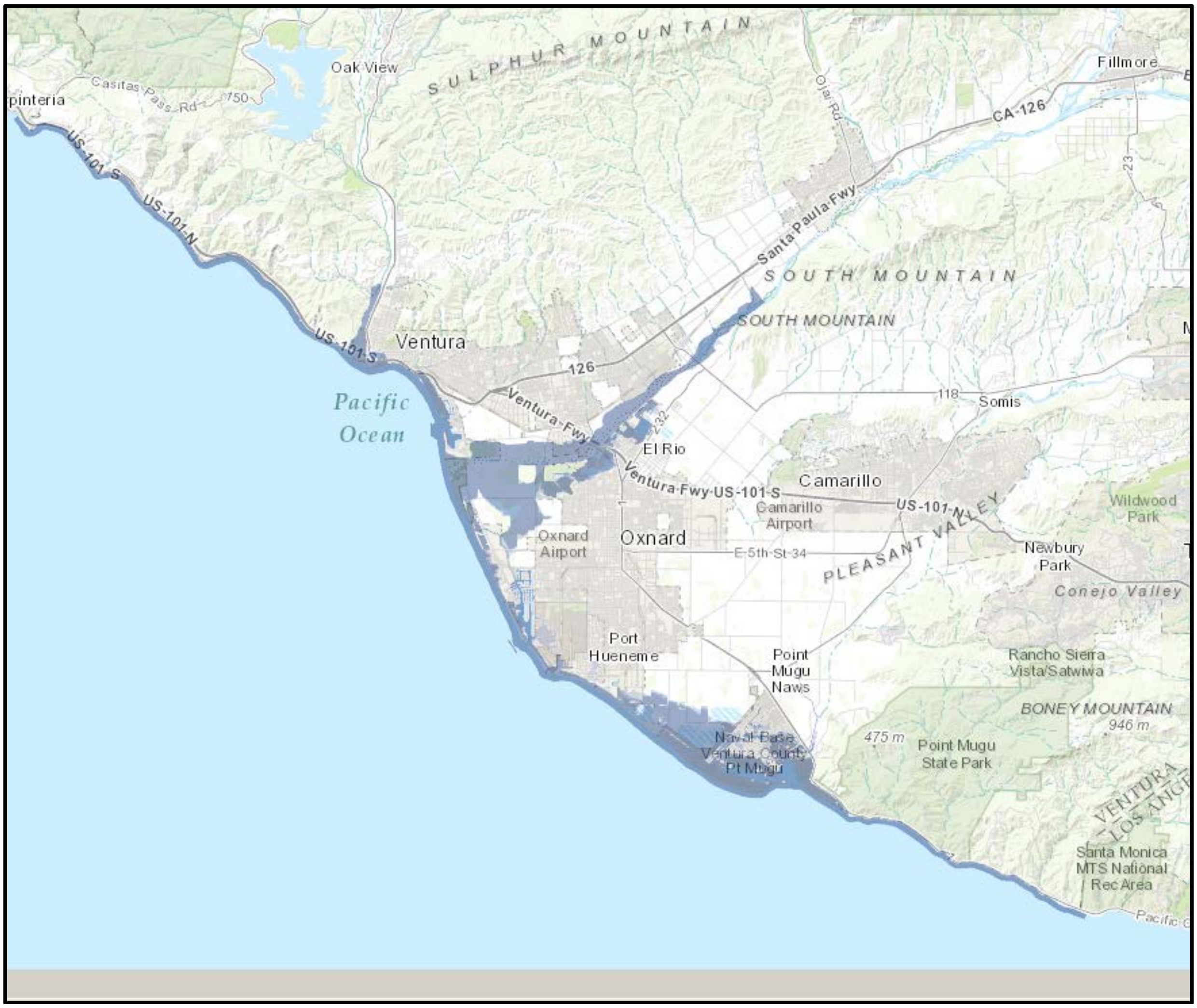


Figure 3 Combined Storm Hazard Forecast for 2060
Source: http://maps.coastalresilience.org/ventura/#

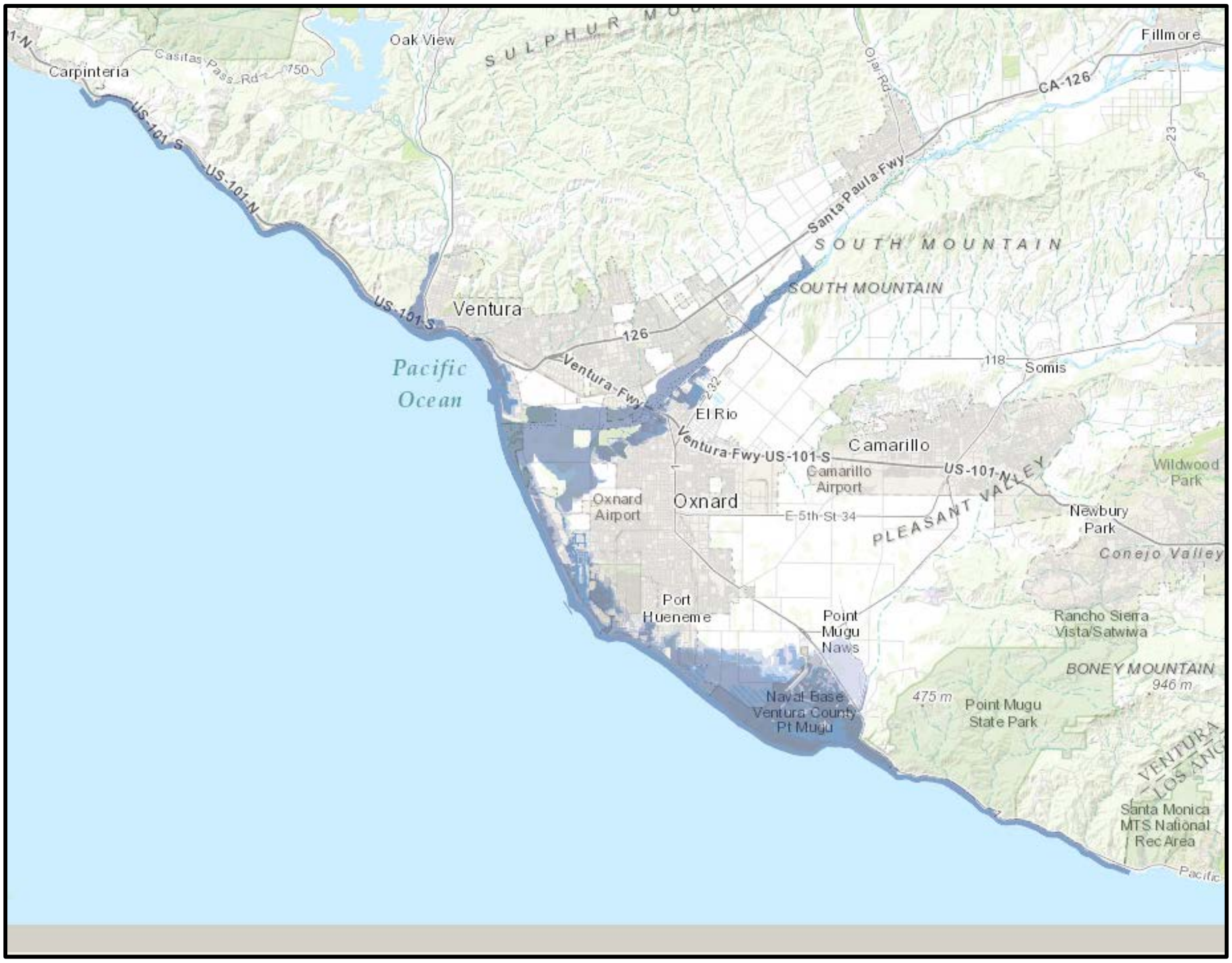


Figure 4 Combined Storm Hazard Forecast for 2100
Source: http://maps.coastalresilience.org/ventura/#

In addition to reevaluating the hazards under the NBA and CAA management scenarios, ESA PWA developed two other analyses for this study. First, an analysis of changing land cover focusing on wetland migration was completed using the Sea Level Affecting Marshes Model (SLAMM). This analysis was completed for the area between Ormond Beach and Point Mugu. The second analysis completed was a beach width analysis. The beach width analysis was completed at three separate transects in the county, and provides an estimate of the degree of beach gain or loss under the two management scenarios and under the baseline condition. Technical details of these two modeling efforts are available in Appendices C and D. The hazard zones are each described below, and then a summary of the SLAMM model results and the beach width analysis results are presented.

2.1 Coastal Hazard Modeling

The effects of SLR along the Ventura Coast were modeled at three planning horizons (2030, 2060, and 2100) and three climate change scenarios, based on guidance from the CRV steering committee. : The three climate change scenarios are called low, medium, and a high, and are based on National Research Council[2] and U.S. Army Corps of Engineers[3] guidance. The results of the coastal modeling form the foundation of an online mapping tool that allows users to explore how alternative SLR hazards will affect the Ventura coastline. This tool is publicly available at http://maps.coastalresilience.org/ventura/#. Each of the hazards is described briefly below.

2.1.1 Coastal Erosion Hazard Zones

Future coastal erosion hazard zones that incorporate site-specific historic trends in erosion, additional erosion caused by SLR, and the potential erosion impact of a large storm wave event are contained within this hazard category. The following details describe the Geographic Information Systems (GIS) files associated with this hazard.

- Erosion hazard zones
  - 27 polygon shapefiles: 3 planning horizons x 3 wave climates x 3 SLR scenarios
- Spatially aggregated erosion hazard zones
  - 3 polygon shapefiles: 3 planning horizons

2.1.2 Fluvial 100-year Storm Floodplains

Floodplains showing the anticipated floodplain for a one percent annual chance flood projected into the future for the Santa Clara River and Ventura River, based on hydraulic modeling for future run-off projections and increasing ocean water levels. The future run-off projections were developed using downscaled climate models. The GIS files for this hazard include:

- 100-year floodplain inundation areas

[2] NRC (2012). “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.” Prepublication. National Academy Press: Washington, D. C.

[3] USACE (2011). “Sea-Level Change Considerations for Civil Works Programs.” US Army Corps of Engineers, EC 1165-2-212.

– 7 polygon shapefiles: existing conditions, 3 planning horizons x 2 SLR scenarios

2.1.3 Rising Tide Inundation Zones

These zones show the area and depth of inundation caused only by rising tide levels and not by storm. This is known as the potential inundation area of Extreme Monthly High Water (EMHW). The GIS files contain:

- 10 polygon shapefiles: existing conditions and 3 planning horizons, 3 SLR scenarios
  - Depth of water within the rising tide inundation zone (in meters)
  - 10 rasters (5 meter cell size): existing conditions and 3 planning horizons x 3 SLR scenarios, erosion, or river discharge.

2.1.4 Coastal Storm Wave Impact Area

This impact area is one component of the coastal storm flood hazard zone (similar to FEMA V-zone) and is characterized by an increased wave momentum that could rush inland and cause considerable damage.

- Flooded areas within the wave impact zone
  - 10 polygon shapefiles: existing conditions and 3 planning horizons x 3 SLR scenarios

2.1.5 Coastal Storm Flood Hazard Zones

This hazard zone maps two types of flooding caused by coastal processes: flooding caused by storm waves rushing inland, and flooding caused by ocean storm events such as storm surge (a rise in the ocean water level caused by waves and pressure changes during a storm). The zones were developed using representative wave conditions and based on observed historical events, with added SLR. The GIS files are made up of:

- Storm flood hazard zones
  - 10 polygon shapefiles: existing conditions and 3 planning horizons x 3 SLR scenarios

2.1.6 Combined Storm Flood Hazard Zones

This hazard zone combines all of the above hazard zones (coastal erosion, fluvial storm flooding, wave impact area, and coastal storm flood hazards) into a single comprehensive combined storm flood hazard area. The mapping tool shows:

- Storm flood hazard zones
  - 10 polygon shapefiles: existing conditions and 3 planning horizons x 3 SLR scenarios
- Spatially aggregated storm flood hazard zones
  - 3 polygon shapefiles: 3 planning horizons

The hazard zones listed above (excluding the combined storm flood hazard zones) were delivered independently so map users may see the cause(s) of flooding at a particular location. However, at each planning horizon, the flood hazard zones for all scenarios are overlaid into a single “spatially aggregated” layer that counts the number of scenarios that are projected to cause flooding at a particular location. The goal of the planning tool was to help identify which areas will be hazardous for all SLR scenarios and which areas may only be hazardous for the worst case scenarios, for a given planning horizon.

2.2 Sea Level Affecting Marshes Model (SLAMM)

SLAMM was first developed in the mid-1980s with EPA funding to evaluate changes to east coast habitats and wetlands and has evolved over time with support from many other funding sources, including TNC. SLAMM was chosen for use in this study because it is well known by policymakers and has been applied widely in the U.S. The software is open source and freely available. Please refer to Appendix C for more detailed information regarding the model.

SLAMM simulates the dominant processes involved in certain types of wetland conversions during long-term SLR: inundation, erosion, overwash, saturation, and accretion. A complex decision tree incorporates both geometric and qualitative relationships to model land cover conversions in coastal habitats through spatial relationships (e.g. adjacency, elevation). The primary inputs to SLAMM include a high resolution digital elevation model, a map of current wetland habitats, future SLR projections, marsh accretion rates, tide ranges, and erosion rates. The following model processes are applied to the Ventura application at each time step:

- Inundation: As sea levels rise, land elevations lower relative to mean sea level. This causes habitats to convert to habitats found lower in the tide frame.
- Erosion: Horizontal erosion triggered given a minimum fetch threshold and proximity of the wetland to estuarine water or open ocean.
- Saturation: Migration of coastal and freshwater wetlands onto adjacent uplands as driven by a rising water table.
- Accretion: Vertical rise of marsh due to buildup of organic and inorganic matter on the marsh surface.

ESA PWA conducted modeling of the precipitation and SLR impacts of climate change to coastal and fluvial hazards in a previous phase of Coastal Resilience Ventura. Results and interim data sets generated during that modeling were incorporated whenever possible into the SLAMM model. These methods are described in a separate technical report titled Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping.[4] The report is provided in its entirety as Appendix C of this document. The SLAMM model looked at several scenarios including SLR and management scenarios. Figure 5 shows the study area evaluated, which included just the Ormond Beach and the Mugu Lagoon areas rather than the entire coast. . Table 1 provides the scenarios analyzed in the SLAMM Model.

[4] ESA PWA 2014. Coastal Resilience Ventura. Technical Report for Sea Level Affecting Marshes Model (SLAMM). Prepared for the Nature Conservancy. San Francisco, CA.

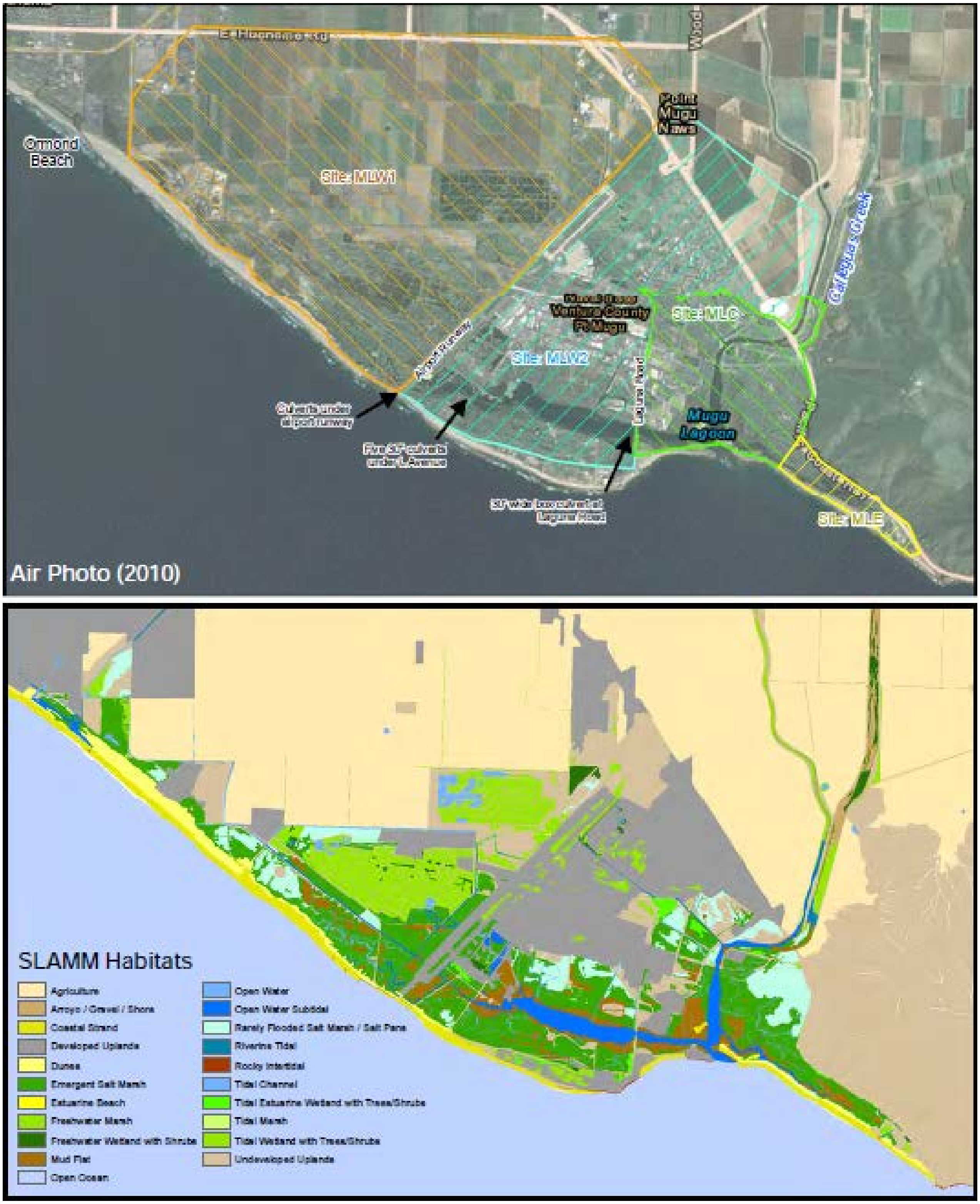


Figure 5. Study Area for SLAMM Modeling, and Initial Land Cover Types

Table 1: SLAMM Scenarios	
Type	**Scenarios**
SLR	High (1.47 meters between 2010 and 2100)
Management Scenario 1 (M1)	Allow marshes to transgress into dry land
Management Scenario 2 (M2)	Fortify developed dry land (excluding agricultural land)
Management Scenario 3 (M3)	Fortify developed dry land (including agricultural land)

Figure 6 provides a simplified summary of the changes in acres by land cover type for each scenario between 2010 and 2100. The changes by land cover type are described below.

Agricultural lands show a decrease of over 1,000 acres for M1 and M2. M3 has no change as it is protected under this scenario. For beaches, there is a small increase in acreage with m1 (<100 acres), a very small decrease with M2 and no change with M3. The small increase for M1 could be viewed as substantial because of the low number of acres that exist currently. Developed lands indicate a more than 1,500 acre decrease in m1 but no change in M2 and M3 as they are protected. Dunes indicate about a 100 acre decrease across all management scenarios.

The most substantial change in spatial extent for a habitat type is estuarine open water with M1 increasing by more than 2,600 acres, M2 by 2,500 acres and m3 by about 2,300 acres. Open ocean increases by over 100 acres for all scenarios while fresh water wetland decrease for all scenarios by between about 700-800 acres. Inland open water has slight decreases across all management scenarios. Mud flats are predicted to increase by more than 1,000 acres in m1, 900 in M2 and about 600 in m3.

Salt water wetlands indicate an increase in the m1 scenario by about 400 acres but a decrease in M2 (800 acres) and M3 (1,300 acres). All three scenarios are estimated to lose around 600 acres for undeveloped land.

.

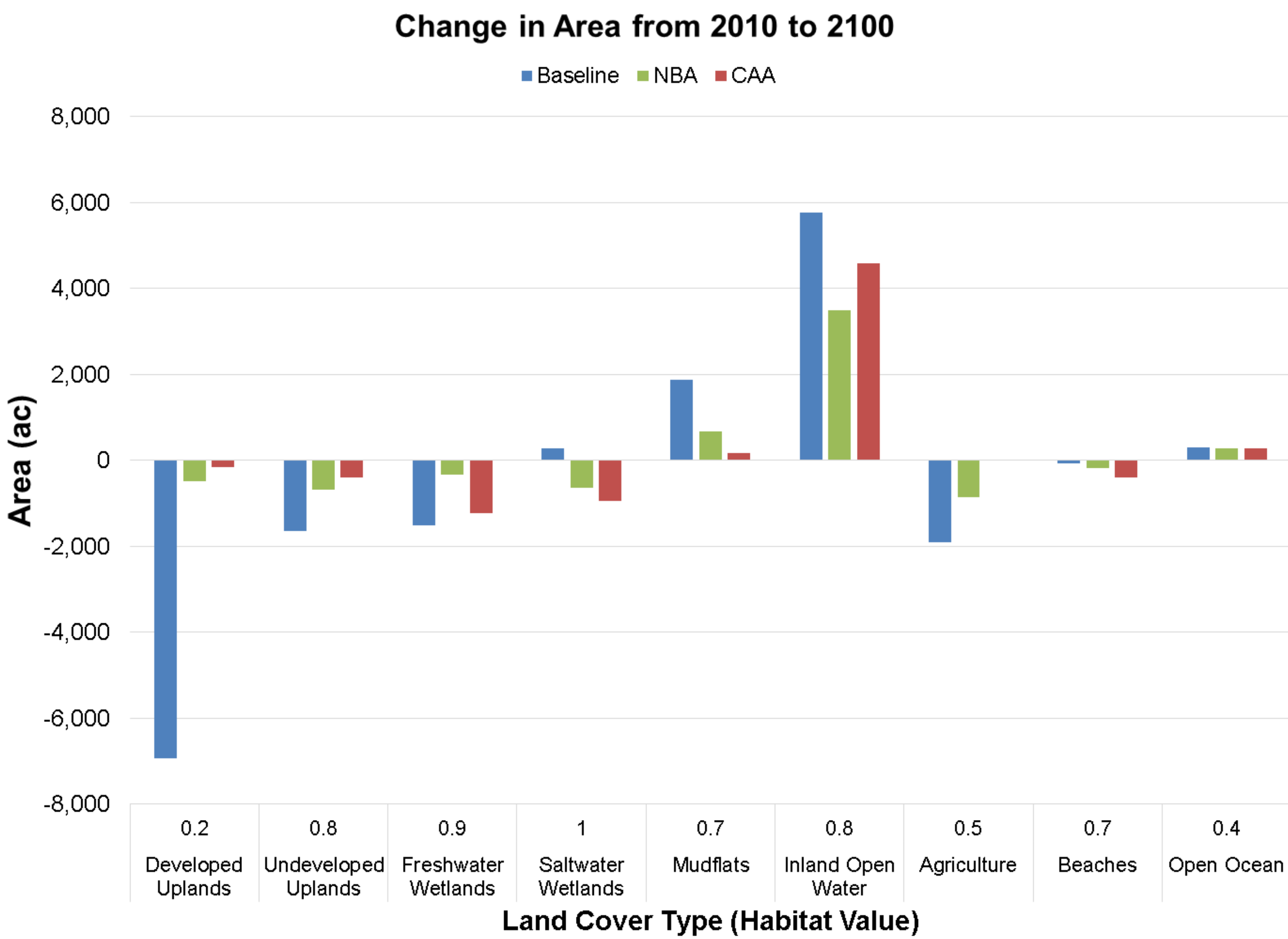


Figure 6. Forecast for Change in Area due to SLR by Land Cover Type based on SLAMM Model Results for 2100

2.3 Beach Width Analysis

The beach width analysis (BWA) conducted by ESA PWA is based on the hazard modeling described above (see Section 2.1). The analysis was evaluated under the CAA and NBA alternatives. The BWA determines changes to beach width under the adaptation alternatives at three reaches in Ventura County, which were selected to represent a broad range of ecological and recreational values, and to be representative of the Ventura coastline. Details of the analysis are provided in Appendix D.

3 Approach and Methodology

This analysis compares the two SLR adaptation strategies against a baseline in terms of how each mitigates the impacts of SLR. The approach to evaluating NBA and CAA strategies is presented in this chapter. The process began with a series of meetings with key stakeholders to ascertain their understanding of, and preferences for, different approaches. This process is outlined in Section 3.1. Using the input from the stakeholder interviews, the research team worked to define two coastwide management scenarios that would represent the NBA and CAA alternative adaptation styles. To define the NBA and CAA strategies, assumptions were made about the baseline scenario that would be in place absent any adaptation strategy (for detailed information on the baseline scenario, see 3.2). The physical SLR scenario (rising tides, increases in storms, and erosion) was already in place at the outset of the project as described in Chapter 2. However, a management scenario was also needed so that the physical results could be compiled into a baseline for the economic analysis. Much of the climate change research assumes a baseline similar to current conditions, and therefore measures the impacts of climate change. However, to measure climate change adaptation benefits and costs, this effort needed to start with an assumption of climate change, and then measure the reduction in impact as the change that can be expected from each adaptation scenario.

Section 3.2.1 presents a review of similar literature that employs alternative baseline definitions. In the final sub section, the proposed baseline configurations are evaluated under different sea level rise scenarios in order to arrive at the final “baseline” definition that is utilized throughout the remainder of the report. Section 3.3 outlines the components of the NBA and CAA scenarios. Section 3.4 provides an explanation of the methodology used to capture and quantify impacts, in particular the development of a database to support the analysis. Section 3.5 provides a discussion of the consequences to ecosystem services that are expected with SLR, and how the Habitat Equivalency Analysis (HEA) may be used to estimate some of the ecosystem services affected both by SLR and each adaptation strategy.

3.1 Stakeholder Engagement

A series of stakeholder meetings were held to gather information about existing community assets, neighborhood designations and characteristics, and to identify areas that stakeholders felt were most at risk from SLR. An additional purpose of the stakeholder meetings was to engage stakeholders in a series of exercises to identify the options that might be implemented to protect key features in the communities.

3.1.1 Stakeholder Participants

With TNC guidance, the project team reached out to local stakeholders in the study area including city and county representatives, the California Coastal Commission, the California Coastal Conservancy, emergency planning personnel, Naval Base representatives, and some local environmental groups. Many of the stakeholders had participated in other aspects of the CRV project, organized by TNC. The stakeholder meetings were held over a two day period at the TNC office located in downtown Ventura in September, 2013. Those who could not make these meetings but were interested in contributing were invited to participate over the phone or at meetings at a later date. Stakeholders were met with individually or in groups (if they were from the same office). Table 2 summarizes the stakeholder representatives that participated in the meetings.

Table 2: Participating Stakeholders

Stakeholder	Representative	Title	Date Attended
Naval Base Ventura County	Anna Shepherd	Community Plans and Liaison Officer	September 10, 2013
Naval Base Ventura County	Jordan Young	Interdisciplinary Community Planner	September 10, 2013
Supervisor Long's Office	Lauren Bianchi-Klemann	Field Representative	September 10, 2013
California Coastal Commission	Jonna Engel	Ecologist	September 10, 2013
City of Ventura	Maggie Ide	Community Plan	September 10, 2013
City of Ventura	Dave Ward	Planning Manager	September 10, 2013
Office of Emergency Services	Kevin McGowan	Manager	September 11, 2013
California Coastal Conservancy	Peter Brand	Senior Project Manager	September 11, 2013
City of Oxnard	Chris Williamson	Principal Planner	September 11, 2013
City of Port Hueneme	Greg Brown	Community Development and Housing Authority	September 11, 2013
Surf Rider Foundation	Paul Jenkin	Environmental Coordinator	September 17, 2013
County of Ventura	Rosemary Rowen	Plans, Ordinances, and Regional Planning Manager	September 18, 2013
County of Ventura	Jennifer Welch	Case Planner	September 18, 2013

3.1.2 Stakeholder Process

Project team members included Kelly Leo from TNC, Gretchen Greene and Stephanie Burr from ENVIRON, and Dave Revell from ESA PWA. Sarah Newkirk from TNC also participated in some of the later interviews. First, a general overview of the CRV process and project goals was presented along with the beta version of the TNC SLR portal showing the results of the coastal hazard modeling completed in the summer of 2013. During the presentation, stakeholders were encouraged to ask questions and provide feedback regarding information that they felt could be gained from this project. Next, ENVIRON staff presented an overview of the economic portion of the larger CRV project, and encouraged stakeholders to ask questions and share their thoughts about how the project might be of use to them in their own decision-making. Finally, each stakeholder, or group of stakeholders were asked the following open-ended questions:

- Has your office started thinking about how climate change and SLR will impact Ventura County?

- What areas of Ventura County are viewed as containing a lot of value to the coastal community and why?
- What are current erosion and flooding issues? Where do they occur and what is the public response to the loss or the degradation it causes?
- What is the current status of education and outreach about SLR and climate change?
- What adaptation strategies have been considered or thought about?
- In your opinion, what are the benefits and costs economically and ecologically from different adaptation strategies?

Large maps of Ventura County were used as a way to engage stakeholders in asset identification and proposal of management tools to protect key areas. Stakeholders were provided markers and were allowed to physically draw on maps and mark areas under their jurisdiction or management as well as features of great value to the community.

3.1.3 SLR Adaptation Themes

Several overall themes emerged during the stakeholder meetings.

- SLR and climate change were a concern for future planning, erosion protection, and community protection. Several agencies are studying the risks to Ventura County and California from climate change and SLR. There was a strong desire to learn from cross agency work and to more uniformly develop goals and solutions.
- While climate change and SLR were a concern across all groups, there is a great deal of jurisdictional overlap in Ventura County that requires interagency cooperation. This is challenging when each organization is already working hard to fulfill its own specific mandate – in many cases with reduced financial support – let alone taking on additional collaborative projects. Participants expressed support for and concerns about streamlining certain planning documents (such as those associated with the Local Coastal Program: http://www.ventura.org/rma/planning/programs/local-coastal/index.html) that could more quickly move climate change to the forefront of decision making processes.
- Several coastal areas, such as the Port Hueneme Beach Park, already require regular management due to severe erosion caused by the original channel design. Going forward, stakeholders were concerned about these areas in part because their management actions are subject to the uncertainty of the federal budgeting process. In the face of increased erosion potential with climate change, this has the potential to aggravate a coastal management issue that is already the subject of uncertainty outside the control of local stakeholders.
- Adaptation strategies that can balance benefits across a broad spectrum of coastal values were generally identified as preferred. Ecologically sensitive strategies such as wetland restoration and dune replenishment were viewed positively but concerns were raised about the cost of such projects to homeowners, farmers, businesses, and other community members. Engineered strategies that solely focused on defensive or protective measures were viewed as less politically complicated, though these suggested more long term costs including maintenance, impact to beaches, and loss of vital habitat. Managed retreat was

viewed as difficult to implement except in the case of public utilities and other public infrastructure that would not impact the interest of private citizens.

- Environmental justice and impacts to lower income communities were discussed. Planners were concerned that some management tools would favor higher income communities.

3.1.4 Outcome and Key Findings

The spirit of these meetings was conversational and intended to inform the team as to how the study might best be shaped to meet the needs of the various stakeholders. Ideas were discussed in terms of ways to solve the most critical of climate change concerns, and to identify the type of information that would be most useful to the local organizations. Many of the ideas, or adaptation strategies in the management scenarios, that were developed and evaluated in this report came from these stakeholder interviews. Because none of the stakeholders requested that a specific element be included in the study, stakeholder needs were combined with study goals and evaluated for technical feasibility to develop draft "nature based adaptation" (NBA) and "engineering-based adaptation" (EBA). Later the EBA was renamed the "coastal armoring adaptation," or CAA scenario. Stakeholders were shown the scenarios and asked for additional input at the October 24, 2013 Steering Committee meeting. Additional comments were incorporated into the final NBA and CAA scenarios.

3.2 Baseline Development

In any economic analysis, determining the baseline is a key element to setting up an appropriate framework for analysis. The baseline is what all benefits and costs are compared to, so defining the baseline determines the meaning of the results.

The primary purpose of the analysis presented in this report is to compare the impacts of nature-based adaptation strategies with engineered, coastal armoring adaptation strategies. This comparison suggests that the baseline needs to be the absence of any adaptation strategy. At the same time, the adaptation strategies being evaluated are to respond to changing climate and so the baseline scenario should include climate change impacts. There are potential advantages to defining a baseline scenario in a manner consistent with approaches used in other similar research so that the results from this study might be more easily compared with other efforts. However, many climate change studies do not include climate change effects through time, and instead simply use a baseline of the current conditions to demonstrate how conditions in the future will be different from those we know now. ENVIRON reviewed a number of prior studies on the economic impacts associated with adaptation strategies to better understand the options and the implications of different baseline definition strategies.

3.2.1 Literature Defining Baseline Conditions for Climate Change Adaptation

Many studies that focus on climate change impacts in California assume a baseline scenario as the "**Current Conditions"**. Examples are Heberger et al.[5] (2009) and Cayan et al.[6] Heberger et

[5] Heberger, Mathew, Heather Cooley, Pablo Herrera, Peter H. Gleick, and Eli Moore of the Pacific Institute. 2009. The Impacts of Sea-Level Rise on the California Coast. A paper from the California Climate Change Center. Website (http://www.energy.ca.gov/2009publications/CEC-500-2009-024/CEC-500-2009-024-F.PDF) accessed June 19, 2013.

al. (2012) include detailed analyses of the current population, infrastructure, and property at risk from projected sea-level rise if no actions were taken to protect the coast. The sea-level rise scenarios presented in these studies were developed by the State of California based on the medium to high greenhouse gas emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC http://www.ipcc.ch)[7], but did not reflect the worst-case sea-level rise that could occur. Heberger et al. (2009) evaluated the cost of building structural measures to reduce that risk, including levees and seawalls. Costs for building new levees, raising existing levees, and building new seawalls were presented. The authors noted that if development continued in the areas at risk, all of the estimates would rise. The work evaluated the cost of replacing infrastructure, identified the risks, and discussed (qualitatively) what could be done to reduce those risks. Hence although adaptation was a focus of the research, the fundamental measurement is how conditions will change with SLR compared with the baseline of current conditions. In order to measure adaptation impacts more accurately, SLR needs to become the baseline from which alternatives reduce damages.

Cayan et al. (2009) provided an evaluation of physical elements of climate change and SLR that are contained in the California Climate Change Vulnerability and Adaptation Assessment. The approach follows a methodology developed by Rahmstorf [8]. This approach produced global sea-level estimates based on projected surface air temperatures from global climate simulations for both the IPCC A2 and B1 scenarios using the output from six global climate models: the National Center for Atmospheric Research (NCAR) Parallel Climate Model (PCM); the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluids Dynamics Laboratory (GFDL) version 2.1; the NCAR Community Climate System Model (CCSM); the Max Planck Institute ECHAM3; the MIROC 3.2 medium-resolution model from the Center for Climate System Research of the University of Tokyo and collaborators; and the French Centre National de Recherches Météorologiques (CNRM) models. So while this kind of study is very effective at measuring the impacts of climate change, it is less effective at measuring adaptation. Such studies instead could potentially become the baseline for a study of adaptation impacts.

Heberger, Mathew, Heather Cooley, Eli Moore, and Pablo Herrera of the Pacific Institute. 2012. The Impacts of SLR on the San Francisco Bay. A White Paper from the California Energy Commission's California Climate Change Center. Public Interest Energy Research (PIER) Program Report – Publication # CEC-500-2012-014. Website (http://www.energy.ca.gov/2012publications/CEC-500-2012-014/CEC-500-2012-014.pdf) accessed June 19, 2013.

[6] Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and SLR Estimates for California 2008 Climate Change Scenarios Assessment. California Climate Change Center. CEC-500-2009-014-F. Website (http://www.energy.ca.gov/2009publications/CEC-500-2009-014/CEC-500-2009-014-F.PDF) accessed July 16, 2013.

[7] Intergovernmental Panel on Climate Change. 2000. Special Report on Emissions Scenarios. Cambridge University Press, UK. 570 pp.

[8] Rahmstorf, S., A. Cazenave, J. A. Church, J. E. Hansen, R. F. Keeling, D. E. Parker, and R. C. J. Somerville. 2007. "Recent Climate Observations Compared to Projections." Science 316(5825): 709. Website (http://www.soest.hawaii.edu/oceanography/zij/education/ocn201/climatechange.pdf) accessed July 16, 2013.

Two other recent studies used "**No SLR; Business as Usual**" as the baseline, Brown et al.[9] and World Bank[10]. Brown et al. (2011) investigated potential multi-sectorial impacts and economic costs of climate change throughout Europe, particularly focusing on climate mitigation and adaptation. The analysis used the Dynamic Interactive Vulnerability Assessment (DIVA) Model, and considered future climate and socioeconomic change. It presented broad-scaled analyses from present day to 2100 for Europe as a whole, and 22 European countries individually. Four climate scenarios were developed, impacts assessed, costs of sea-level rise and adaptation costs estimated, and policy implications discussed. For Europe, based on the projected sea-level rise for the mid-range projections for a medium-to-high emissions scenario, the annual economic costs were anticipated to be €11 billion (mid estimate) for the 2050s, rising to €25 billion by the 2080s. Hard (dike building) and soft (beach nourishment) adaptation greatly reduced the overall cost of flood damage. The annual cost of adaptation was estimated at €1.5 billion in the 2050s (EU, current prices, undiscounted), and achieved a benefit-to-cost ratio of 6:1 for the mid scenario. The benefit-to-cost ratios increased throughout the 21st century.

Still another approach was developed by Neumann et al.[11] and Costa et al.[12]. In these studies, the authors identify baseline as "**SLR with No New Adaptation Investment**." As part of its Public Interest Energy Research program, the California Energy Commission undertook a major study of the potential impacts of climate change on California and the effectiveness of adaptation responses. Neumann et al. (2003), a part of that study assessed the economic costs of SLR on a statewide basis for California. The paper examined a broad array of potentially affected sectors as well as the interactions between climate change and increased population, economic growth, and technological change in California. It considered a wide range of climate change scenarios, ranging from warmer and much wetter to warmer and much drier. The focus was on effects on coastal structures. The study reports the economic cost of sea-level rise under four scenarios at two discount rates (3 percent and 5 percent) for seven individual sites and for the state as a whole using several differing aggregation schemes. The values presented show that the total estimated economic impact of a 100 cm SLR in California varies from $148 million (based on CVI scaling and a 5 percent discount rate) to $635 million (based on shore length scaling, a 3 percent discount rate, and the LA adjustment). Comparison across scenarios

---

[9] Brown, Sally, Robert Nicholls, Athanasios Vafeidis, Jochen Hinkel, and Paul Watkiss. 2011. Sea-Level Rise – The Impacts and Economic Costs of Sea-Level Rise on Coastal Zones in the EU and Costs and Benefits of Adaptation. Climate Cost Technical Briefing Note No. 2. Summary of Sector Results from the Climate Cost project, Funded by the European Community's Seventh Framework Programme. Website (http://www.climatecost.cc/images/Policy_brief_2_Coastal_10_lowres.pdf) accessed June 18, 2013.

[10] World Bank. 2010. Economics of adaptation to climate change - Synthesis report. Washington D.C. - The World bank. http://documents.worldbank.org/curated/en/2010/01/16436675/economics-adaptation-climate-change-synthesis-report

[11] Neumann, James E., Daniel E. Hudgens, Jane Leber Herr, and Jennifer Kassakian. 2003. Market Impacts of SLR on California Coasts, Appendix XIII in Wilson, T., L. Williams, J. Smith, and R Mendelsohn, Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy (2003). Website (http://www.energy.ca.gov/reports/500-03-058/2003-10-31_500-03-058CF_A13.PDF) accessed June 18, 2013.

[12] Costa, L., V. Tekken, and J. Kropp. 2009. Threat of Sea-Level Rise: Costs and Benefits of Adaptation in European Union Coastal Countries. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), 223-227. Lisbon, Portugal, ISSN 0749-0258. Website (http://e-geo.fcsh.unl.pt/ics2009/_docs/ICS2009_Volume_I/223.227_L.Costa_ICS2009.pdf)

revealed that the estimates follow the expected pattern; the expected economic impact of sea-level rise increases sharply with steeper sea-level rise. The study also provides figures that illustrate the geographic distribution of costs within California, and presents these costs for three regions; North Coast, San Francisco Bay, Mid Coast, and South Coast. Costa et al. (2009) presents the results of using The DIVA tool to calculate the benefits of a normative coastal protection target versus a business as usual scenario for European Union coastal countries.

Another method, developed by Yohe[13] and followed by other authors estimates the cost of rising sea level over time by comparing the cost of protecting the coastline from inundation with the value of property land that benefits from the protection. The model stresses that the true opportunity cost should reflect the value of the property at the future time of inundation as well as adaptive measures that would be taken to minimize the property loss. Therefore, the model allows the value of property and the value of land to change overtime such that the future value reflects risks associated with inundation. Future property values were based on a property value model developed by Federal Reserve researchers that relied on projected changes in national gross domestic product, construction costs, and household income.. With inundation, the Yohe method assumes that land values will imply migration inland, and thus, the economic value of lost land will approach the value of interior land. To estimate SLR impacts, land cover was divided into a grid and at each decade through 2100 the model would show which cells in the grid would be inundated. Based on property values and estimated costs of protection, the model would then assume that if the protection costs are less than the property value that protection will be applied . For each year thereafter, annual maintenance costs are applied. This approach could be described as "**SLR with best guess of private actions absent community adaptation"**, or **"without project"** using the BCA vernacular.

Heberger (2012) noted several limitations to the Yohe method including: (1) it ignores any transfer among property owners and looks only at net social cost; (2) it assumes that coastal protection will be constructed just in time to avoid climate change related damages; (3) the model looks at changes in mean sea level and does not include changes in storm surge, extreme events, and other climate change related impacts; (4) the model does not include impacts to public infrastructure such as roads and rail, and (5) prioritizing on the value of property results in some populations facing the cost of relocating while other groups receive protection.

For the purpose of comparing one adaptation scenario to another, it is helpful to start with a baseline that is well-specified and has the SLR impacts defined, as is done with the Yohe approacht. From there, adaptation strategies may be compared in terms of how each serves to reduce anticipated impacts.

---

[13] Yohe, G. 1989. "The Cost of Not Holding Back the Sea: Phase 1 Economic Vulnerability" In The Potential Effects of Global Climate Change on the United States. Report to Congress. Appendix B: SLR. Washington, D.C.: U.S. Environmental Protection Agency. EPA 230-05-89-052.

Yohe, G., J. Neumann, P. Marshall, and H. Ameden. 1996. "The Economic Cost of Greenhouse-Induced Sea-Level Rise for Developed Property in the United States." Climatic Change 32(4): 387–410.

Yohe, G. W., and M. E. Schlesinger. 1998. "Sea-Level Change: The Expected Economic Cost of Protection or Abandonment in the United States." Climatic Change 38: 447–472.

3.2.2 Baseline Characterization and Selection

Based on the literature review, six alternatives were identified and discussed with stakeholders for potential use in the analysis. These were:

- Current Conditions
- No Sea-Level Rise, business as usual (going forward in time)
- SLR with no new adaptation investment
- SLR with mandated level of performance response
- SLR with 'best guess' of response in the absence of adaptation, and
- Multiple baselines

Each alternative was considered and assessed for efficacy in relation to this project. The criteria considered included:

- consistency with other research;
- internal consistency (or how well would the baseline work with the modeling that had already been completed through TNC's CRV project);
- how well the definition would serve to assist the team in evaluating adaptation benefits and costs;
- the overall analytic simplicity in terms of the level of time and effort needed to complete the work;
- how well the process could be communicated to the public and stakeholders;
- whether the approach would assist the local stakeholders in meeting their identified needs, and
- whether or not the approach was at all realistic, or was likely to ever occur.

Additional evaluation criteria and notes on the different approaches are provided in Table 3 below.

Table 3: Potential Baseline Scenarios Reviewed

	Potential Baseline Scenario	Description of Baseline	Studies Where Applied	Advantages for Use For Ventura County Project	Disadvantages For Use For Ventura County Project
1.	Current conditions	Conditions as they stand at the present time. No SLR and no adaptation measures.	Heberger et al. 2009; Heberger et al. 2012; Cayan et al. 2009	Consistency- Many SLR impact studies use this.	Doesn't really focus on differences between adaptation strategies
2.	No SLR; Business as Usual	Current SL into the future; population and economic growth continues following state forecasts and full build out following zoning	Brown et al. 2011; World Bank 2010	Provides a good way to think about how SLR will affect life in the future.	Requires forecasts and creation of unrealistic scenario Difficult to isolate current adaptation efforts
3.	SLR with no new adaptation investment	Laissez faire - SLR will occur as predicted, but no new adaptation activities. Current levels of maintenance funding OK. All conservation activities stop (e.g. TNC purchases of Santa Clara River)	Neumann et al. 2003; Costa et al. 2009	Theoretically valid baseline for public decision makers to evaluate investment	Time consuming difficult to define Potential to frustrate stakeholders
4.	SLR with mandated level of performance response	SLR will occur as predicted and the responses mandated under current regulations will take place. For example, the dredging requirements for ports to maintain certain depths.	None known	More realistic – allows discretionary spending evaluation May simplify modeling assumptions May provide local decision makers with best guidance	Time-consuming to define and develop Potential to confound baseline with management scenario

Table 3: Potential Baseline Scenarios Reviewed

	Potential Baseline Scenario	Description of Baseline	Studies Where Applied	Advantages for Use For Ventura County Project	Disadvantages For Use For Ventura County Project
5.	SLR with best guess of “without project”	Involving estimates of going forward with SLR, assuming likely responses absent the specific management scenarios under question	None known	Most realistic way to evaluate benefits of the management scenarios in isolation If plausible, assumptions about “without project” lends credibility to effort	Most difficult to define and justify Will be subject to criticism that assumptions drive results
6.	Multiple baselines	Use of more than one baseline scenario.	According to UNFCC 2009, very few studies have used this	Baseline is tailored to the specific management scenario More appropriate to local community trying to decide best option	Not as commonly used – no known guidance document recommends this Can’t provide objective comparison between NBA and CAA across situations

Note: The shaded row represents the selected baseline for this project

Option 4 was chosen from the six options. The team determined that including SLR was essential in the baseline, but that contriving a future scenario with an economic shock (such as a port closure) was not going to be helpful to the analysis. Therefore, the mandated activities similar to and including dredging at the port were included in the baseline. As outlined in the previous section an initial baseline scenario was developed taking into account existing coastal modeling efforts developed by ESA PWA, which forecast future coastal erosion, coastal storm surge flooding, a wave velocity zone, and rising tide inundation under existing conditions, for 2030, 2060, and 2100.

This baseline was evaluated under the same three different SLR scenarios developed in the previous modeling. All curves used to forecast SLR include an adjustment for local vertical land motion using the Santa Monica tide station. The SLR at each planning horizon is shown in Table 4. For the purposes of defining a baseline for economic subsequent analysis in this report, a high scenario was presumed.

Table 4: Sea Level Rise Projections

Year	Low SLR	Medium SLR	High SLR
2030	6 cm (2.3 inches)	13 cm (5.2 inches)	20 cm (8.0 inches)
2060	19 cm (7.4 inches)	41 cm (16.1 inches)	64 cm (25.3 inches)
2100	44 cm (17.1 inches)	93 cm (36.5 inches)	148 cm (58.1 inches)

Further definition of the baseline scenario clarified the assumptions about how benefits and costs were measured in both the NBA and CAA scenarios (as defined in section 3.3 above):

1. The baseline consists of projected high SLR and associated impacts as described in ESA PWA final report to TNC.[14]
2. Mandated activities such as federal dredging of ports to maintain specified channel depths will continue to occur.
3. Other public expenditures on responses to SLR are frozen at current levels. It is assumed that some private adaptation will occur. This follows other assumptions about SLR that have been developed by Yohe (1996) and followed by others in California (e.g. Neumann et al., 2003).
4. The population of Ventura County will continue to grow following the forecast by the California Department of Finance (DOF), though some adjustments will be made to account for anticipated changes in coast-specific activities.
5. The economy of Ventura County will adjust in minor ways should SLR impacts target key coast-dependent activities such as tourism.

Baseline conditions for the purpose of the remainder of this analysis are the best estimates of conditions as they would occur assuming SLR occurs within the high scenarios as anticipated,

[14] ESA PWA 2014. Technical Report for Coastal Hazards Mapping, prepared for the Nature Conservancy. San Francisco, CA, July 31.

and assuming that the county continues to follow the population growth forecast developed by the California DOF. Slight shifts in the location of commercial and residential activities may be expected in light of the additional assumption used to define the baseline, which is the absence of public sector monies to adapt to the impacts of SLR.

3.3 Alternative Adaptation Scenarios

Alternative adaptation scenarios were designed to explore how different strategies (nature-based or engineering-based) compare in terms of gains and losses over and above what would otherwise occur. The analysis was done based on the assumption that the elements of the scenario would be carried out between now and the year 2100. The baseline concept as articulated in section 3.2 (or the best estimate of what would occur in Ventura County in the absence of the adaptation strategy) is also defined over an 86 year time period.

Two alternative adaptation scenarios were developed in cooperation with TNC staff, local stakeholders, and the consultant team (ENVIRON and ESA PWA). One management scenario was designed with the intention of maximizing use of natural ecological processes to help mitigate the impacts of SLR and simultaneously striving for long run preservation of ecosystem services. This is called the Nature Based Adaptation (NBA) scenario. A second management scenario employed a more engineering based approach involving defensive structures designed to mitigate SLR impacts at lower immediate financial costs, and without necessarily placing a priority on ecosystem services. This approach is referred to as the Coastal Armoring Adaptation, or CAA scenario. These two represent fundamentally different approaches to provide decision makers in Ventura with an understanding of the potential tradeoffs between the two approaches. The two management scenarios are not intended to be specific prescriptions for management of coastal Ventura County, but rather to demonstrate the costs and benefits of alternative management types so that decision makers may craft specific adaptation strategies to suit their needs. All scenarios were evaluated using the High SLR projections to the capture all potential impacts. Actual adaptation will likely be a combination of the different strategies presented in these scenarios.

The scenarios are presented in detail along with a set of tiled maps (tile layout in Appendix B, Figure 1), with the NBA scenarios in Appendix B, Figure 2a through c and the CAA scenarios in Appendix B, Figure 3a through c.

3.3.1 Nature Based Adaptation (NBA) Scenario

The nature based adaptation scenario was developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. NBA options evaluated include a set of management tools including restoration of wetlands, dunes, and other natural processes, as well as managed retreat. Managed retreat allows the shoreline to advance inward unimpeded.[15] This is most often accomplished through the removal and/or relocation of structures and assets that require flood protection. Allowing the return to a natural process in an area where it is

[15] From National Oceanographic and Atmospheric Administration's webpage on Coastal and Ocean Resources, available at: http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html

naturally disposed to occur, will, in principle, lessen the probability of flood damage in adjacent areas.

Areas where open land is available, and where restoration of natural functions and processes could take place, were considered most appropriate for application of “natural processes”. In areas where public infrastructure was located, managed retreat options were considered most appropriate as these tend to fall within the jurisdiction of the state, county, or city governments. In the case of private property, selected adaptation options were chosen that would allow homeowners to retain their location for the present time and to the extent possible, maintain the integrity of the oceanfront home values.

The elements of the proposed NBA scenario are presented in Appendix B, Figure 2a through c. It consists of beach and dune restoration projects, wetland restoration projects, managed retreat areas, and elevated neighborhoods. The relevant lengths and areas of proposed adaptation scenarios are also shown in the Appendix B.

3.3.2 Coastal Armoring Adaptation (CAA) Scenario

An engineering based adaptation scenario was developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. This alternative involved extensive coastal armoring and therefore is referred to as CAA scenario. The CAA option includes a set of management tools that focused on protection through construction of sea walls, levees, and other armoring. The CAA elements are shown in Figure 3 of Appendix B, and summarized below, with the relevant lengths and areas reported in Table 2 of Appendix B.

The CAA approach includes coastal armoring along most of the study area between the Ventura River and Point Mugu. Revetments and/or seawalls would be reinforced or placed along the backshore toe of the existing shoreline to protect it against erosion. The armoring options are separated into “reinforce existing” or “construct new” armoring, based on an existing geospatial coastal armoring inventory[16].

Escalating maintenance costs were assessed by increasing levels of wave attack on the structure as the beach width was lost. Shoreline armoring is known to result in a long term narrowing of the beach in front of structures (i.e. passive erosion). Additionally, some beach is lost to the footprint of the structure (i.e. placement loss). Both passive erosion and placement loss were evaluated in the beach width analysis.

3.4 Quantifying Impacts: Approach and Methods

One of the primary goals of this study was to quantify not only the gains and losses in financial terms (e.g. project costs and damages reduced) of different management scenarios, but to also compare ecosystem service gains and losses, and other relevant land-based changes associated with the NBA and CAA strategies. Ecosystem services are the benefits that humans receive from naturally functioning processes such as the provision of clean water, recreation,

[16] California Coastal Commission Coastal Armoring Database (2005).

and habitat for species. Changes in the natural environment will therefore impact the flow of ecosystem services. For example, some impacts to the natural environment from SLR and climate change could include water storage and treatment, production and protection of wildlife, erosion of beaches that affect recreation, and saltwater intrusion. Together, these types of measurements can be used to capture the economic gains and losses to society from alternative investment in climate change adaptation.

Three alternative future scenarios – including the baseline scenario - were developed and evaluated. Benefits and costs of the alternatives were quantified using several metrics. Benefits are measured as damages avoided plus ancillary benefits from investment in ecosystem services (such as increased recreational areas and improved habitat for species). Costs consist of the costs associated with constructing and carrying out the adaptation strategies. . Overall, the alternative adaptation scenarios examine tradeoffs involved with planning for SLR and adapting to climate change. A full discussion of how the results may be used and interpreted by decision makers is provided in the Chapter 5.

As mentioned in the introduction, there are different asset classes placed at risk from SLR. Many of the assets evaluated were measured using a spatial database that connects location-specific impacts of SLR (as developed in the previous physical modeling, see Chapter 2) with parcels as delineated by Ventura County. All of the Buildings and Built Infrastructure assets, all of the Agriculture assets, and some of the Ecosystem Service assets (recreation) are analyzed in the data base. A description of the components of this database is presented below in Section 3.4.1. This is followed by a discussion of the different types of economic assets, or ‘asset classes’ and an overview of the methodology used to estimate damages in Sections 3.4.2, 3.4.3, and 3.4.4. Estimating impacts to jobs, income, and gross domestic product (GDP) is beyond the scope of the current effort.

The overall conceptual framework for quantifying the impacts of SLR on the Ventura coastline is illustrated in Figure 3. The very top box shows that climate change is acting on the economic system and altering how the system works together. Climate change, and in particular SLR will affect the ‘asset classes,’ which are grouped into a) Buildings and the Built Infrastructure, b) Agriculture, and c) Ecosystem Services. Management options and overall impacts from SLR will ultimately change the distribution of ecosystem services currently provided to the community of Ventura County from the local environment. The influence of SLR will ultimately alter the economic value of the assets, in terms of property and infrastructure values, agricultural land values, or through the benefits provided by ecosystem services such as recreation and habitat values.

When an adaptation strategy is employed, the strategy should help mitigate some of the impacts of SLR on the asset class values. Hence the arrow to the right of the ‘Change in Economic Value’ box shows that ‘Damages Avoided’ can be thought of as the benefit of an adaptation scenario. This can be compared with the cost of the adaptation scenario (shown as a grey arrow coming from above) and together the benefits (damages, or losses avoided) minus the costs of an adaptation scenario will produce the net benefit of the adaptation scenario (shown in the blue box to the right in the middle of the diagram.) This net benefit and the closer examination of the costs and benefits through time is the information decision makers need to be able to evaluate different adaptation choices.

As discussed more in Chapter 5, formal benefit cost analysis (BCA) uses the information contained in the dark blue boxes of Figure 3, compared with the cost information. If the net benefits through time are positive, then the adaptation scenario is considered ‘feasible’ and if the costs exceed the benefits (damages, or losses avoided) through time, then the adaptation is considered infeasible. When there are more than one feasible alternative, then the alternative with the largest ‘net benefit’ is considered favorable to the others.

The basic benefit cost dynamics described above provide formal economic data, but in reality other factors also play a role in decision making. For example, cultural preferences, safety considerations, and impacts to the total regional economy may influence decisions. Changes in the regional economy are shown in the greenish-blue box at the bottom of the diagram. In formal BCA, such regional economic impacts as jobs, income, GDP and tax impacts are assumed to occur elsewhere if they are shut down within a particular geography. Consequently, these are not counted as a net benefit or a net cost. But to a local jurisdiction, which risks losing out on revenue and economic activity to a nearby competitor, these impacts can be significant. Such impacts include business interruptions, reduced payroll, and tourism impacts. In turn, the reductions or impacts can then trigger additional economic slowdowns. Although regional economic impact analysis (EIA) is outside the scope of this research, it is important to understand that these impacts exist, and can add a layer of complexity for decision makers.

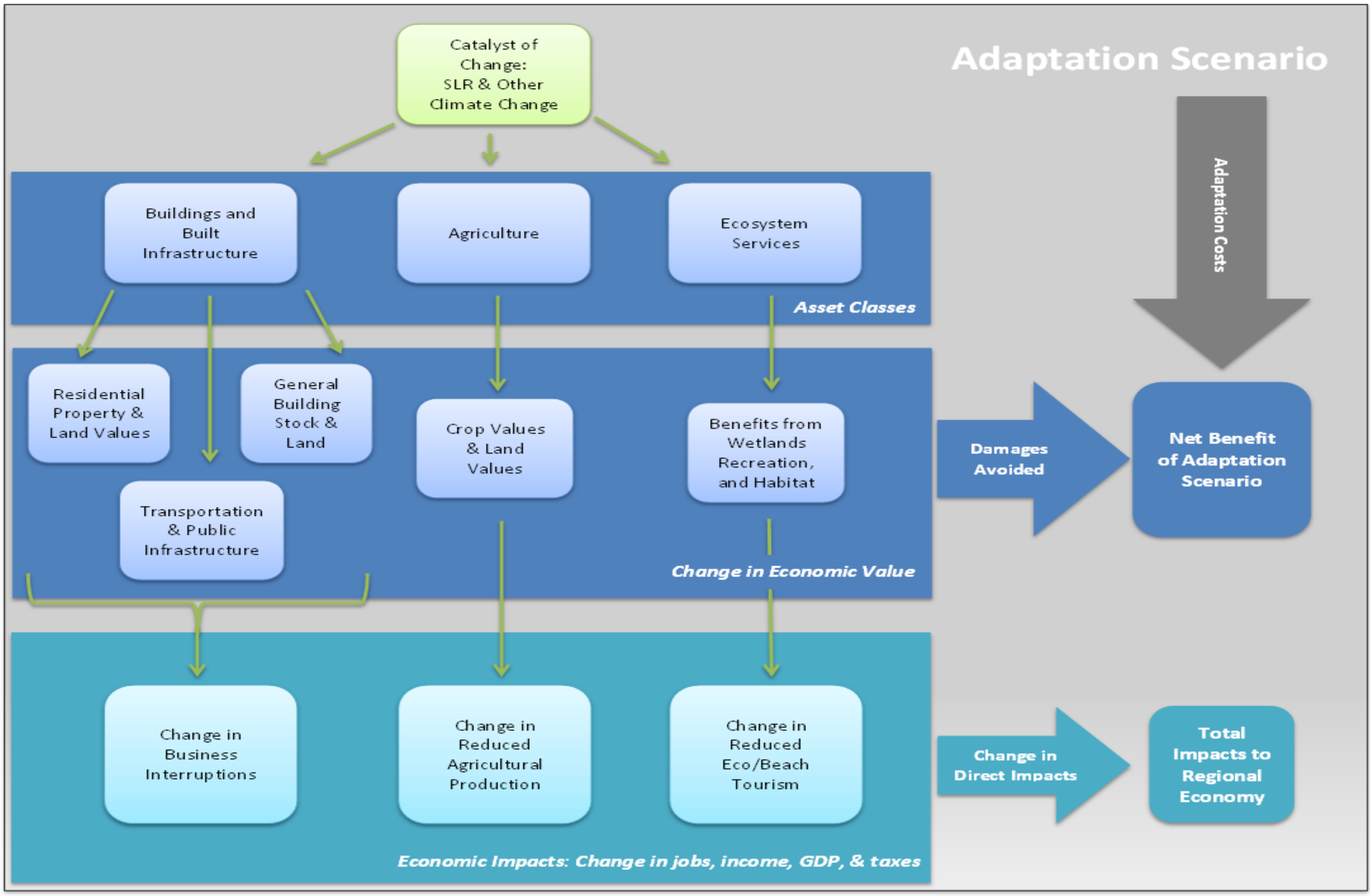


Figure 7: Conceptual Framework for Impact Characterization

3.4.1 Parcel Database Development

The changes in value to Ventura County asset classes are estimated in part through development of a comprehensive database comprising a combination of known assets (both built and natural) and potential hazards as modeled by ESA PWA. In addition to the results from the hazards modeled earlier, several data sources were used by ENVIRON to create the overall database. Sources utilized included the Ventura County Assessor's Office, Hazus data[17], real estate experts, DataQuick[18], Ventura County Agricultural Commissioner's Office, California's Protected Area Database[19], land cover data, and coastal hazards modeled by ESA PWA.

The database was designed using parcel-specific data collected from the Ventura County Assessor's Office as the overall basic structure. The database was built using a combination of spatial overlay in GIS and spreadsheet modeling. Each parcel was populated with information on land size, land use, land value, building types, and building values, acres of crop by type, public parks, and other asset information described below. Storm related flooding, erosion, and

[17] FEMA. The Federal Emergency Management Agency's Methodology for Estimating Potential Losses from Disasters. Available online at: http://www.fema.gov/hazus

[18] For more information about the services provided by DataQuick, please visit: http://www.dataquick.com/

[19] For more information, please visit: http://www.calands.org/

inundation were estimated by ESA PWA at the center point of each parcel, thereby providing information of flood depth and erosion potential on a parcel basis. Roads, rail, and other linear assets did not fall within parcels, but rather between parcels, and were managed in a separate database. Estimates of damages involve the development of formulas to estimate first the value of structures and property, and second the economic value of the losses that will occur to each property due to SLR.

Soon after reviewing the Assessor's value data, it became obvious that the assessed value provided does not accurately represent the current market value of homes. In response to this concern, ENVIRON worked with TNC staff to develop a methodology to adjust the value of each parcel to be a market value. After reviewing several alternatives, the team decided to utilize monthly home sale values per square foot published by the Los Angeles Times in a data base called DataQuick. Values from 2014 for Ventura County were then multiplied by the square footage of each structure in the assessor database.

The parcel database was then completed with the addition of information on public parcels acquired from the Federal Emergency Management Agency (FEMA) Hazus model, which has information on public infrastructure data, and is readily available online. ENVIRON worked with TNC staff to compile additional information on public parks and recreational and agricultural areas within the county using the Coastal Resilience Ventura GIS interface. Additional information on linear infrastructure such as roads and railways was also added into the database with existing values estimated for every item in the parcel database. Information on agricultural properties, crops, and values were compiled from the Ventura County agricultural office.[20] A variety of parks and recreation data were also added, as available, including data on the numbers of visits to each park. The value of roads are based on road function class-specific values from the California Flood Rapid Assessment Model (F-RAM)[21] applied to function class-specific road miles. Table 5 shows the sources of data in the parcel data base.

[20] Personal communication from Scott Wilson, Agricultural Inspector, Ventura County Agricultural Commissioner's Office sending GIS files for the County.

[21] State of California, Department of Water Resources, Division of Flood Management, 2008, Flood Rapid Assessment Model (F-RAM) Development 2008, November.

Table 5: Primary Data Sources	
DATA	**SOURCE**
Coastal Hazard Data	ESA PWA
Public Infrastructure	Hazus
Parks and Recreation	Multiple public sources
Parcel Data	Ventra County Assessor's Office
Replacement Cost of Public Infrastructure	Hazus
Market Value of Residential Homes	DataQuick via LA Times
Recreational use data	Multiple Public sources
Agricultural Value	Ventura County Agricultural Commissioner's Office
Recreational Value	USFS Database
Agricultural Crop Acreage	Ventura County Agricultural Commissioner's Office
Road Value	State of California Flood Rapid Assessment Model (F-RAM) Development

Table 6 shows the numbers of parcels, area, and value for all of the assets in the parcel database. Added together, the private, public, agricultural, recreational, and road miles total 31,121 units which are potentially at risk of damage from SLR. The value of the property at risk totals over $17.7 billion.

Table 6: Parcel Data Base Totals			
Asset Class	**Basic Units**	**# of Units**	**Value (Millions)**
Private	Parcels with structures	30,151	$15,751.2
Public	Parcels	92	$918.8
Ag	Parcels	408	$936.5
Recreational	Parcels	236	$115.8
Roads	Miles impacted under current conditions	234	$12.7
Totals		**31,121**	**$17,735**

3.4.2 Impacts to the Buildings and Infrastructure

The built assets of Ventura County consist of the general building stock, residential homes, utilities, transportation systems, and other elements of public and private infrastructure. SLR and climate change have the potential to impact these assets through increased frequency and magnitude of flood inundation, and erosion resulting in damage to roads, buildings, and other assets, as well as loss of land where structures currently reside.

Damage from flooding was estimated using depth-damage functions developed by the US Army Corp of Engineers. A depth-damage function is a mathematical relationship between the depth of flood water above or below the first floor of a building and the amount of damage that can be attributed to that water. Depth-damage relationships are generally expressed with structure damage as a percentage of structure value for each foot of inundation[22] These functions are based on past flooding events and the resulting damage to the general building stock. The hazard layers developed by ESA PWA were overlaid with the parcels in GIS, and subsequent data were provided by ESA PWA showing how each hazard layer (storm event, erosion, and wave impact) affected each parcel (see Figures 2 – 4, Chapter 2). Publicly available damage functions were applied to each to determine the dollar value of damages moving through time. Table 7 summarizes data sources and brief descriptions of damage functions used.

Table 7: Economic Hazard Damage Functions

Hazard	Description	Variable Measurement	Variable Names	Economic Damage Function Used
Extreme Monthly High Water	EMHW, a high tidal water level reached approximately once per month. This represents areas that are regularly flooded by ocean tides. This water level does NOT represent a coastal or fluvial storm condition.	Depth of flood used to estimate baseline. After that, % of parcel inundated at EMHW within parcel (High SLR)	• Dm_ec2010 • Dm_s32030 • Dm_s32060 • Dm_s32100	USACE Depth Damage Functions based on number of stories, presence of basement, and depth of water measured in feet. Management Scenario damages used of parcel is more that 50%, not counted if parcel is less than 50%
Flood depth of major coastal storms	This flood depth is based on the highest observed water level (2.35 m NAVD88) at the Rincon Island tide gage (NOAA #9411270), from a record storm in January 1983. Flood depths are only included for areas outside the wave hazard zone.	Mean flood depth of major coastal storm within parcel (High SLR) measured in Meters	• Sm_ec2010 • Sm_s32030 • Sm_s32060 • Sm_s32100	USACE Depth Damage Functions based on number of stories, presence of basement, and depth of water measured in feet
Wave Zone Area	Parcel is located in a wave zone area., dominates flood inundation	Presence of wave hazard in any part of parcel (YES/NO)	• WH_ec2010 • WH_s32030, • WH_s32060 • WH_s32100	Loss of value based on USACE functions.
Long Term Erosion	Area of long-term, continued erosion due to SLR. Does not include erosion from 100-year storm.	Percent of parcel in long-term erosion hazard zone (%)	• El_s32030 • El_s32060 • El_s32100	Set up some breaks (< 50% erosion = 50% loss in value, > 50% erosion = 100% loss in value)

[22] Catalog of Residential Depth Damage Functions Used by the U.S. Army Corps of Engineers, in flood damage estimation, May, 1992, IWR – Report 92-R-3,http://planning.usace.army.mil/toolbox/library/IWRServer/92-R-3.pdf.

The depths used in the depth damage functions were assessed based on the depth of water at the EMHW at the midpoint of the parcel under all three scenarios.

For each asset class, the damage function is multiplied by the value of the asset to estimate damages for each hazard type and year scenario. Results under the baseline scenario make up the total amount of damages anticipated in the absence of adaptation measures. The two adaptation scenarios are then evaluated for damages and compared with baseline to see how much of the baseline damage was reduced. These reduced damages represent the benefits of the adaptation strategy.

For roads, damages under each of the hazards are calculated by applying the value per mile of road to the number of road miles inundated by each hazard, by function class. Table 8 shows the values per mile for each road function class.

Table 8: Road Classes

Road Function Class	Definition	Value per Mile
2	Highway	$250,000
3	Major Road	$100,000
4	Major Road	$100,000
5	Minor Road	$ 30,000

3.4.3 Impacts to Agricultural Systems

Agriculture can be impacted from damages to crop production from flood inundation, and erosion. To estimate these impacts, estimated production data and market values of crops grown in Ventura were collected from reports available from Ventura County Agricultural Commissioner's Office.[23]

Impacts from storm events that are infrequent may not necessarily remove land from agricultural production, but may cause shorter term damage. To capture this dynamic, damage curves were used to estimate losses from storm events.[24]

The values of agricultural lands are based on crop-specific acreages, total agricultural acreage, and crop-specific value per acre from the Ventura County Agricultural Commissioner's Office.[25]

---

[23] Office of the Agricultural Commissioner, 2012, Ventura County's Crop & Livestock Report, Changing Tastes.

[24] Flood risk analysis is a holistic approach, which considers the risk of all kind of flood types and flood events for a study region. Flood risk analysis not only encompasses the risk that one specific or one extreme flood event may occur it also combines the hydrological knowledge about the frequency of different types of flood events, the hydraulic modelling information about inundation behavior of flood water in flood plains and economic flood damage evaluation knowledge in order to provide so-called damage-probability curves for individual floodplains or also for nations as a whole. The total area under the curve represents the average total expected flood damage per year for all kinds of floods. Hence, the damage probability curve contains important risk-related information for decision making on flood risk management policy.

[25] Office of the Agricultural Commissioner, 2012, Ventura County's Crop & Livestock Report, Changing Tastes.

Estimating damages related to agricultural flooding requires making some assumptions regarding the percentage of the crop that is lost based on the various conditions. Most crops in North America are intolerant to flooding and cannot withstand more than 1-2 days of flooding or complete soil saturation.[26] Accordingly, we made the following assumptions for the mean high water and severe coastal storm hazard analysis:

- With 3 feet or more of flooding there is a complete loss for the season (100 percent)
- With 2 to 3 feet of flooding there is a loss of 66 percent
- With 1 to 2 feet of flooding there is a loss of 33 percent
- Less than one foot flooding at center point of parcel is considered no loss (0 percent)

The wave and erosion hazard analysis already includes a percentage loss calculation so the respective percentage is applied to the total crop value of each individual parcel and then summed for both of these hazards, under all three alternatives, same as for the public and private damages analyses. Estimated damage or loss of use from inundation and erosion was analyzed based on the total value of lost agricultural production. At the same time, these areas may present opportunities for wetland restoration or habitat creation that will have positive ecosystem service values associated with them. In addition to SLR impacts, adaptation options could also result in reduced agricultural land if areas are converted to natural systems or to public use through managed retreat options. Although saltwater intrusion is also a potential threat to agriculture resulting from SLR, prior modeling was not adequate to be able to quantify this value with sufficient accuracy.

3.4.4 Impacts to Recreation

Recreation is an asset provided to society by the natural environment and it is included in the "Ecosystem Services" asset class in Figure 3, above. Estimating damages, related to recreational parcels flooding, requires certain assumptions regarding the composition and value of the recreational parcels based on the local conditions. The approach used here is similar to that used for the other parcels in that values are developed, and then hazards represent some sort of loss of value based place-specific impacts. This study's approach to measuring recreational losses is as follows:

- Estimate the average number of visits to parks on a per acre per year basis using state park visitor data for 2013.
- Evaluate the average value per visit based on previous studies of the value of California beach visits as compiled in the USFS database.[27]
- Multiply the average visits per acre by the average value per trip by the number of acres in each of the 236 recreational parcels in the parcel database.

[26] Butzen, Steve, Flooding Impact on Crops, Accessed August 26, 2014 at: https://www.pioneer.com/home/site/us/agronomy/crop-management/adverse-weather-disease/flood-impact/.

[27] Rosenberger, Randall. (2011) Recreational Use Values Database, public version, This database was developed with funding from U.S. EPA STAR Grant #RD-832-421-01 and from USDA Forest Service, Rocky Mountain Research Station RJVA #04-JV-11221617-246, both to Oregon State University

- Reduce the value of the recreation in each recreation parcel by the hazards and damage functions as were used in the private and public parcels.

Data was obtained from various sources. The following table provides an overview of the data received from each of the sources, as well as the specific citations (Table 9).

Table 9: Data Used in Recreation Parcels

Source	Data obtained
California Protected Areas Data Portal[1]	GIS parcel boundaries and park data including acreage
California State Park System. Statistical Report 2011/12 Fiscal Year. Statewide Planning Unit. Planning Division[2]	Numbers of visitors for five state beach parks: Emma Wood; Leo Carillo; McGrath; San Buenaventura; and Mugu parks from 2001 – 2012 by month
USFS Database of Recreation Values[3]	Consumer surplus of park based on number of visits and consumer surplus per visit

[1]Greeninfo Network, 2014, California Protected Areas Data Portal, available at: http://www.calands.org/data
[2]California State Park System. Statistical. Report. 2011/12 Fiscal Year. Statewide Planning Unit. Planning Division. California State Parks, available at http://www.parks.ca.gov/pages/795/files/11-12%20statistical%20report%20internet.pdf
[3]Rosenberger, Randall S., Oregon State University, 2011 , Recreation Use Values Database Public version - August 1, 2011.

We determined that the value of an average visit to a state park or beach park was $93 per visit. The average number of visits per acre per year is 110 based on the visitation at the five state beaches below (see Table 10). The total annual recreational value for all parcels is $115.8 million (see Table 6 above), and is less than the value in Table 10 because only a small portion of Leo Carrillo State Park is in Ventura County.

Table 10: Annual Visits per State Park, Acres, *Visits per Acre, and Recreational Value				
	Visits	**Acres**	**Visits/Acre**	**Rec Value/Year**
Emma Wood State Beach	138,181	109	1,265	$12,899,827
Leo Carrillo State Park	519,901	116	4,472	$48,534,946
McGrath State Beach	165,726	312	531	$15,471,204
Point Mugu State Park	401,588	13,925	29	$37,489,994
San Buenaventura State Beach	380,586	109	3,487	$35,529,341
Total	**1,605,983**	**14,572**	**110***	**$149,925,312**

* Visits per acre is an average based on total acres and visits, all parks

3.5 Ecosystem Services

Much research has covered the idea that when economic decision making affects the environment, attention must be paid to the ecosystem service flows too; regardless of the degree to which those ecosystem services show up in market transactions. This literature was born in part of environmental economic research that attempted to assign a monetary value to ecosystem services (recreation was one of the earliest services to gain attention). Such efforts were pioneered in the 1960s and 1970s and often funded by public agencies such as the US Army Corps of Engineers,[28] which helped to formalize BCA.

Since that time the vast growing interest in taking stock of ecosystem services (natural capital) has taken many forms, including the 2005 global statement on ecosystem services developed through the Millennium Ecosystem Services Assessment (www.mea.org), which supports research on formal methods of ecosystem services analyses. For the question of climate change adaptation decisions, ecosystem services are of paramount importance. However, methods to measure the services still present challenges and new research improves the process daily. In many circumstances the ready availability of GIS resources, such as the system that has been put in place by the Coastal Resilience Ventura network and TNC greatly facilitate the process of measuring ecosystem services.

For the CRV project, which is designed to evaluate all relevant benefits and costs of the CAA and NBA scenarios, the appropriate ecosystem services valuation approach is called NESA and it is designed to calculate the net benefits and/or declines in services from the environment to humans using the same framework as BCA analysis, though the units do not need to be converted into monetary values. When NESA units are converted to monetary units, they may be rolled into the BCA framework for a full analysis of benefits and costs. For the current study, habitat equivalency analysis (HEA), which is an approach that falls within the NESA framework,

[28] See the 1983 “Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies” from the Water Resources Research Council, available at http://planning.usace.army.mil/toolbox/guidance.cfm?Id=269&Option=Principles%20and%20Guidelines or Myrick Freeman’s “The Benefits of Environmental Improvement: Theory and Practice”, Baltimore: Johns Hopkins University Press,1979.

is applied to results from the SLAMM model to evaluate changes in ecosystem services by land cover type. The use of a HEA produces estimates that are all converted into “service-acre years,” or the equivalent of the ecosystem services provided by one acre of saltwater wetland for one year. Results can then be discounted and collapsed into a net gain or loss context just as is done with benefit cost analysis. The other ecosystem services measured are recreation and agriculture, which have been accounted for with monetary estimates within the parcel database, as described above.

3.5.1 Habitat Equivalency Analysis

HEA is an environmental annuities model that has been widely adopted by state and federal agencies for quantifying the relative value of ecosystem services.[29][30] This section provides an overview of HEA and its assumptions, presents the parameter values used in the analysis, and describes the basis for those values. For the present study, the potential impact on ecosystem services of different management scenarios over time was estimated using HEA. Under HEA, ecosystem service flows are quantified based on the area of land cover type or habitat type required to maintain them, thus allowing for direct comparison of services gained through management actions that restore habitats with losses that result from elimination or injuries to natural resources or habitats. The following input parameters are required to complete the HEA:

- Area disturbed or lost and area restored or gained in acres
- Habitat types within the study area.
- Relative habitat quality throughout the project area prior to disturbance (e.g. future climate change effects), during climate change effects, and following management action studied.
- Time frame of project impacts and benefits (start year and end year).

Habitat quality is scored on a scale of 0 (no habitat value) to 1 (maximum habitat value) similar to the United States Fish and Wildlife Service’s (USFWS) Habitat Suitability Indices (HSIs)[31].

The level of ecosystem services provided is assumed to be directly proportional to the habitat quality score. This approach was developed by the NOAA to quantify potential damages associated with habitat degradation (e.g. contamination) and potential credits associated with compensatory restoration actions (Chapman and Taylor[32]). This general approach has been adopted at many sites throughout the U.S.by NOAA, the US Army Corps of Engineers, and others.

[29] Dunford, R.W., Ginn, T.C.,Desvousges, W.H., 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics 48, 49-70.

[30] NOAA. 2006. Habitat Equivalency Analysis: An Overview. National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program. March 21. Revised 2000, 2006. 23. http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

[31] http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiindex.htm

[32] Chapman, D.J. and R.A. Taylor. 2002. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Appendix F: Equating Contaminant-Related Ecological Service Losses and Restoration-Generated Service Gains for the Hylebos Waterway Using Habitat Equivalency Analysis. National Oceanic and Atmospheric Administration. Seattle, WA. March 1. http://www.cbrestoration.noaa.gov/documents/cbhy-f.pdf

Depending on the analysis, other key inputs for the analysis are the slope and shape of the ecosystem service recovery curves (e.g., linear, logarithmic, sigmoidal, etc.) following change and the social discount rate for estimating the social value of future natural resource services (percent). The recovery of habitats (succession time to reach mature habitat function) was not incorporated because to the time frame of 90 years (from 2010 through 2100) is quite long and it is assumed that the recovery of the habitats take place over those 90 years. Hence the exact pace of the recovery was not essential to the analysis. These parameters are combined to estimate the natural resource services gained (credits) or lost (debits) by management scenario. The unit of measurement used in this analysis is service acre years (SAYs), which is an estimate of the services provided by an acre of habitat over a year period. The following equation is used in estimating SAYs:

$$SAY_s = \sum_{l}^{9} \left[\sum_{t=0}^{n} \left(H_{l_t} - H_{l_b} \right) \quad _t \times A_l \right]$$

Where:

SAY_s:	Service acre years associated with the management scenarios where a negative value indicates net debit and a positive value indicates a net credit to ecosystem services
l:	Habitat type. For the purposes of this analysis, eleven habitat types were evaluated (described in detail below).
t:	Year operations commence (2010)
n:	Final year of management timeline (the last year that credits/debits are tallied). For the purposes of this analysis, the management timeline was estimated at 90 years.
H_{lb}:	Baseline habitat suitability value of habitat type l
H_{lt}:	Habitat suitability value of habitat type l in year t following the management initiation (assumed to be 2010)
A_l:	Number of acres disturbed and reclaimed within habitat type l

The approach for developing the habitat quality values for each habitat type is summarized below.

3.5.2 Input Data for HEA Estimates

The HEA uses input from the Sea Level Affecting Marshes Model (SLAMM). Refer to the technical report (ESA PWA) in Appendix C for more detailed information regarding the model. As discussed above, SLAMM simulates the dominant processes involved in some wetland conversions during long-term SLR: inundation, erosion, overwash, saturation, and accretion. The primary inputs to SLAMM include a high resolution digital elevation model, a map of current wetland habitats, future SLR projections, marsh accretion rates, tide ranges, and erosion rates. The SLAMM ecological vulnerability study focused on the Mugu Lagoon site, which includes the coastal wetland habitats from Ormond Beach to Point Mugu. Two other major coastal wetland systems exist in Ventura County, the Santa Clara River and Ventura River estuaries. During initial efforts to apply SLAMM to these estuaries it became clear that the conceptual model in

SLAMM version 6.2 (the most recent version) does not account for many of the dominant processes occurring in these highly dynamic, seasonally closed systems. Therefore, subsequent effort was focused on Mugu Lagoon, a large open tidal system where wetland extent and habitats that have been relatively stable through time.

As described above, the HEA approach is used to estimate the level of ecosystem services provided by each land cover type. Total ecosystem services are assumed to be proportional to the relative habitat value such that the highest quality habitat (often called the “gold standard”) is assumed to provide the maximum amount of services. The level of ecosystem services provided by the other habitat types is estimated relative to the “gold standard” habitat. The relative habitat scores used in this HEA are listed in Table 11.

For the purposes of this assessment, the habitat types are based on the land cover designations presented in the SLAMM Model, and the changes through time are estimated by extrapolating from the earlier SLAMM model results. To ensure that the analysis does not imply more accuracy than is presented, and to make the analyses simpler, we combined several of the land cover types. The analysis is completed using seven land cover types representing all of the SLAMM land cover types.

Table 11 also provides estimates of the level of ecosystem services provided by each land cover type. The levels of services are scored for each land cover type by the ecosystem services, dependent on the physical, chemical and human use values assigned to each land cover type. Table 11 shows a score (none = 0, low =1, medium =2 or high =3). The service value can be thought of as a collection of criteria known to be linked to the function of an ecosystem. Values are estimated to describe the level of ecological services provided, and are scaled for value in relation to each other. The same type of service value is used across all land cover types and the relative change in services through time are estimated through changes in the spatial extent or each land cover at different times (2010 vs 2100). For those land cover types that are combined, we used an average score that is normalized based on the current area represented by each of the individual land cover types.

Land cover types support many ecosystem services and the value placed on those land covers are estimated through an understanding of what is important to the local stakeholders and the actual physical, chemical, biological (and ultimately) societal services that are provided by each habitat type. The Coastal Resilience Steering Committee identified several ecological asset data categories. These reflect the general values that local stakeholders place on the services provided by the land cover analyzed. These are provided below and include regional assets and those considered important in the Mugu Lagoon and Ormond Beach study areas.

Table 11: Relative Habitat Scores for Net Ecosystem Services Analysis

	Land Cover Group	Developed Uplands	Undeveloped Uplands	Agriculture	Freshwater Wetlands				Saltwater Wetlands			Mudflats	Beaches					Inland Open water				Open Ocean
Ecosystem Service (Function)	Raw Land Cover Type	Developed Uplands	Undeveloped Uplands	Agriculture	Freshwater Wetland with Trees/Shrubs/Riparian	Freshwater Marsh	Tidal Marsh	Tidal Wetland with Trees/Shrubs	Tidal Estuarine Wetland with Trees/Shrubs	Emergent Salt Marsh	Rarely Flooded Salt Marsh / Salt Pans	Mud Flat	Dunes	Coastal Strand	Rocky Intertidal	Estuarine Beach	Arroyo / Gravel / Shore	Riverine Tidal	Tidal Channel	Open Water	Open Water Subtidal	Open Ocean
Recreation	Hunting Fishing	0	3	1	3	3	3	3	3	3	3	3	2	2	3	2	2	3	3	3	3	3
	Bird Watching	1	2	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
	Hiking	0	3	1	3	3	2	2	3	3	3	2	3	3	3	3	2	3	2	2	3	0
	Biking	2	3	1	3	2	2	2	3	3	3	0	2	3	1	3	1	3	1	1	2	0
	Boating	0	0	0	1	1	1	2	3	3	1	2	0	2	1	0	0	3	3	3	3	2
	Country Drives	0	3	2	3	2	2	2	3	3	2	1	3	3	2	3	2	3	2	2	3	0
Socio-Economic	Jobs	3	1	3	2	2	2	2	3	2	2	2	2	3	2	2	0	1	1	1	2	2
	Income	3	1	3	2	2	2	2	3	3	2	2	2	3	2	2	0	1	1	1	2	2
	Cultural - Institutional	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Habitat for Animals	Upland Birds	0	3	2	2	1	1	2	3	2	2	0	2	0	0	2	0	2	1	0	0	0
	Mammals	0	3	2	3	3	3	3	3	3	2	1	2	2	2	1	3	3	3	2	3	1
	Aquatic Species	0	0	0	3	3	3	3	3	3	3	3	0	2	3	1	2	3	3	3	3	3
	Waterfowl	0	2	2	3	3	3	3	3	3	3	3	0	2	3	2	2	3	3	3	3	2
	Reptiles and Amphibians	0	3	1	3	3	3	3	3	3	3	1	3	2	2	1	3	3	2	1	2	0
Water Quality	Sediment Filtration	0	3	1	3	3	3	3	3	3	3	3	3	2	2	2	2	3	2	2	3	0
	Nutrient Cycling	0	3	1	3	3	3	3	3	3	3	3	2	2	2	2	2	3	3	3	3	3
	Slope Stability	2	3	1	3	2	2	3	3	3	3	1	3	3	3	2	3	2	2	1	3	0
Water Quantity	Aquifer Recharge	0	3	2	3	3	3	3	3	3	3	1	2	1	1	1	2	3	3	3	2	0
	Water Storage	0	2	2	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**1**	**2**	**1**	**1**	**1**	**2**	**3**	**3**	**3**	**3**	**0**
	Flood Control	0	2	1	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**3**	**0**
Air Quality	Carbon Sequestration	0	3	1	3	3	3	3	3	3	3	2	2	1	2	1	1	3	3	3	3	3
	Dust Control	2	3	0	3	3	3	3	3	3	2	3	2	3	1	1	2	3	2	2	0	0
	Total Score	15	52	31	61	57	56	58	66	64	58	42	46	49	45	41	40	60	52	47	55	25
	Baseline Area (ac)	3579	4215	9179	115	1079	5	7	65	1802	597	475	264	360	9	1	182	11	130	102	385	12102
	Combined Average (weighted)	15	52	31	57				63			42	46					53				25
	Normalized Score	**0.20**	**0.80**	**0.50**	**0.90**				**1.00**			**0.70**	**0.70**					**0.80**				**0.40**

Regional Ecological Assets Identified by Steering Committee:

- Habitat
  - Wetlands
  - Beaches
  - Bird habitat
  - Estuaries
  - Dunes
- Species
  - Listed Species
  - Rare Species
  - Charismatic species
  - Economic Species (fish, etc)
  - Common Species
  - Birds (migratory)
  - Marine mammals
- Water Quality
  - Drinking water quality
  - Surface water quality
    - Agriculturally derived pollutants
    - Urban runoff
    - Legacy pollutants
- Water Supply
  - Surface water
  - Groundwater
  - Treated water
- Plans
  - General Plans
  - Zoning
  - River parkway plans (SC and Ventura)
  - Conservation Lands
  - National/State/NGO lands
  - Easements
  - Navy Lands

Original Ecological Assets Identified in Ormond/Mugu Area by Steering Committee

- Duck Clubs
- Wetlands
- Beach
- Endangered Species
- Non-endangered Species
- Fisheries
- Protected Wetlands
- Snowy Plover
- Pacific Flyway Stopover
- Harbor Seals
- Migratory Bird Wintering Area
- Bird Nesting

3.5.3 Land Cover (Habitat) Scaling

The scaling of land cover types is used to estimate how each land cover type compares with the highest value or “Gold Standard” in ecosystem services, which is provided by saltwater/estuarine wetlands. Habitat scaling for each of the other land cover types will lie between a zero, and 1.0. The scaling is dependent on the composite service flow scores shown in Table 11. Other land covers that provide greater ecosystem services include freshwater wetlands (0.9), undeveloped lands (0.8) beaches and shorelines (0.7). Those with medium to low value include agriculture (0.5), open water (0.4) and developed lands (0.3).

3.5.4 Extrapolation from SLAMM Results

The challenge to conducting a HEA analysis for this research is in modeling how habitats will change through time with SLR. Although the SLAMM model results are limited because the model was developed for east coast marshes, these results are currently the best available estimate of how land cover types will change with SLR. For this reason, the SLAMM results for the Mugu Lagoon and Ormond Beach are used to estimate how land cover types will change along the remaining Ventura coastline. Mugu Lagoon is representative of an area with abundant wetlands and Ormond Beach is more representative of area dominated by beach shoreline. Areas are slightly modified from the original analysis, so that they are more consistent with the assumptions behind the NBA and CAA scenarios. More details of this process are available in Appendix F. Results are then applied to the remainder of the coastline after a review of specific areas outside the original Mugu/Ormond Beach study area. Areas that have more wetlands are assumed to be similar to Mugu Lagoon and those with more of a beach coastline like Ormond Beach. Spatial differences were accounted for but it was assumed that the ratio of ecosystem services produced would reasonably be expected to replicate the results in the SLAMM study area. The research team agreed that this approach provides the best estimates of how land cover types (and the ecosystem services derived from those land cover types) would change under the baseline, and alternative adaptation strategies, given that the SLAMM model could not be run for the entire project area. Therefore, increases and decreases in the wetland areas outside the study area are assumed to follow patterns similar to the SLAMM study area, except where constrained by an adaptation approach.

3.6 Summary

Though an attempt has been made to capture all of the relevant benefits and costs of SLR along the coast of Ventura County, it is not possible to capture everything. Some impacts from SLR are excluded from this effort because there are little to no data available, while others are excluded because they exceed the scope of this project. Additional impacts from SLR not captured in this study include additional ecosystem service impacts such as reduced carbon sequestration, changes in emissions and energy consumption from construction for adaptation, and ecological risks from superfund sites or other industrial sites that could result in releases of heavy metals, toxins, or other hazardous materials if flooded. Additional socioeconomic impacts not addressed in this analysis include the regional economic impacts described in more detail in Section 3.4.5, and changes in distributional impacts. Distributional impacts describe how different sub populations (such as low-income or other disadvantaged groups) might be differentially impacted by damages from SLR.

A summary of the different coastal hazards that may affect different coastal assets is shown in Table 12 along with the methods for measuring the impact. With the exception of the last two columns in the table (Regional Economic Impacts, and Additional Risks) each type of impact is evaluated at the baseline, which assumes that climate change will occur with no adaptation. Each type of impact is also evaluated under the two adaptation scenarios – the NBA and the CAA - to ultimately determine whether the adaptation approaches are able to reduce the SLR damages sufficiently to warrant the cost of the adaptation strategy.

Table 12: Methodologies and Measures to Quantify Economic Costs and Benefits

	Assets at Risk	Structures	Infrastructure	Recreation	Wetland Habitat	Upland Habitat	Agriculture	Additional Risks
Hazard		**Methodologies and Measures**						
Rising Tide Inundation		• Depth of inundation • Property characteristics • Property values • Depth damage functions	• Depth of inundation • Property characteristics • Property values • Depth damage functions	• Recreational visitation data (Camping, beach use, surfing, bike trails, etc.) • Changes due to floods • Value estimates from comparable sites	• Acres of habitat lost or gained compared to baseline • Dollar values from the literature for comparable habitats	• Acres of habitat lost or gained compared to baseline • Dollar values from the literature for comparable habitats	• Acres of agriculture lost or gained • Loss or gain in profits	• Impacts to high-risk sites such as superfund, waste water treatment plants, power, etc. • Impacts to lower income communities • Impacts from emissions and energy consumption during adaptation measures • Other ecosystem services that are difficult to quantify
Changes to Flood Zone		Same as above	Same as above	Same as above	Same as above	Same as above	Same as above	Same as above
Storm Wave Impact		Complete loss within wave-zone	Complete loss within V-Zone	Complete loss within V-Zone	Above method modified f or wave impact	Same as above	Complete loss within V-Zone	Same as above
Changes to Coastal Erosion Zone		Complete loss w/in zone	Complete loss w/in zone	Complete loss w/in zone	Same approach described for floods	Same approach described for floods	Complete loss w/in zone	Same as above
Changes in Beach Width		N/A	N/A	• Recreational visitation data (as above) • Changes due to lost beach width • Value estimates from comparable sites	Same as above	Same as above	N/A	Same as above

4 Results

Results are presented by several categories in this chapter. The first set of results covers the anticipated damages attributable to SLR as calculated in monetary terms through time. These monetary damages are calculated for private and public structures, roads, agricultural properties, to public roadways, and to recreation (which is an ecosystem service). These damages are presented first for the baseline scenario, which shows the kinds of damages expected if no adaptation were to occur. The SLR scenarios show how the damages increase at each point in time under this baseline.

Following the damages for the baseline, the results are presented for each type of SLR hazard, showing how the alternative adaptation strategies each produce a set of damages that are generally lower than those calculated at the baseline. These reduced damages make up the benefits attributed to each alternative. A summary section shows how the benefits compare between the two adaptations scenarios.

The results of the HEA analysis are then presented to demonstrate how ecosystem service values change for the baseline scenario, and the two adaptation scenarios. These results are presented in service acre years (SAYs) and discounted service acre years, or dSAYs. The dSAY calculation simply adds up all of the service acre years over the study time horizon (2014 – 2100) using a discount rate for each year in the future that the gain or loss in SAY is expected to occur.

4.1 Baseline Results

Tables 13 through 17 show the baseline structure and infrastructure damages at present, and show how these are forecast to increase with time. Results are shown in 2013 dollars.

Table 13 shows the damages through time for the extreme mean high tide (EMHW); the results do not include existing damages because current erosion damages have no historical or geological reference point. The results show that damages will only increase slightly in the early years ($3.7 million in 2030 and $16.0 million in 2060), but then increase more than ten-fold between 2060 and 2100 from to over $171 million. This suggests that the high tides are not expected to affect many properties for several decades. Damages are calculated on an annual basis, which assumes that there is one EMHW per year, and that damages from this are repaired annually. This is a simplifying assumption, which is reasonable when damages are relatively small, but property owners might respond differently once the magnitude of damages is larger (between 2060 and 2100).

Table 14 shows damages anticipated to occur in the event of a one-percent annual chance flood. The impacts of such a storm are not expected to cause much damage under existing conditions, with estimates at just $3.9 million. However, this same storm under SLR conditions is expected to cause over $21 million in damages by 2030, and over $75 million by 2060. These early year impacts are low in comparison to the 2100 damages, which total more than $324 million.

Table 13: Baseline Depth Damages - Mean High Water				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$2,979,091	$6,812,856	$110,292,023
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$0	$534,959	$8,863,902	$58,491,811
Recreational Damages	$0	$2,424	$2,894	$4,139
Road Damages	$0	$227,273	$412,322	$2,281,582
Total Damages	**$0**	**$3,743,746**	**$16,091,974**	**$171,069,555**

Table 14: Baseline Depth Damages – Storm Damages				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$1,264,245	$3,784,383	$20,273,603	$183,831,269
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$806,830	$14,701,267	$50,292,563	$132,811,996
Recreational Damages	$0	$422	$1,750	$4,500
Road Damages	$1,815,231	$2,728,970	$4,728,006	$8,150,626
Total Damages	**$3,886,306**	**$21,215,042**	**$75,295,923**	**$324,798,391**

Wave damages are caused by waves associated with the 100 year frequency storm event that significantly magnify the damages from the flood waters. For example, with a large magnitude wave brought on by a 100 year (or one percent annual chance) storm event, the damages to coastal properties could exceed $1 billion under existing conditions. Due to SLR, this same wave damage could increase to over $3.8 billion by 2100, or nearly one quarter of the value of the study area properties (see Table 15). Damages anticipated from erosion are shown in Table 16. A review of these results suggests that erosion will be increasingly important even by 2030, especially to private properties that might experience erosion damages totaling about $470 million. Erosion damages are then expected to increase to more than $820 million by 2100. The damages are calculated for one year, but because they would likely occur slowly, they are spread evenly over the relevant time period in the benefit cost analysis.[33]

[33] These estimates are based on somewhat crude assumptions about damages at the parcel level, and further assume that no efforts to mitigate the effects of climate change are adopted. In reality, it may be that parcels with erosion do not experience the erosion in a way that affects property value, or it might be that the error of a foot or two of spatial accuracy causes an over- or under-estimate. The purpose of establishing this baseline is to provide a starting point from which to measure reductions in damages. If the same approach is used to estimate damages for the alternative adaptation scenarios, the changes attributable to the scenarios should still be valid.

Table 15: Baseline Damages – Wave Damages				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$1,195,565,635	$2,047,677,430	$2,550,157,771	$3,166,280,921
Public Structures/Property Damages	$378,717,000	$378,717,000	$378,717,000	$535,893,000
Agricultural Damages	$18,686,546	$18,686,554	$26,153,427	$47,646,544
Recreational Damages	$42,595,868	$42,742,695	$47,605,061	$48,618,346
Road Damages	$1,685,073	$2,567,193	$3,675,314	$5,432,622
Total Damages	**$1,637,250,122**	**$2,490,390,872**	**$3,006,308,574**	**$3,803,871,433**

Table 16: Baseline Damages – Erosion Damages				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$376,293,098	$680,635,704	$723,031,389
Public Structures/Property Damages	$0	$85,105,500	$85,105,500	$85,105,500
Agricultural Damages	$0	$4,420	$8,692	$1,749,907
Recreational Damages	$0	$8,220,703	$8,497,206	$11,986,038
Road Damages	$0	$279,081	$439,099	$742,200
Total Damages	**$0**	**$469,902,801**	**$774,686,201**	**$822,615,034**

Table 17 shows the aggregate total damages by hazard type through time under the baseline. These results show that waves and erosion are anticipated to be the most costly sources of future SLR damages. Hazard damage is expected to increase nearly 4 times in terms of the value between 2014 and 2100, from a total of $1.6 billion to more than $5.2 billion dollars of damages in 2100. By far the greatest degree of damage is anticipated in wave action damages which come from the wave impact expected to occur in addition to the major storm. Storm surge damages are only anticipated to occur in the year of the storm, which might occur only once every few years as the storm modeling was based on a storm with a one percent probability of occurrence in any given year. The frequency of this modeled storm event is not estimated in relation to climate change and will certainly increase. For example, a storm that used to occur with a one percent probability frequency (anticipated to occur on average once per century) could occur in the future once every twenty years, or with a five percent chance of occurrence in any given year.

Table 17: Summary of Baseline Results				
	Existing	**2030**	**2060**	**2100**
Mean High Water	$0	$3,743,746	$16,091,974	$171,069,555
Storm	$3,886,306	$21,215,042	$75,295,923	$324,798,391
Wave	$1,637,250,122	$2,490,390,872	$3,006,308,574	$3,803,871,433
Erosion	$0	$469,902,801	$774,686,201	$822,615,034
Total Baseline	**$1,641,136,427**	**$2,985,252,461**	**$3,872,382,671**	**$5,122,354,414**

4.2 Comparing Benefits of NBA and CAA Strategies

The two adaptation strategies – NBA and CAA – are applied to the baseline scenario to produce monetary benefits in terms of reducing these anticipated damages. Results by hazard type are shown below.

4.2.1 Extreme Mean High Water

Results for the EMHW through time for the NBA and CAA scenarios are shown below. By the year 2100, it is clear that the CAA reduces damages to private structures and property damage by more than the NBA. This is related to greater protection provided by the armoring for some low-lying neighborhoods. Agricultural damages are the same for both scenarios, showing a nearly 100 fold increase between 2030 impacts and 2100. This is because most of the agricultural lands are not affected by rising tides until later in the century. Road damages under both management scenarios are similar until 2060 and after that estimated to be more severe under the CAA scenario. This is likely due to roads that are elevated within neighborhoods under the NBA scenario. Noticeable in these tables is that the two scenarios perform very similarly through 2060, and then ramp up by 2100 through agricultural damages, and the increase in private structure/property damages, which are greater under the NBA scenario.

Table 18: EMHW – NBA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$2,979,091	$6,660,830	$30,936,246
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$0	$534,959	$8,863,902	$58,491,811
Recreational Damages	$0	$2,424	$2,894	$4,139
Road Damages	$0	$219,467	$308,830	$467,207
Total Damages	**$0**	**$3,735,941**	**$15,836,457**	**$89,899,403**

Table 19: EMHW – CAA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$2,979,091	$6,660,830	$11,891,383
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$0	$534,959	$8,863,902	$58,491,811
Recreational Damages	$0	$2,424	$2,894	$4,139
Road Damages	$0	$217,571	$361,209	$772,045
Total Damages	**$-**	**$3,734,044**	**$15,888,835**	**$71,159,378**

Tables 20 and 21 show the benefits produced by each strategy in terms of reduced damage values. These estimates are developed by subtracting the baseline damages from the adaptation scenario damages. The results above that show that the NBA strategy produces benefits at approximately the same level as the CAA through the year 2030, with the NBA producing over seven thousand, and the CAA producing over nine thousand. By the year 2060, the NBA produces more benefits than the CAA, and by 2100, the CAA benefits outstrip the NBA benefits.

Table 20: EMHW – NBA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$0	$152,026	$79,355,777
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$0	$0	$0	$0
Recreational Damages	$0	$0	$0	$0
Road Damages	$0	$7,806	$103,491	$1,814,375
Total Damages	**$0**	**$7,806**	**$255,517**	**$81,170,152**

Table 21: EMHW – CAA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$0	$152,026	$98,400,641
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$0	$0	$0	$0
Recreational Damages	$0	$0	$0	$0
Road Damages	$0	$9,702	$51,113	$1,509,537
Total Damages	**$-**	**$9,702**	**$203,139**	**$99,910,177**

4.2.2 Major Storm Event Results

As mentioned above, the major storm event damages will occur with an unknown frequency in the future although the event was modeled based on a one percent annual probability of occurrence. Tables 22 and 23 show anticipated damages under the NBA scenario and the CAA scenario respectively. The damages are relatively small in both cases (under ten million dollars) through 2030. Using the nature based strategy; the damages expected from such a storm increase to over $25 million by 2030, and by the year 2100 are expected to be over $158 million much greater than the damages from the same storm under the CAA scenario.

Table 22: Major Storm Event – NBA Scenario

Damage Category	Existing	2030	2060	2100
Private Structures/Property Damages	$1,039,202	$1,094,022	$1,959,079	$79,691,209
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$804,676	$7,035,994	$21,411,331	$75,652,151
Recreational Damages	$0	$0	$0	$0
Road Damages	$1,109,364	$1,440,748	$2,086,060	$2,829,811
Total Damages	**$2,953,242**	**$9,570,765**	**$25,456,470**	**$158,173,172**

Table 23: Major Storm Event – CAA Scenario

Damage Category	Existing	2030	2060	2100
Private Structures/Property Damages	$1,264,245	$1,264,245	$1,264,245	$1,384,565
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$804,676	$3,268,745	$2,804,580	$6,844,674
Recreational Damages	$0	$0	$0	$0
Road Damages	$1,235,925	$1,656,069	$2,494,884	$3,771,470
Total Damages	**$3,304,846**	**$6,189,059**	**$6,563,709**	**$12,000,709**

Tables 24 and 25 show the benefits produced by each strategy in terms of reduced damage values. These estimates are developed by subtracting the baseline damages from the adaptation scenario damages. The results that show the NBA strategy produces approximately the same level of damages through the year 2060. Results for the year 2100 demonstrate significantly greater damages. The tables show that both scenarios have similar benefits through 2060, with the NBA showing over $47 million, and the CAA showing about 20 percent more benefits, at over 68 million. By 2100 the benefits of the CAA are nearly twice as high as the NBA, with over $312 million for the CAA and $161 million under the NBA. It should be noted that these are the raw results from a storm event, and will not necessarily occur in each of these years. When the benefit cost analysis is completed, the expected damage in any given year is included through time, and the calculation will take into consideration the chance that the storm does occur.

Table 24: Major Storm Event – NBA Benefits

Damage Category	Existing	2030	2060	2100
Private Structures/Property Damages	$225,043	$2,690,360	$18,314,525	$104,140,060
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$2,154	$7,665,274	$28,881,232	$57,159,845
Recreational Damages	$0	$422	$1,750	$4,500
Road Damages	$3,729,520	$4,532,873	$5,346,033	$7,600,890
Total Damages	**$3,956,717**	**$10,356,056**	**$47,197,507**	**$161,304,405**

Table 25: Major Storm Event – CAA Benefits

Damage Category	Existing	2030	2060	2100
Private Structures/Property Damages	$0	$2,520,138	$19,009,358	$182,446,705
Public Structures/Property Damages	$0	$0	$0	$0
Agricultural Damages	$2,154	$11,432,523	$47,487,983	$125,967,321
Recreational Damages	$0	$422	$1,750	$4,500
Road Damages	$579,306	$1,072,900	$2,233,122	$4,379,156
Total Damages	**$581,460**	**$15,025,983**	**$68,732,214**	**$312,797,682**

4.2.3 Wave Damage Results

Wave damage estimates suggest that wave damage during a storm could be fairly high at more than $1.6 billion under current conditions, and more than doubling by 2100 to over $3.8 billion per year. Both the NBA scenario and the CAA scenario reduce the damages to under $1 billion in the year 2100, with the NBA damages totaling just under $1 billion and the CAA damages totaling just under $800 million. Results for wave damages under both adaptation scenarios are shown in Tables 26 and 27 for the NBA and CAA scenarios respectively.

Table 26: Wave Damages – NBA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$412,685,908	$421,332,862	$436,016,094	$441,228,228
Public Structures/Property Damages	$378,717,000	$378,717,000	$378,717,000	$457,305,000
Agricultural Damages	$18,686,546	$18,686,554	$26,153,427	$47,646,544
Recreational Damages	$40,345,143	$40,490,863	$45,247,694	$48,267,617
Road Damages	$938,275	$1,269,690	$1,920,379	$2,288,788
Total Damages	**$851,372,872**	**$860,496,969**	**$888,054,594**	**$996,736,177**

Table 27: Wave Damages – CAA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$328,940,212	$337,587,166	$342,733,962	$347,946,096
Public Structures/Property Damages	$378,717,000	$378,717,000	$378,717,000	$378,717,000
Agricultural Damages	$18,686,546	$18,686,554	$26,153,427	$28,532,708
Recreational Damages	$39,625,018	$39,882,559	$39,913,148	$40,695,616
Road Damages	$1,962,201	$2,302,907	$2,710,994	$3,173,551
Total Damages	**$767,930,976**	**$777,176,185**	**$790,228,531**	**$799,064,971**

Tables 28 and 29 show the benefits produced by each strategy in terms of reduced damage values. Because the damages under both adaptation scenarios are comparable, so are the benefit estimates, with the benefits of both strategies totaling more than $2 billion in the year 2060 in the event of the storm. By later in the century the benefits from the CAA slightly exceed those from the NBA, with benefits topping $3 billion for the CAA, and $2.8 billion for the NBA..

Table 28: Wave Damages – NBA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$782,879,727	$1,626,344,568	$2,114,141,677	$2,725,052,693
Public Structures/Property Damages	$0	$0	$0	$78,588,000
Agricultural Damages	$0	$0	$0	$0
Recreational Damages	$2,250,725	$2,251,832	$2,357,368	$350,729
Road Damages	$2,008,774	$2,504,269	$2,786,281	$4,205,625
Total Damages	**$787,139,226**	**$1,631,100,669**	**$2,119,285,326**	**$2,808,197,047**

Table 29: Wave Damages – CAA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$866,625,423	$1,710,090,264	$2,207,423,809	$2,818,334,825
Public Structures/Property Damages	$0	$0	$0	$157,176,000
Agricultural Damages	$0	$0	$0	$19,113,836
Recreational Damages	$2,970,850	$2,860,137	$7,691,914	$7,922,729
Road Damages	$984,849	$1,471,053	$1,995,666	$3,320,862
Total Damages	**$870,581,122**	**$1,714,421,453**	**$2,217,111,389**	**$3,005,868,254**

4.2.4 Long Term Erosion Results

Erosion damages under baseline conditions are significant, totaling over $469 million by 2030, and increasing to more than $822 million by 2100 (see Table 17). Both NBA and CAA strategies have outstanding success at reducing these damages, with the NBA reducing damages by approximately 75 percent and the CAA reducing damages by more than 90 percent. Results are shown in Tables 30 and 31.

Table 30: Long Term Erosion - NBA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$47,998,701	$71,074,709	$73,928,651
Public Structures/Property Damages	$0	$64,900,000	$85,105,500	$85,105,500
Agricultural Damages	$0	$4,272	$8,692	$1,749,907
Recreational Damages	$0	$4,677,161	$8,493,525	$11,993,864
Road Damages	$0	$18,818	$19,722	$30,368
Total Damages	**$0**	**$117,598,953**	**$164,702,148**	**$172,808,289**

Table 31 – Long Term Erosion - CAA Scenario				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$10,491,096	$10,491,096	$10,491,096
Public Structures/Property Damages	$0	$20,205,500	$20,205,500	$20,205,500
Agricultural Damages	$0	$4,420	$8,692	$1,749,907
Recreational Damages	$0	$8,038,022	$8,251,730	$9,463,568
Road Damages	$0	$332,144	$350,290	$397,268
Total Damages	**$0**	**$39,071,182**	**$39,307,307**	**$42,307,339**

Tables 32 and 33 show the benefits produced by each strategy in terms of reduced damage values. Because the damages under the NBA scenario are higher than under the CAA, the benefits are therefore lower. Over the three time periods reported, the CAA benefits are higher than those in under the NBA scenario. Noticeable is that the recreation damages are actually greater under the NBA than under the baseline by the year 2100 and so there are no benefits, and in fact slight costs to the NBA strategy. This may be due to the managed retreat from beach activities that exist in the baseline scenario (therefore a loss in recreation) that is not otherwise counter balanced by gains from the NBA elsewhere.

Table 32: Long Term Erosion - NBA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$328,294,397	$609,560,996	$649,102,739
Public Structures/Property Damages	$0	$20,205,500	$0	$0
Agricultural Damages	$0	$147	$0	$0
Recreational Damages	$0	$3,543,542	$3,681	($7,826)
Road Damages	$0	$591,599	$794,684	$1,149,841
Total Damages	**$0**	**$352,635,184**	**$610,359,360**	**$650,244,754**

Table 33: Long Term Erosion - CAA Benefits				
Damage Category	**Existing**	**2030**	**2060**	**2100**
Private Structures/Property Damages	$0	$365,802,002	$670,144,608	$712,540,293
Public Structures/Property Damages	$0	$64,900,000	$64,900,000	$64,900,000
Agricultural Damages	$0	$0	$0	$0
Recreational Damages	$0	$182,681	$245,476	$2,522,470
Road Damages	$0	$278,273	$464,116	$782,941
Total Damages	**$0**	**$431,162,955**	**$735,754,201**	**$780,745,704**

4.2.5 Aggregate Benefits to Parcels

Overall, several observations may be taken from this static analysis of benefits associated with the alternative adaptation strategies described in the parcel database. One point is that using NBA solutions does not seem to compromise the potential benefits gained from SLR adaptation. Indeed, the risk reduction benefits of the NBA scenario are surprisingly close to those provided by the CAA scenario, although for the storm benefits, the long term CAA solution is expected to produce significantly better reductions in damages compared with the NBA. A summary of the results of the static analysis of benefits from the NBA and CAA solutions is provided in Tables 34 and 35 respectively. Viewing the totals in 2100, it appears that the NBA produces $3.7 billion in benefits, compared with the CAA which produces $4.1 billion. However, the storm and wave results are irregular, and will only occur in some years, while the Mean High Water and Erosion totals are fully expected. Comparing just those two impacts, the annual benefits in 2100 are $730 million for the NBA alternative and $880 million for the CAA alternative.

Table 34: Summary of All Benefits – NBA

TOTAL	2030	2060	2100
Mean High Water	$7,806	$255,517	$81,170,152
Storm	$2,690,360	$18,314,525	$104,140,060
Wave	$1,631,100,669	$2,119,285,326	$2,808,197,047
Erosion	$352,635,184	$610,359,360	$650,244,754
Total NBA	**$1,986,426,214**	**$2,747,959,211**	**$3,562,581,861**

Table 35: Summary of All Benefits – CAA

TOTAL	2030	2060	2100
Mean High Water	$9,702	$203,139	$99,910,177
Storm	$15,025,983	$68,732,214	$312,797,682
Wave	$1,714,421,453	$2,217,111,389	$3,005,868,254
Erosion	$431,162,955	$735,754,201	$780,745,704
Total CAA	**$2,160,610,391**	**$3,021,597,803**	**$4,099,411,639**

4.3 Ecosystem Services

The static results above suggest that an evaluation of ecosystem services could be influential in the decision making process. That is, the CAA has larger projected benefits, but the two are comparable. The results of the HEA analysis show that each of the alternative adaptation scenarios produces slightly different results in terms of the total acreage by land cover type in 2100 and the service acre years (SAY) by land cover type.

4.3.1 Net Ecosystem Services by Land Cover Type

Figure 6 in Chapter 2 provides a summary of the changes in acreage by land cover type for each scenario from 2010 to 2100. The changes in SAYs by land cover type are the sum of the acreage in each year, weighted by the scaling described in Section 3.5 of this report. Figure 8 below shows the changes in SAYs by land cover type. Fundamentally, the diagram shows that the Baseline scenario results in a loss of developed acreage, and the adaptation scenarios both prevent this from happening. Looking at the blue lines, we can see that the land that was developed is lost, and also some agricultural lands, undeveloped uplands, and some freshwater wetlands. Meanwhile inland open water and mudflats area are gained in this alternative. In contrast, the adaptation strategies reduce the losses in developed, undeveloped, agricultural, and freshwater wetlands, and also reduce the gains in mudflats and inland open water.

Comparing the green (NBA) and the red (CAA) shows that the NBA reduces the losses of both types of wetlands (salt and fresh) when compared with the CAA, and has less loss of beach areas compared to the CAA, although this result is slight. Meanwhile the NBA allows a greater loss of agriculture and other uplands when compared with the CAA because more are converted to wetlands. It also shows less of an increase in inland open water than is seen in the CAA.

Clearly there are trade-offs for any decision going forward including the decision not to adapt at all, which is portrayed as the baseline scenario. The HEA analysis is helpful because it takes into account the value scores for the different types of land cover which were developed using stakeholder-specified priorities. The HEA approach also allows for credit to occur through time. This aspect of the analysis does two things. First, it allows decision makers to include consideration of the long term (in this case, 86 years) environmental impacts of their decision. Second, it allows decision makers to quantify these values in terms of the services they actually provide on an annual basis. For example, if wetland habitat is increased, then the wetland benefits (e.g. flood prevention, habitat) occur on an annual basis, and are not simply reflected as a change in acreage as shown in Figure 8.

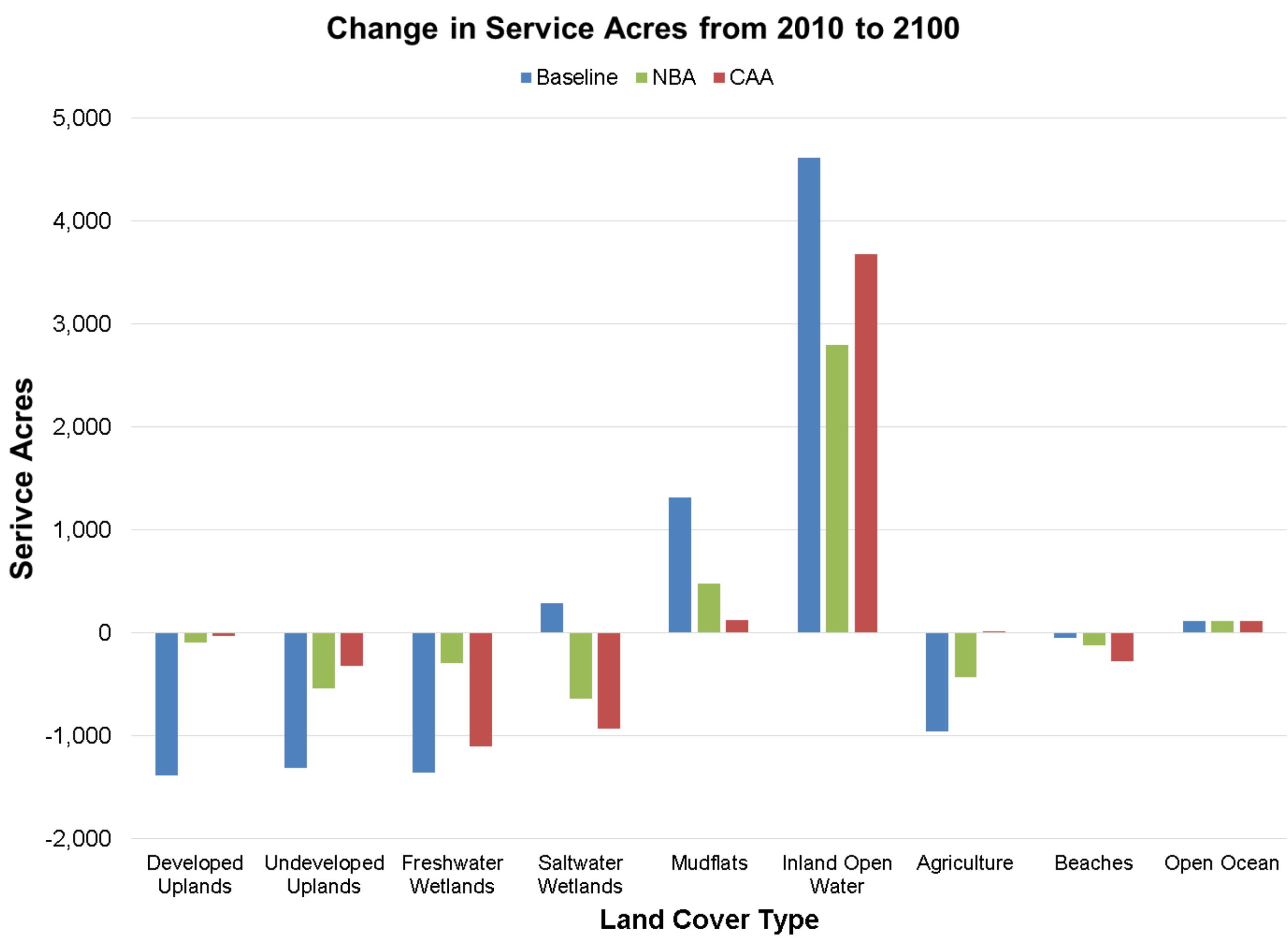


Figure 8: Service Acre Changes from 2010 to 2100

4.3.2 Total Ecosystem Services

The net difference in all ecosystem services totaled for all land covers demonstrates the overall difference between the management scenarios. Figure 8 provides a summary of the net changes in the SAYs through time. For land cover value, the baseline scenario actually produces an increase in SAYs through time because the developed land with low ecosystem service value is being converted to inland open water, which has a higher land cover value (see Figure 6 and Table 11). The adaptation strategies that are simultaneously protecting developed lands each show lower ecosystem service values compared to the baseline. However, the NBA SAY total is always higher than the CAA SAY total. The inset in Figure 8 shows that sometime after the year 2030, both adaptation alternatives produce fewer SAYs than the Baseline scenario.

The net difference in all ecosystem services totaled for all land cover types demonstrates the overall difference between the adaptation alternatives. In undiscounted SAYs, or if we did not discount future gains and losses at all under any of the three scenarios, the results suggest that the CAA strategy will produce 97,327 SAYs less than the baseline. That is, the sum of SAYs over the study period (2014 – 2100) is 97,327 less than the same total produced by the baseline scenario. The NBA will produce 52,835 fewer SAYs than the baseline, and so the improvement in performance of the NBA over the CAA is a gain of 44,492 SAYS (see Table 36). This result will change depending on assumptions about the discount rate which adjust future SAYs for the rate of time preference, uncertainty, and the opportunity cost of capital. Using a three percent discount rate, the discounted service acre year (dSAY) gain is reduced to 15,616. A three percent discount rate is recommended for decision making, but there are arguments that can be made about using different discount rates, and it is the research team's view that decision makers should explore results at a variety of discount rates. At other discount rates, the total dSAYS might change from nearly 45 thousand, to over 15 thousand, to over 7 thousand at a seven percent discount rate (see Table 36).

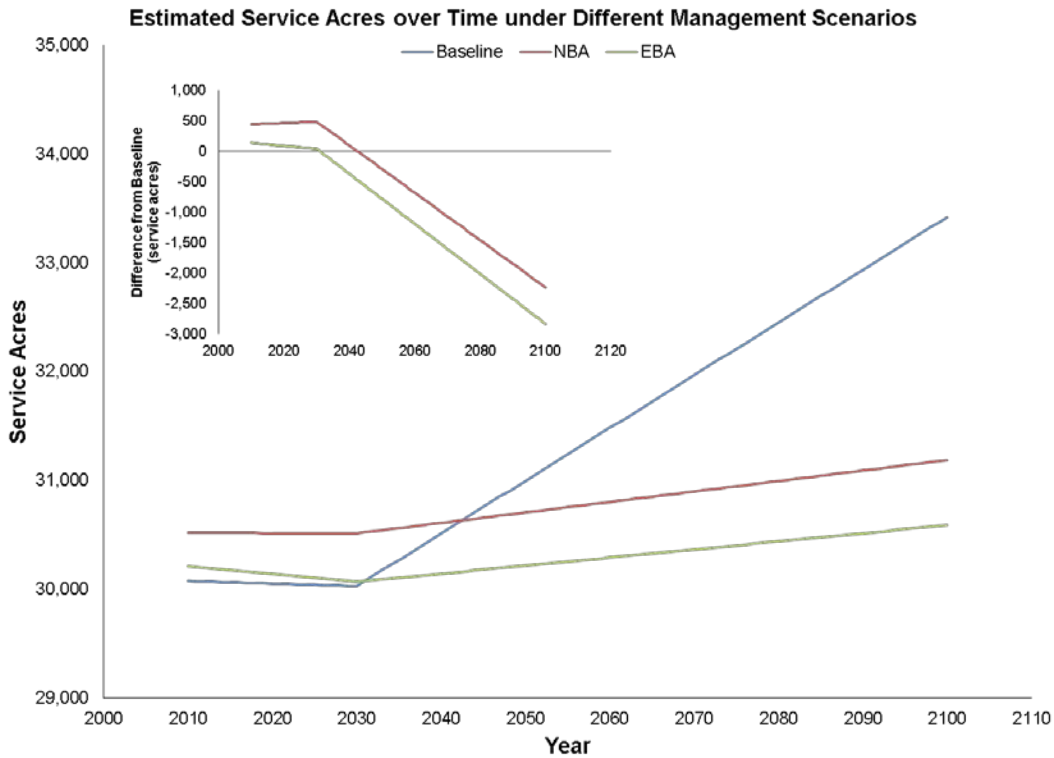


Figure 9: Ecosystem Service Changes in 2100 by Land Cover Type and Adaptation Strategy

Table 36: Comparing Service Acre Year Land Cover Benefits by Adaptation Strategy and Discount Rate

Discount Rate	0%	1%	3%	5%	7%
NBA Difference from Baseline	-52,835	-22,366	-11	5,425	6,572
CAA Difference from Baseline	-97,327	-51,752	-15,627	-4,823	-1,168
NBA Improvement over CAA	**44,492**	**29,387**	**15,616**	**10,248**	**7,740**

4.3.3 Summary

This preliminary HEA is based on the most readily available information for the site and is intended to 1) provide initial, general estimates of the net effects on ecosystem services associated with SLR in the project area, and 2) identify the ecosystem services most significantly affected. It would seem practical that land covers like dunes would increase over time with the baseline scenario and it would be at least trending toward the ecosystem that existed 200 years ago before substantial development (Beller et al.)[34]). Freshwater wetlands

[34] Beller, EE, RM Grosinger, MN Saloman, SJ Dark, ED Stein, BK Orr, PW Downs, TR Longcore, GC Coffman, AA Wipple, RA Askevold, B Stanford, RJ Beagle, 2011. Historical ecology of the lower Santa Clara River, Ventura River and Oxnard Plain: an analysis of terrestrial, riverine, and coastal habitats. Prepared for the State Coastal Conservancy. A report of SFEI's Historical Ecology Program, SFEI Publication #641, San Francisco Estuary Institute, Oakland, CA.

and estuarine open water are other land covers that would likely trend toward a more natural state, rather than being equal to or similar to the two adaptation scenarios.

To make better decisions about any adaptation strategy, an analysis of the value of changes in land cover types is essential. For this study, this analysis was completed for one area of Ventura County and then extrapolated to the larger coastal area. This method is appropriate for estimating values that can be used to compare broad alternative scenarios. However, for specific adaptation decisions, it is recommended that this approach be used with a more detailed and accurate estimate of the SLR induced land cover changes, and how the specific adaptation strategy will impact the local land covers.

5 Benefit Cost Analysis

The analysis of the benefits presented in Chapter 4 is combined with costs over time to understand if either adaptation strategy is feasible. A feasible project is a project where the benefits exceed the costs. This can take different mathematical forms. Either the benefits divided by the costs is greater than the value of 1, or when costs are subtracted from benefits, the result is greater than zero. In either case, the results are developed by considering how benefits and costs occur through time, In this analysis (the NESA approach, which includes ecosystem services and the HEA results as well as recreation and other ecosystem services), it is also important to show how ecosystem services may affect the decision, and how changing assumptions can influence the outcome of the analysis. The latter process is typically called sensitivity analysis. Each is addressed below.

5.1 Costs of Alternative Adaptation Scenarios

The costs for both management scenarios were estimated using the best available information on construction costs, materials, and program costs. The cost estimates were developed by ENVIRON and reviewed by ESA PWA. Details of the unit cost and total cost for each restoration measure are included in Appendix G.

For NBA infrastructure, the unit costs for beach and dune restoration, conversion of wetlands and agricultural areas, were all determined as the cost per acre of the land. The unit cost for construction of the ring levee was determined as the cost per one cubic yard, assuming 10 feet high levee with 3H:1V side slopes. The raising of the bulkheads were calculated using the cost per one linear foot of the bulkhead. The $100,000 per acre cost was assumed as the unit cost in relocating the McGrath State Beach Park property; $500,000 per acre was the cost assumed in relocating residential structures, and $150,000 per house was the cost in elevating existing residential houses.

For CAA infrastructure, the unit cost of the revetment was based on the cost per linear foot of the revetment. The unit cost of new levees was based on the cost of the cubic yard of the levee material. Total costs of new tide gates and new tidal barriers were calculated as the lumped sum costs based on the available costs for similar structures.

For the NBA strategy, the upfront cost totals over $856 million, with nearly half of that cost stemming from the costs of elevating 2,680 residential homes. Because the overall NBA cost is so sensitive to the cost of home elevation, additional information was sought. It is difficult to know how costs might decrease if there are many homes that are to be elevated and so the per unit cost is subject to market force changes in the future. In addition, it varies significantly by the size of the home and other factors. Because the benefit cost results are sensitive to this number, it is highlighted as an uncertainty worth exploring for

Some of the costs (strengthen bulkheads, seawalls, and revetments in the harbors, and to build a small ring levee around the Mugu airfield and the north side of Ormond Beach restoration) are assumed to be repeated in years 2050 and 2070 to respond to higher sea levels, and for maintenance purposes.

For the CAA strategy, the upfront cost would be over $1 billion and are estimated to be slightly higher than the NBA upfront cost. Some of the most costly elements of the CAA scenario are the three tidal barrier/lock combinations designed to protect the harbors. These three elements create approximately half the costs of the program.

Some of the costs (including reinforcing existing armoring, and building new revetments and ring levees) are assumed to be repeated in years 2050 and 2070 to respond to higher sea levels, and for maintenance purposes.

Table 37 shows the two management scenarios and their respective costs. It is assumed in both cases that the initial construction costs are spread across a five year time horizon and that some costs are repeated in 2050 and 2070.

The comparison shows that for both management scenarios costs are around $1 billion, with the NBA scenario slightly lower than the CAA. The CAA appears to be about 26 percent more costly over the first five years. However, once an adjustment is made for the on-going costs of

Table 37: Comparing Costs of CAA and NBA

	5 year costs	Net Present Value
NBA	**$856,044,622**	**$1,017,348,462**
CAA	**$1,074,554,548**	**$1,153,096,384**
CAA – NBA difference	*$218,509,926*	*$135,747,922*
% CAA higher than NBA	26%	13%

both programs, and the long-term costs are converted and compared in terms of Net Present Value (NPV), the difference between scenarios is less, with the NBA costing $1.02 billion, and the CAA costing $1.15 in discounted 2014 dollars using a three percent discount rate.

5.2 Benefits and Costs through Time

The time horizon for this study is from 2014 through 2100; a period of 86 years. The appropriate way to think about benefits and costs is to anticipate all possible benefits and costs through the time horizon. In the case of the costs, most would occur during construction, or during the first five years. Additional maintenance and rebuilding costs were forecast for 2050 and 2070 so that all future costs would be included. Both future benefits and future costs are considered, and then added up using a discount factor to produce a ‘present value’ of all costs and benefits. Future benefits and costs are discounted for a variety of reasons including the social rate of time preference (that people tend to prefer benefits now to benefits later, and costs later to costs now) and to account for increasing degrees of uncertainty about future conditions.

Spreading out the benefits over time is somewhat difficult because the occurrence of the hazards is not entirely predictable. The EMHW hazard is an estimate, but is slightly more predictable than some of the other measures. Erosion is likely to occur slowly, and so the benefit (reduced damages benefit) is assumed to occur evenly through time for both of these hazards. For the storm and wave hazards, both are connected to a storm actually occurring in a given year, and because this is difficult to predict, we again assume that the avoided damages occur evenly through time. This produces a benefit that is connected to the expected annual damages, or EAD.

Assuming that the storm and associated wave impacts were to occur with a frequency of once every 100 years, those damages are given an 'expected' value of one percent in any given year. With this assumption, the overall reduced damages, or benefits of the NBA scenario are $1.16 billion, and the NPV of the CAA is a little higher, at $1.33 billion (see Table 38). Subtracting the costs from the benefits of each program produces the 'net benefits'. The net benefits of the scenarios are $138 million and $180 million respectively for the NBA and the CAA. Because both alternatives produce positive net benefits, both are considered to be feasible alternatives.

Table 38: Comparing Costs and Benefits of CAA and NBA (Storm = 1% Chance per Year)

	C - Net Present Value of Costs	B - Net Present Value of Benefits	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017,348,462**	**$1,156,289,745**	**1.14**	**$138,941,283**
CAA	**$1,153,096,384**	**$1,333,697,150**	**1.16**	**$180,600,766**
CAA – NBA difference	*$135,747,922*	*$177,407,406*	*2.0%*	*$41,659,484*
Change as % of NBA	13%	15%	2%	30%

Another way to evaluate the results demonstrates that the benefit to cost ratio (BCR) for each is 1.14 and 1.16 for the NBA and CAA respectively. Because the BCR is greater than 1 we also know that both alternatives are feasible, or expected to justify their costs. The CAA costs are about 13 percent higher than the NBA costs, and the benefits are about 15 percent higher. However, once costs have been subtracted, the net benefit results shows that the net benefits of the CAA are about 30 percent higher than the net benefits of the NBA before the other ecosystem services have been included (recreation losses and agricultural losses are included here).

5.3 Sensitivity Analysis and Making Decisions

For the purpose of making adaptation decisions, the first question is whether or not an option is feasible – or whether the benefits justify the costs. This analysis suggests that both proposed alternatives are feasible even prior to considering the value of the ecosystem services offered by land covers. The NBA alternative is feasible and provides greater net benefits than the CAA under reasonable assumptions about the value of ecosystem service.

In the case of making a long term decision, such as the adaptation decision that applies for a time horizon of 86 years, the question of uncertainty is also important to consider. There is uncertainty in the analysis due to uncertainty in climate change assumptions, cost estimates, economic considerations, and many other sources such as limited modeling capabilities. To the extent that a decision maker is able to explore how the assumptions will change the outcome, their understanding of the significance of that uncertainty will be enhanced.

For example, two assumptions associated with the benefit cost model are explored below to examine two uncertain inputs to understand how they change our thinking about the adaptation question. The first assumption examines how frequent or infrequent might the modeled storm be. The storm and wave damages estimated in this document are based on a storm which is believed to have one percent chance of occurring in any given year. But what if it were actually an event with an expected frequency of one and a half percent per year (one in 75 years) or two percent (one in 50 years) or five percent (one in 20 years)? The results of these assumptions are presented below in Tables 39 through 41.

Table 39 Comparing Costs and Benefits of CAA and NBA (Storm = 1.5% Chance per Year)

	Net Present Value of Costs	Net Present Value of Benefits	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017,348,462**	**$1,329,448,229**	**1.31**	**$312,099,767**
CAA	**$1,153,096,384**	**$1,520,462,881**	**1.32**	**$367,366,497**
CAA – NBA difference	*$135,747,922*	*$191,014,652*	*1.2%*	*$55,266,730*
Difference as % of NBA	13%	14%	1%	18%

Table 40: Comparing Costs and Benefits of EBA and NBA (Storm = 2% Chance per Year)

	Net Present Value of Costs	Net Present Value of Benefits	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017,348,462**	**$1,675,765,197**	**1.65**	**$658,416,735**
CAA	**$1,153,096,384**	**$1,893,994,341**	**1.64**	**$740,897,957**
CAA – NBA difference	*$135,747,922*	*$218,229,144*	*-0.5%*	*$82,481,222*
Difference as % of NBA	13%	13%	0%	13%

Table 41: Comparing Costs and Benefits of CAA and NBA (Storm = 5% Chance per Year)

	Net Present Value of Costs	Net Present Value of Benefits	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017,348,462**	**$3,234,191,552**	**3.18**	**$2,216,843,090**
CAA	**$1,153,096,384**	**$3,574,885,914**	**3.10**	**$2,421,789,530**
CAA – NBA difference	*$135,747,922*	*$340,694,361*	*-7.9%*	*$204,946,439*
Difference as % of NBA	13%	11%	-2%	9%

The results of this exercise are instructive. First, if the storm frequency is greater than one percent per year, the net benefits for either adaptation scenario dramatically increase from a few hundred thousand dollars under the original assumption, to over two billion dollars if the storm has a frequency of five percent per year. Second, the BCRs improve accordingly. Third, because the cost of the NBA is lower than the CAA, the BCR for the NBA is higher than the CAA, if we assume that the storm will occur with frequency of two percent per year instead of one percent. The net benefits are still higher with the CAA compared to the NBA. Graphic representations of these different outcomes are shown in Figures 10 through Figure 13.

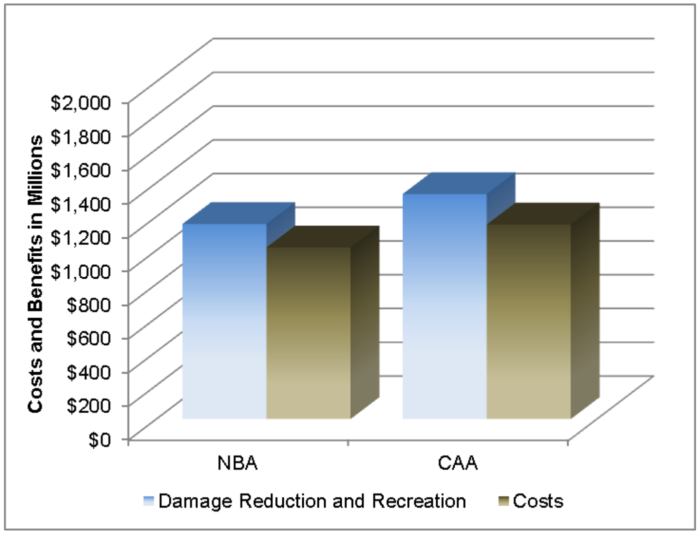


Figure 10: Comparing Costs and Benefits of CAA and NBA (Storm = 1% Chance per Year)

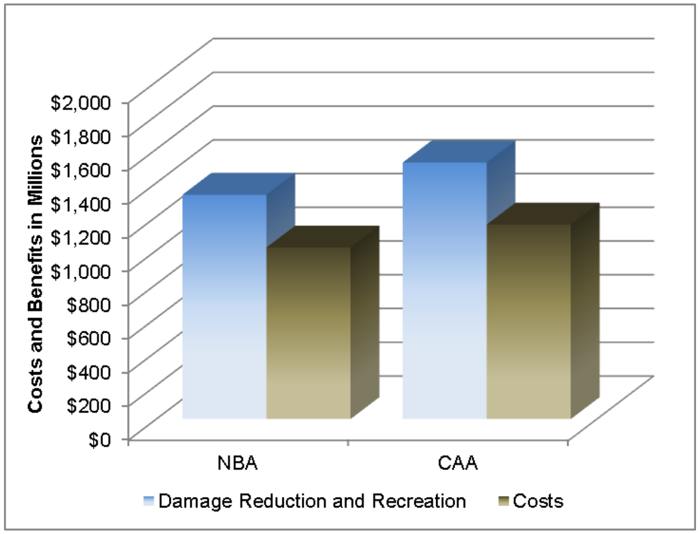


Figure 11: Comparing Costs and Benefits of CAA and NBA (Storm = 1.5% Chance per Year)

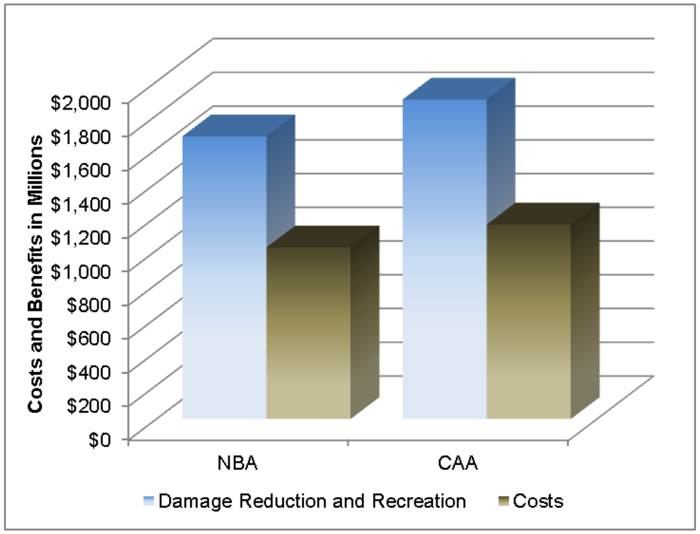


Figure 12: Comparing Costs and Benefits of CAA and NBA (Storm = 2% Chance per Year)

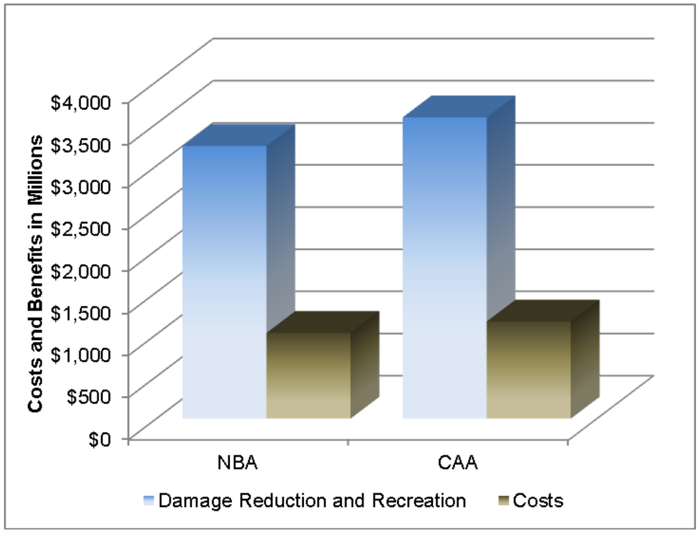


Figure 13: Comparing Costs and Benefits of CAA and NBA (Storm = 5% Chance per Year)NOTE VERTICAL AXIS has DIFFERENT SCALE****

The figures demonstrate that the benefits become increasingly larger than the costs the more frequent we anticipate the storm arriving.

The second major assumption explored is the discount rate. There are many different approaches to determine an appropriate discount rate. These include legal and regulatory protocols, community rates of time preference, financial interest rates, and adjustments for uncertainty. For this effort, all costs and benefits are presented in current year dollars, which means that we do not inflate future benefits and costs to account for anticipated inflation although it will occur. Because future inflation is unknown, it is mathematically simpler to not inflate the dollar value estimates to reflect inflation. This is known as conducting the analysis in 'real' dollars as opposed to 'nominal' dollars, and has an implication for the discount rate. If dollars are inflated to account for future year dollars, then when all values are summed into a present value, that inflation will need to be removed with the discount rate. A nominal discount rate should be higher than a real discount rate. Typically, a two to three percent discount rate is used because it is close to the social rate of time preference, the real return on investment, and a good representation of uncertainty. A three percent rate is used for all of the foregoing analysis presented above.

It is prudent that decision makers reflect on how assumptions about discounting for the future may produce a different result in the analysis. It is worth exploring alternative discount rates and how decisions might change given different assumptions. Tables 42 through 44 show how the results of the estimates from the parcel database will be influenced by assumptions about the discount rate. Table 42 shows how undiscounted values (a zero percent discount rate) significantly increase the present value of the benefits (which occur throughout the study time horizon) when compared with costs (which are experienced much more in the near future). Table 42 shows how a one percent discount rate reduces the value of the benefits from the undiscounted version by about half. The results for a three percent discount rate are shown above in Table 34, and are about 10 percent of the benefits determined when using a one percent discount rate. These significant changes occur because the benefits occur over an 86 year time frame (2014 – 2100), while the costs are assumed to occur all in the first year (for simplicity). Finally, if we use a higher discount rate (which could be argued, given the degree of uncertainty in this analysis), we see that benefits from these impacts alone do not sufficiently justify the costs. (N.B., the storm frequency is returned to a one percent probability in Tables 42-44).

Graphical representations of the gains and losses and how they change given different discount rates are shown in Figures 14 through 17.

The purpose of demonstrating the sensitivity of these decisions to input assumptions is to emphasize how benefit cost analysis should be used as a tool to inform decision makers and not simply to provide decision makers with an answer. The same thinking is brought to bear on the next section that addresses incorporating the value of land cover types into the decision framework.

Table 42: Comparing Costs and Benefits of CAA and NBA (Discount rate = 0%))

	Net Present Value of Costs ($ Millions)	Net Present Value of Benefits ($ Millions)	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017**	**$4,637**	**4.56**	**$3,620**
CAA	**$1,153**	**$5,422**	**4.70**	**$4,269**
CAA – NBA difference	*$135*	*$785*	*14.4%*	*$649*
difference as % of NBA	13%	17%	3%	18%

Table 43: Comparing Costs and Benefits of EBA and NBA (Discount rate = 1%))

	Net Present Value of Costs ($ Millions)	Net Present Value of Benefits ($ Millions)	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017**	**$2,686**	**2.64**	**$1,668**
CAA	**$1,153**	**$3,123**	**2.71**	**$1,970**
CAA – NBA difference	*$136*	*$437*	*6.8%*	*$301*
Difference as % of NBA	13%	16%	3%	18%

Table 44: Comparing Costs and Benefits of CAA and NBA (Discount rate = 5%)

	Net Present Value of Costs ($ Millions)	Net Present Value of Benefits ($ Millions)	B/C Ratio	Net Benefits (B – C)
NBA	**$1,017**	**$670**	**0.66**	**-$347**
CAA	**$1,153**	**$772**	**0.67**	**-$381**
CAA – NBA difference	*$136*	*$102*	*1.1%*	*($34)*
difference as % of NBA	13%	15%	2%	10%

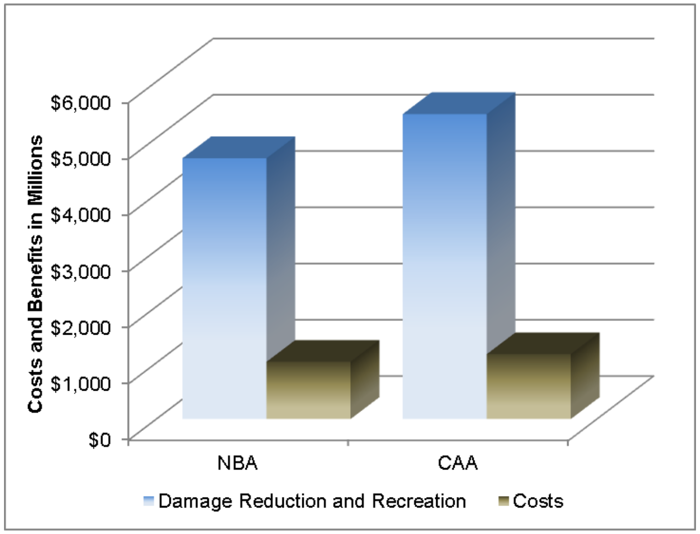


Figure 14: Comparing Costs and Benefits of CAA and NBA (Discount rate of 0 %)

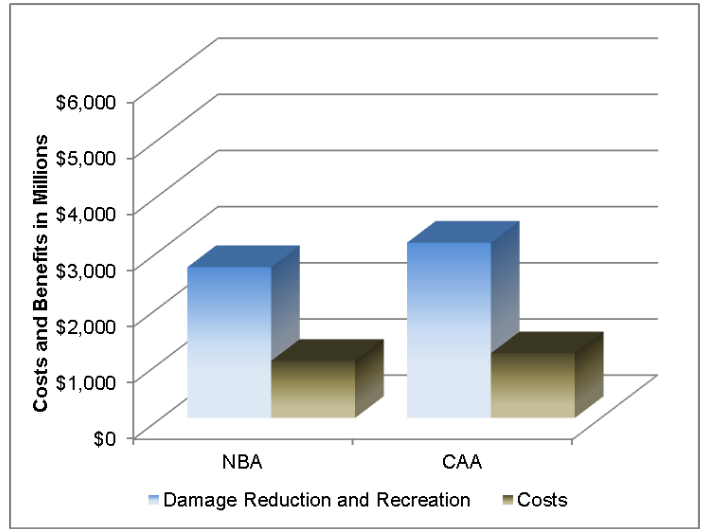


Figure 15: Comparing Costs and Benefits of CAA and NBA (Discounted at 1 %)

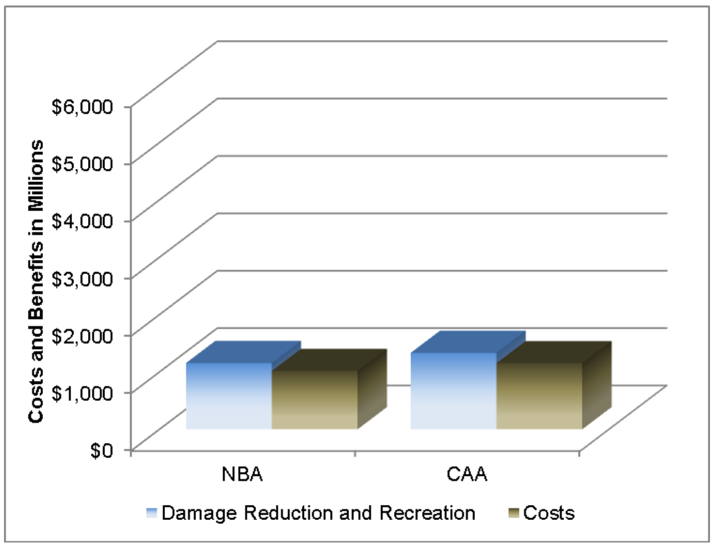


Figure 16: Comparing Costs and Benefits of CAA and NBA (Discounted at 3%)

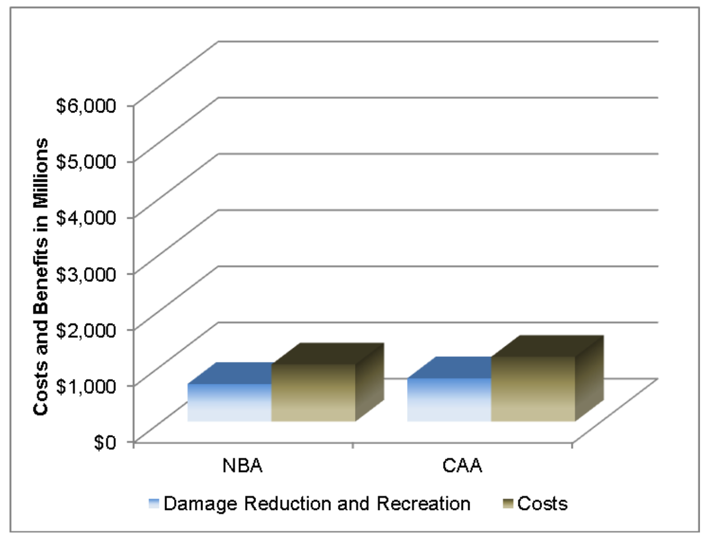


Figure 17: Comparing Costs and Benefits of CAA and NBA (Discounted at 5%)

5.4 Incorporating Ecosystem Services

The initial results from the parcel database demonstrate that designing adaptation with conservation of ecosystem services in mind, is nearly as effective in mitigating risk as designing with traditional engineering solutions. Consequently, quantifying the ecosystem services is an important criterion in selecting a design.

The analysis below adds in the net ecosystem service values developed Section 4.3. The analysis showed that the NBA always produced higher SAYs than the CAA. Consequently, the benefits and costs need to include values for the ecosystem services of the land. Figure 18 shows how the value of the net dSAYS could figure into a benefit cost decision using the 100 year storm frequency with a three percent discount rate. The net benefits, or the benefits minus the costs from the parcel data base results are shown in red, and the value of one SAY is assumed to be $2,000. That is, if we assume the services of one acre of saltwater wetland is worth $2,000 per year, then the results would still favor the CAA approach over the NBA approach. However, in Figure 19, the same result is produced assuming that one SAY is worth $5,000. In this case the total net benefits of the NBA are now greater that the CAA.

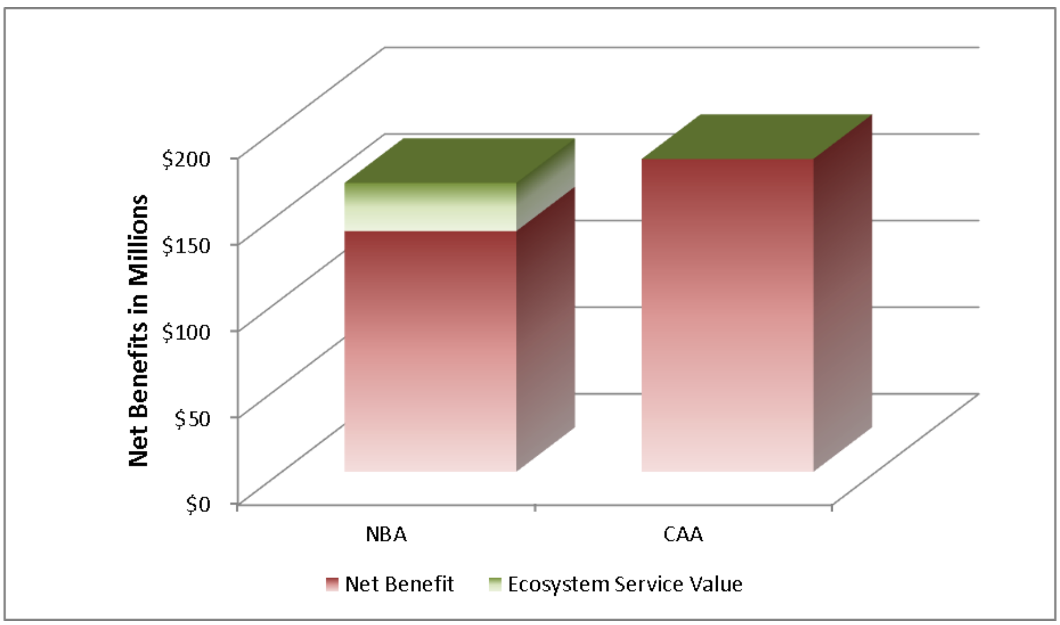


Figure 18: Benefits and Costs of Climate Change Adaptation Scenarios (One Saltwater Wetland Service Acre Year = $2,000)

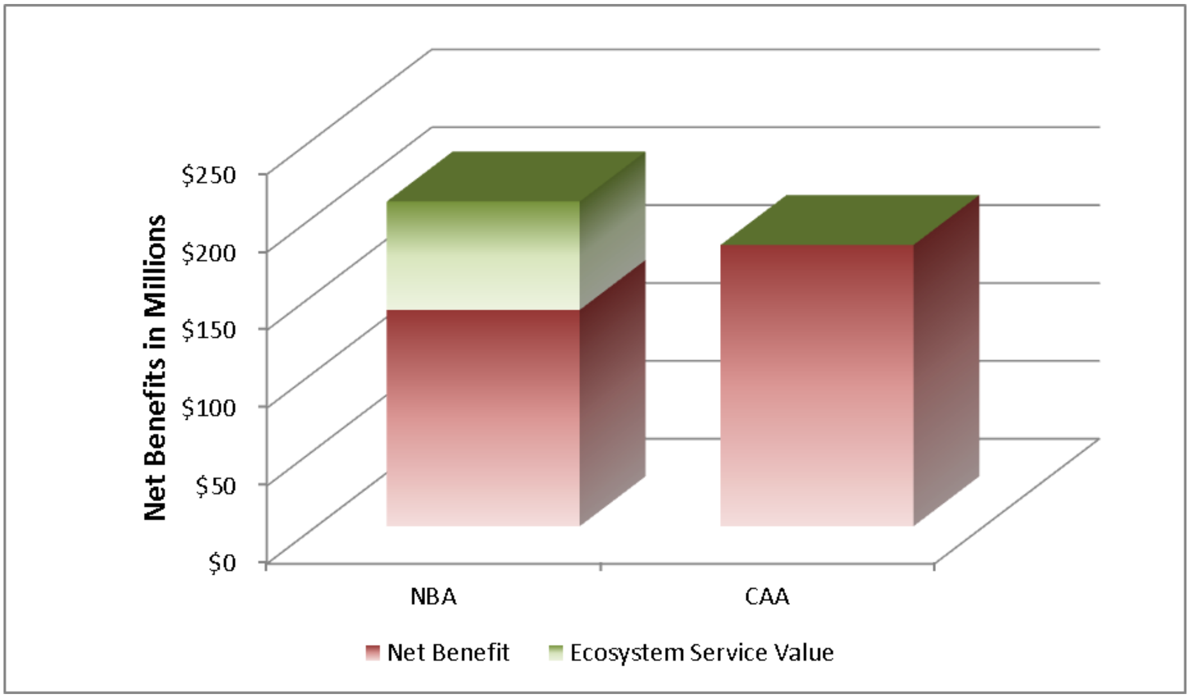


Figure 19: Benefits and Costs of Climate Change Adaptation Scenarios (One Saltwater Wetland Service Acre Year = $5,000)

Estimates of the value of a service acre year of wetland ranges from a few hundred dollars to tens of thousands. For example, a study of wetlands in national wildlife refuges was completed in 2012 and produced a range of per acre per year values from $99 to $550 (updated to 2014 dollars) for storm protection, water quality, commercial fishing, and carbon storage in four different states[35]. Another recent study completed for New Jersey concluded that saltwater wetlands had an ecosystem service value of $6,527 per year, and this number updates to $8,159 in 2014 dollars.[36] Other resources review a wide variety of literature that suggests reported values can be even higher.[37] In general, the value of saltwater wetlands will depend upon the location of the wetland, the ecosystem services provided, the local community preferences, and the quality of the wetland. Another approach is to consider what the local community is willing to pay to restore wetlands. For example, the Ormond Beach wetland

[35] Patton, Douglas, John Bergstrom, Alan Covich, Rebecca Moore, 2012, National Wildlife Refuge Wetland Ecosystem Service Valuation Model, Phase 1 Report: An Assessment of Ecosystem Services Associated with National Wildlife Refuges. Prepared for the Division of Refuges and Division of Economics, US Fish and Wildlife Service, Washington DC. Available at: http://www.fws.gov/economics/Discussion%20Papers/USFWS_Ecosystem%20Services_Phase%20I%20Report_04-25-2012.pdf

[36] Costanza 2007) Robert Costanza, Matthew Wilson, Austin Troy, Alexey Voinov, Shuang Liu, John D'Agostino, The Value of New Jersey's Ecosystem Services and Natural Capital, Gund Institute for Ecological Economics, University of Vermont, Burlington, Vermont, USA and New Jersey Department of Environmental Protection, Trenton, New Jersey, USA, 2006.07, http://www.state.nj.us/dep/dsr/naturalcap/nat-cap-2.pdf

[37] Raheem, Nejem; Talberth, John; Fleishman, Erica; Swedeen, Paula; Boyle, Kevin J.; Rudd, Murray A.; Lopez, Ricardo D.; O'Higgins, Tim; Willer, Chuck; Boumans, Roelof M. 2009. The economic value of coastal ecosystems in California, available at: https://www.nceas.ucsb.edu/files/news/Raheemreport.pdf

restoration project cost approximately $125,000 per acre.[38] This number suggests that the services provided by such wetlands are worth about $3,750 per year in perpetuity.[39] Conducting a wetland valuation specifically for the coast of Ventura is outside the scope of this study.

5.5 Limitations of Current Analysis

For planning purposes we provide order of magnitude estimates to allow comparison of alternative adaptation measures. These estimates are intended to provide an approximation of SLR and associated damages, and a conceptual level approximation of benefits and costs of two adaptation scenarios. These estimates do not explicitly include consideration of all possible costs, such as design, environmental review, permitting, construction administration, monitoring, property purchase and other costs. In particular, significant costs can be expected for sand mitigation fees for coastal armoring projects. These estimates do not consider all possible benefits and costs including indirect, consequential, aesthetic, and community health and well-being. Estimation of benefits is less certain than construction costs. Higher confidence is found in recreational economics, while ecological values are inherently uncertain. ENVIRON and ESA PWA make no warranty, expressed or implied, as to the accuracy of opinions of hazards or values.

[38] Personal communication with Peter Brand, November, 2014.

[39] The discounted present value of an annual payment of $3,750 in perpetuity at a three percent discount rate is $125,000

6 Conclusions and Recommendations

This research comprehensively analyzed two alternative strategies for climate change adaptation in Ventura County California. One strategy focuses on adaptation that takes advantage of natural processes and the other employs more traditional engineering based strategies involving coastal armoring. The purpose of the effort is to explore how the two strategies compare in terms of benefits and costs through time. The approach incorporates formal quantification of combined ecosystem services by land cover type for the study area. The study provides a holistic means of evaluating adaptation decisions going forward. Conclusions and recommendations for further research are offered below.

6.1 Conclusions

Several conclusions can be drawn from this research.

- Nature-based approaches to climate change adaptation can provide benefits in terms of damages reduced that are comparable to coastal armoring approaches.
- The Net Ecosystem Services Approach (NESA) blends environmental gains and losses with traditional monetary metrics in a theoretically consistent manner.
- Baseline estimates of coastal damage total $1.75 billion in net present value using a three percent discount rate, and assuming a static storm frequency of one percent per year for the modeled event.
- For the CAA alternative, the benefits are expected to exceed the costs using three percent discount and a storm frequency of one percent chance per year for the modeled event.
- For the NBA alternative, the benefits are also expected to exceed the costs using three percent discount and a storm frequency of one percent chance per year for the modeled event.
- If the value of the services of a saltwater wetland for one year are assumed to be greater than $3,000 per year, the NBA will produce greater net benefits than the CAA approach.
- The analysis includes estimates for wave damage, which has not been extensively studied before in economic terms.
- The analysis does not include other storms at different frequencies and so may be considered a low estimate of damages and benefits from adaptation.
- Many factors affect good adaptation decisions. This analysis allows users to explore how choices compare as assumptions about storm frequencies, discount rates, and the value of ecosystem services are varied.
- Secondary factors that also influence outcomes are:
  - Cost estimates
  - SLR severity
  - Model accuracy, and
  - Baseline definition

6.2 Recommendations for Further Research

Additional research surrounding the benefits and costs of climate change adaptation in Ventura County can build on the current analysis and improve the usefulness for decision makers. The parcel database developed for this research can be utilized to evaluate specific adaptation questions. More detailed analyses of local adaptation choices would not only aid local decision makers but provide interesting results to inform others of the types of conditions that favor different adaptation strategies.

Because the purpose of this research is to provide useful tools for local stakeholders, some of the information developed in this report could be developed more fully into a user-friendly spreadsheet tool that would allow decision makers to alter assumptions (such as was done in the sensitivity analysis in Chapter 5) and explore how benefits and costs change under different assumptions.

Several additional recommendations pertain to the incorporation of ecosystem services analysis into the decision making tool. It would be important to obtain a better understanding of the actual gains and losses of ecosystem services from management actions and climate change. As demands for these services increase and supply decreases, the value of services such as clean water, flood protection, food supply and others will become significantly more valuable. Given the budget and time constraints, the current analysis only provides a rough estimate of the ecosystem services at risk of SLR. Ideal data for such an analysis should include spatial and temporal aspects of changing land cover/habitats in combination with an understanding and valuation of the ecosystem services provided to society as those land forms change through time. Currently, the only easily utilized data that provides the necessary change in land use through time is the SLAMM Model.

Other research that could build on existing work might be:

- Regional economic impact analysis
- Applying the same approach and data to specific adaptation projects in Ventura. In these cases, location specific benefits and costs could be calculated with greater accuracy.
- Improve the understanding and valuation by stakeholders for ecosystem services. This would include both an informational phase that clearly explains what ecosystem services are and where they are derived in terms of habitats and land cover types. The second phase would be a more focused evaluation of the values that stakeholders place on ecosystem services. This would improve a critical component of the NESA, which is the value placed on services and therefore habitats.
- Include slope and shape of the ecosystem service recovery curves (e.g., linear, logarithmic, sigmoidal, etc.) following changes in HEA. This would recognize and incorporate the fact that full functioning ecosystems take time to develop.
- Incorporate ecological components into the modeling aspect. Currently, the SLAMM model is driven by physical components (e.g. hydrology, sediment transport, etc). Integration of the actual ecological evolution of habitat types and the service functions they provide would greatly improve the estimates. A fabulous source of information that could be

incorporated is the historical ecology of the lower Santa Clara River, Ventura River and Oxnard Plain (Beller et al.). This analysis of terrestrial, riverine and coastal habitats provides extremely valuable insights into what could be expected if nature was allowed to restore ecosystems and ecosystem function.

- Examine the ecosystem service changes by an analysis of the important linkages between the impacts of climate change and management actions and ecological functions. This approach has been employed in a quantitative fashion on several Habitat Conservation Plans.
- Explore costs associated with saltwater intrusion from SLR for agriculture, municipal, and other water users.

7 References

Beller, EE, RM Grosinger, MN Saloman, SJ Dark, ED Stein, BK Orr, PW Downs, TR Longcore, GC Coffman, AA Wipple, RA Askevold, B Stanford, RJ Beagle, 2011. Historical ecology of the lower Santa Clara River, Ventura River and Oxnard Plain: an analysis of terrestrial, riverine, and coastal habitats. Prepared for the State Coastal Conservancy. A report of SFEI's Historical Ecology Program, SFEI Publication #641, San Francisco Estuary Institute, Oakland, CA.

Brown, Sally, Robert Nicholls, Athanasios Vafeidis, Jochen Hinkel, and Paul Watkiss. 2011. Sea-Level Rise – The Impacts and Economic Costs of Sea-Level Rise on Coastal Zones in the EU and Costs and Benefits of Adaptation. Climate Cost Technical Briefing Note No. 2. Summary of Sector Results from the Climate Cost project, Funded by the European Community's Seventh Framework Programme. Website (http://www.climatecost.cc/images/Policy_brief_2_Coastal_10_lowres.pdf) accessed June 18, 2013.

Butzen, Steve, Flooding Impact on Crops, Accessed August 26, 2014 at: https://www.pioneer.com/home/site/us/agronomy/crop-management/adverse-weather-disease/flood-impact/

California Coastal Commission, 2005. Coastal Armoring Database. Coastal armoring along the coast of California, created to provide a database of all existing coastal armoring based on data available at the time of creation. Dataset developed by Jennifer Dare at the California Coastal Commission. Available for Download at: http://www.dbw.ca.gov/csmw/SpatialData.aspx

California Department of Finance (DOF), Demographic Research Unit. January 31, 2013. Report P-1 (County) - State and County Population Projections - July 1, 2010-2060 (5-year increments). Website (http://www.dof.ca.gov/research/demographic/reports/projections/) accessed August 27, 2013.

Catalog of Residential Depth-Damage Functions, Used by the Army Corps of Engineers in Flood Damage Estimation, 1992, May.

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and SLR Estimates for California 2008 Climate Change Scenarios Assessment. California Climate Change Center. CEC-500-2009-014-F. Website (http://www.energy.ca.gov/2009publications/CEC-500-2009-014/CEC-500-2009-014-F.PDF) accessed July 16, 2013.

Cayan, Dan, Mary Tyree, David Pierce, and Tapash Das of the Scripps Institution of Oceanography. 2012. Climate Change and SLR Scenarios for California Vulnerability and Adaptation Assessment. A White Paper from the California Energy Commission's California Climate Change Center. Public Interest Energy Research (PIER) Program Report – Publication # CEC-500-2012-008. Website (http://www.energy.ca.gov/2012publications/CEC-500-2012-008/CEC-500-2012-008.pdf) accessed June 19, 2013.

Chapman, D.J. and R.A. Taylor. 2002. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Appendix F: Equating Contaminant-Related Ecological Service

Losses and Restoration-Generated Service Gains for the Hylebos Waterway Using Habitat Equivalency Analysis. National Oceanic and Atmospheric Administration. Seattle, WA. March 1. http://www.cbrestoration.noaa.gov/documents/cbhy-f.pdf

Cooley, Heather, Eli Moore, Matthew Heberger, and Lucy Allen of the Pacific Institute. 2012. Social Vulnerability to Climate Change in California. A White Paper from the California Energy Commission's California Climate Change Center. Public Interest Energy Research (PIER) Program Report – Publication # CEC-500-2012-013. Website (http://www.energy.ca.gov/2012publications/CEC-500-2012-013/CEC-500-2012-013.pdf) accessed June 19, 2013.

Costa, L., V. Tekken, and J. Kropp. 2009. Threat of Sea-Level Rise: Costs and Benefits of Adaptation in European Union Coastal Countries. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), 223-227. Lisbon, Portugal, ISSN 0749-0258. Website (http://e-geo.fcsh.unl.pt/ics2009/_docs/ICS2009_Volume_I/223.227_L.Costa_ICS2009.pdf)

DataQuick News, available at: http://www.dqnews.com/

Dunford, R.W., Ginn, T.C.,Desvousges, W.H., 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics 48, 49-70.

ESA PWA 2014. Coastal Resilience Ventura. Technical Report for Sea Level Affecting Marshes Model (SLAMM). Prepared for the Nature Conservancy. San Francisco, CA.

ESA PWA 2014. Technical Report for Coastal Hazards Mapping, prepared for the Nature Conservancy. San Francisco, CA, July 31.

Federal Emergency Management Agency, Mitigation Division, Multi-hazard Loss Estimation Methodology Flood Model Hazus®-MH Technical Manual.

Garzon, Catalina, Heather Cooley, Matthew Heberger, Eli Moore, Lucy Allen, Eyal Matalon, Anna Doty, and the Oakland Climate Action Coalition. 2012. Community-Based Climate Adaptation Planning: Case Study of Oakland, California. A White Paper from the California Energy Commission's California Climate Change Center. Public Interest Energy Research (PIER) Program Report – Publication # CEC-500-2012-038. Website (http://www.energy.ca.gov/2012publications/CEC-500-2012-038/CEC-500-2012-038.pdf) accessed June 19, 2013.

Grannis, Jessica – Georgetown Climate Center. 2011. Threat of Sea-Level Rise: Costs and Benefits of Adaptation in European Union Coastal Countries. Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use - How Governments Can Use Land-Use Practices to Adapt to Sea-Level Rise. Website (http://www.georgetownclimate.org/sites/default/files/Adaptation_Tool_Kit_SLR.pdf) accessed June 19, 2013.

Greeninfo Network, 2014, California Protected Areas Data Portal, available at: http://www.calands.org/data

Heberger, Mathew, Heather Cooley, Eli Moore, and Pablo Herrera of the Pacific Institute. 2012. The Impacts of SLR on the San Francisco Bay. A White Paper from the California Energy

Commission's California Climate Change Center. Public Interest Energy Research (PIER) Program Report – Publication # CEC-500-2012-014. Website (http://www.energy.ca.gov/2012publications/CEC-500-2012-014/CEC-500-2012-014.pdf) accessed June 19, 2013.

Heberger, Mathew, Heather Cooley, Pablo Herrera, Peter H. Gleick, and Eli Moore of the Pacific Institute. 2009. The Impacts of Sea-Level Rise on the California Coast. A paper from the California Climate Change Center. Website (http://www.energy.ca.gov/2009publications/CEC-500-2009-024/CEC-500-2009-024-F.PDF) accessed June 19, 2013.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change. 2000. Special Report on Emissions Scenarios. Cambridge University Press, UK. 570 pp.

Jenks, G., J. Dah and D. Bergin, 2005: Changing paradigms in coastal protection ideology: The role of dune management. Presentation to NZ Coastal Society Annual Conference, 12-14 October, Tutukaka, Northland New Zealand, 27 pp.

NRC (2012). "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future." Prepublication. National Academy Press: Washington, D. C.

Neumann, J.E., Yohe, G., Nicholls, R.J. and Manion, M., 2001. SLR and its Effects on Global Resources. In: Claussen, E. (ed.) Climate Change: Science, Strategies and Solutions, Brill, Boston,pp. 43-62.

Neumann, J.E., G. Yohe, R.J. Nicholls and M. Manion, 2000: SLR and Global Climate Change: A Review of Impacts to U.S. Coasts. Pew Center on Global Climate Change, Arlington, Virginia43 pp.

Neumann, James E., Daniel E. Hudgens, Jane Leber Herr, and Jennifer Kassakian. 2003. Market Impacts of SLR on California Coasts, Appendix XIII in Wilson, T., L. Williams, J. Smith, and R Mendelsohn, Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy (2003). Website (http://www.energy.ca.gov/reports/500-03-058/2003-10-31_500-03-058CF_A13.PDF) accessed June 18, 2013.

New Jersey Department of Environmental Protection, Office of Coastal Management. June 2011. Coastal Community Vulnerability & Resilience Assessment Pilot - Greenwich Township, Cumberland County, NJ

Nicholls, Robert J. 2003. Case Study on Sea-level Rise Impacts. Paper prepared for an Organization for Economic Cooperation and Development (OECD) Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers, held 12-13 December 2002. Website (http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/338/Global_Case_Study_on_Climate_Policy_Benefits_-_Nicholls_2003.pdf) accessed June 18, 2013.

Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe. 2007. Coastal Systems and Low-lying Areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 315-356. Website (http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm) accessed June 18, 2013.

NOAA. 2006. Habitat Equivalency Analysis: An Overview. National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program. March 21. Revised 2000, 2006. 23. http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

Office of the Agricultural Commissioner, 2012, Ventura County's Crop & Livestock Report, Changing Tastes.

Park, R., M. Trehan, P. Mausel, and R. Howe. 1989. The Effects of SLR on U.S. Coastal Wetlands. The Potential Effects of Global Climate Change on the United States: Appendix B, SLR. Report to Congress. U.S. Environmental Protection Agency, Washington, DC. Website (http://papers.risingsea.net/federal_reports/rtc_park_wetlands.pdf) accessed July 23, 2013.

Perez, Pat – California Energy Commission. 2009. Potential Impacts of Climate Change on California's Energy Infrastructure and Identification of Adaptation Measures. California Energy Commission Publication # CEC-150-2009-001. Website (http://www.energy.ca.gov/2009publications/CEC-150-2009-001/CEC-150-2009-001.PDF) accessed June 19, 2013.

Rahmstorf, S. 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise." Science 315(5810): 368.

Rahmstorf, S., A. Cazenave, J. A. Church, J. E. Hansen, R. F. Keeling, D. E. Parker, and R. C. J. Somerville. 2007. "Recent Climate Observations Compared to Projections." Science 316(5825): 709. Website (http://www.soest.hawaii.edu/oceanography/zij/education/ocn201/climatechange.pdf) accessed July 16, 2013.

Rosenberger, Randall S., Oregon State University, 2011, Recreation Use Values Database Public version - August 1, 2011.

State of California, Department of Water Resources, Division of Flood Management, 2008, Flood Rapid Assessment Model (F-RAM) Development 2008, November.

Watkiss, Paul and Alistair Hunt. 2010. The Costs and Benefits of Adaptation in Europe: Review Summary and Synthesis. As part of the EC 7th FWP Climate Cost Study, based on work by the Climate Cost Consortium. This review has also benefited from review work as part of work for the European Environment Agency as part of the input to the SOER, 2010, and also review work by this team for the UNFCCC (2009) and from UK Defra as part of the UK Adaptation Assessment. Version1, March 2010. Website (http://www.climatecost.cc/images/Policy_brief_2_Costs_and_Benefits_of_Adaptation_Review_vs_2_watermark.pdf) accessed June 19, 2013.

United Nations Framework Convention on Climate Change (UNFCC). 2009. Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature. December. Website (http://unfccc.int/resource/docs/2009/tp/02.pdf) accessed June 18, 2013.

United States Fish and Wildlife Service's (USFWS) Habitat Suitability Indices (HSIs). http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiindex.htm

United States Army Corps of Engineers, 1992. Catalog of Residential Depth Damage Functions Used by the U.S. Army Corps of Engineers, in flood damage estimation, May, 1992, IWR – Report 92-R-3, available at: http://planning.usace.army.mil/toolbox/library/IWRServer/92-R-3.pdf

USACE (2011). "Sea-Level Change Considerations for Civil Works Programs." US Army Corps of Engineers, EC-1165-2-212.

Ventura County Assessor's Office, County Tax Database, available for purchase at: http://assessor.countyofventura.org/research/dataforsale.html

Ventura Council of Governments (VCOG). May 2008. 2040 Population Forecast - Ventura Cities and County. Website (http://www.ventura.org/rma/planning/pdf/demograghics/2040_revised_Decapolis%205_23_08_Final.pdf) accessed August 27, 2013.

World Bank. 2010. Economics of adaptation to climate change - Synthesis report. Washington D.C. - The World bank. http://documents.worldbank.org/curated/en/2010/01/16436675/economics-adaptation-climate-change-synthesis-report

Yohe, G. 1989. "The Cost of Not Holding Back the Sea: Phase 1 Economic Vulnerability" In The Potential Effects of Global Climate Change on the United States. Report to Congress. Appendix B: SLR. Washington, D.C.: U.S. Environmental Protection Agency. EPA 230-05-89-052.

Yohe, G., J. Neumann, P. Marshall, and H. Ameden. 1996. "The Economic Cost of Greenhouse-Induced Sea-Level Rise for Developed Property in the United States." Climatic Change 32(4): 387–410.

Yohe, G. W., and M. E. Schlesinger. 1998. "Sea-Level Change: The Expected Economic Cost of Protection or Abandonment in the United States." Climatic Change 38: 447–472.

Appendix A

Current Conditions in Ventura County

A. Current Conditions in Ventura County

This Chapter outlines the current conditions in the area of analysis. It provides a brief overview of the location of the study area, coastal Ventura County. This is followed by summarized socioeconomic profile of the area.

A.1 Location and Geographic Features

Ventura County is located in the southern part of California on California's Pacific coast. It is part of the Greater Los Angeles Area. The County's diverse geography ranges from rugged mountain terrain to coastal plains. The County's ten cities lie in the southern portion of the County. The major cities in coastal Ventura County are Oxnard, Port Hueneme, and Ventura (San Buenaventura). The County has a total area of 2,208.20 square miles, of which 1,845.30 square miles (or 83.6 percent) is land and 362.90 square miles (or 16.4 percent) is water.

Ventura County has many natural assets that are valuable to Southern California. These assets include: Ventura River, Santa Clara River, and Ormond Beach. The Ventura River is the only major watershed in Southern California that does not rely on imported water.[40] Climate change and land use changes could impact this water supply and the communities that depend on water from this source. Preserving the watershed and areas to the north intact as 'green capital' allows the watershed to function naturally and can prove to sustain valuable water sources that are continuously growing scarce in California. Similarly, the Santa Clara River is the one of the largest natural river remaining in Southern California stretching from its headwaters in Mountains until it meets the Pacific Ocean. The Ormond Beach region is considered by wetland experts to be the most important wetland restoration opportunity in southern California. The ongoing restoration of the Ormond Beach wetlands and associated habitat is capable of creating a self-sustaining biological system that can be the largest coastal wetland in Southern California.[41] The location of Ventura County, the major cities within the County, and the natural amenities provided in the county are conveniently viewed in an online mapping tool for coastal resilience provided by TNC.[42]

A.2 Socioeconomic Profile

This section describes the existing socioeconomic environment in the cities of Oxnard, Port Hueneme, and Ventura (San Buenaventura), Ventura County, the State of California, and the U.S. The section is organized into three main components: (1) population trends and projections; (2) income-related measures of social well-being; and (3) discussion of cities and county. The focus of this section is on those socioeconomic parameters most likely to be affected by SLR. These key parameters include demographic characteristics of local residents, and employment and income levels in the cities and county. The data used for the economic

[40] Gardner, R. N. Iqbal, A. Love, B. Ponton, J. Sahl, D. Yocum. 2012. Sustainable Water Use in the Ventura River Watershed. Bren School of Environmental Science and Management. Available online at: http://venturariver.weebly.com/uploads/1/5/9/2/15923202/ventura_river_group_project_proposal_2012.pdf

[41] State of California. Coastal Conservancy. Ormond Beach Wetlands Restoration Project. Available online at: http://scc.ca.gov/2010/01/07/ormond-beach-wetlands-restoration-project/

[42] The mapping tool shows forecasted future storm surges, wave action, and erosion from present conditions through the year 2100. These geographic features may be viewed at: http://maps.coastalresilience.org/ventura/#

and socioeconomic analyses are the most recent available or published data from reliable sources. All efforts are made to ensure that these data are updated to their latest release year.

A.3 Population Trends and Projections

The total population of the County is 823,318 based on the 2010 Census. This number represents a 9.3 percent increase over the County's 2000 population, which is a faster growth rate than either Los Angeles County or Orange County during the same period.

The cities of Oxnard, Port Hueneme, and Ventura (San Buenaventura) together account for about 40 percent of the total population of Ventura County, while Ventura County makes up a little over two percent of the population of the State of California. The City of Oxnard is the most populous city in the county, with a population of 197,899 in 2010.[43] The 2010 population for Ventura County was 823,318, while populations for the cities of Port Hueneme and Ventura were 21,723 and 106,433 individuals, respectively.[44]

As shown in Table A-1, each city and the county experienced growth between 1990 and 2010. The largest rate of population growth in the cities analyzed was in the City of Oxnard, which grew at a rate of over 16 percent between 2000 and 2010, and by more than 39 percent between 1990 and 2009. The other two cities experienced slower, but still some population growth between 1990 and 2010. However, while population in the City of Port Hueneme did increase by about seven percent between 1990 and 2010, it actually had negative population growth between 2000 and 2010. The population of Ventura County grew by over 23 percent between 1990 and 2010.[45]

The population in Ventura County is aging because the potential for economic growth is less, leading to less people moving in and younger people moving out. The economy of the County is also dependent on the economies of Santa Barbara and Los Angeles counties because there is a big part of the population that lives in Ventura County, but commutes to these two counties for work because it is more affordable and these people can enjoy a better lifestyle. The economic downturn in Santa Barbara and Los Angeles counties has, in turn, affected the economy and population growth in Ventura County.

---

[43] United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

[44] United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

[45] United States Census Bureau, American Fact Finder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

United States Census Bureau, Census 2000 Gateway. Website (http://www.census.gov/main/www/cen2000.html) accessed August 20, 2013.

United States Census Bureau, 1990 Census of Population and Housing. Website (http://censtats.census.gov/cgi-bin/pl94/pl94data.pl) accessed August 20, 2013.

Table A-1: Population and Population Growth						
Area	**Population**			**Population Growth**		
	1990	**2000**	**2010**	**1990-2000**	**2000-2010**	**1990-2010**
City of Oxnard	142,216	170,358	197,899	19.8%	16.2%	39.2%
City of Port Hueneme	20,319	21,845	21,723	7.5%	-0.6%	6.9%
City of Ventura (San Buenaventura)	92,575	100,916	106,433	9.0%	5.5%	15.0%
Ventura County	669,016	753,197	823,318	12.6%	9.3%	23.1%
California	29,760,021	33,871,648	37,253,956	13.8%	10.0%	25.2%
United States	248,709,873	281,421,906	308,745,538	13.2%	9.7%	24.1%

Sources:
United States Census Bureau, American Fact Finder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

United States Census Bureau, Census 2000 Gateway. Website (http://www.census.gov/main/www/cen2000.html) accessed August 20, 2013.

United States Census Bureau, 1990 Census of Population and Housing. Website (http://censtats.census.gov/cgi-bin/pl94/pl94data.pl) accessed August 20, 2013.

Population projections through 2040 for the three cities and the State of California are shown in Table A-2. It is projected that the population in Oxnard will continue to increase, with a rate of growth of 9.8 percent between 2010 and 2020. Beyond 2020, this population is expected to increase by 11.3 percent between 2020 and 2040, and by 22.2 percent between 2010 and 2040. The population in Port Hueneme is expected to increase by 10.1 percent from 2010 to 2040. At 24.8 percent, the City of Ventura is projected to have the highest growth rate among the three coastal cities between 2010 and 2040. Overall for Ventura County, the population growth rate between 2010 and 2040 is projected at 16.7 percent, which is much lower than that for the State of California for the same period (28 percent).

Table A-2: Population Projections* (2010-2040)

Area	Population			Population Growth		
	2010	2020	2040	2010-2020	2020-2040	2010-2040
City of Oxnard	197,899	217,293	241,834	9.8%	11.3%	22.2%
City of Port Hueneme	21,723	21,313	23,920	-1.9%*	12.2%	10.1%
City of Ventura (San Buenaventura)	106,433	112,913	132,783	6.1%	17.6%	24.8%
Ventura County	823,318	867,535	960,528	5.4%	10.7%	16.7%
California	37,253,956	40,643,643	47,690,186	9.1%	17.3%	28.0%

Note:

* Projections for Ventura County and the State of California are available through DoF 2013. The most reliable projections for the cities are available in VCOG 2008. However, the VCOG projections are older and based on the 2000 Census populations. These were updated for each city by adjusting the total county projection to the 2013 DoF projection and parsing out the cities based on the share of the county population in the VCOG projection. This approach may have resulted in some discrepancies, such as a negative growth rate for City of Port Hueneme between 2010 and 2020.

Sources:

United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

California Department of Finance (DoF), Demographic Research Unit. January 31, 2013. Report P-1 (County) - State and County Population Projections - July 1, 2010-2060 (5-year increments). Available at (http://www.dof.ca.gov/research/demographic/reports/projections/) accessed August 27, 2013.

Ventura Council of Governments (VCOG). May 2008. 2040 Population Forecast - Ventura Cities and County. Available at (http://www.ventura.org/rma/planning/pdf/demograghics/2040_revised_Decapolis%205_23_08_Final.pdf) accessed August 27, 2013.

A.4 Income-related Measures of Social Well-Being

As derivatives of total personal income, per capita and median household income, poverty rates, and unemployment rates represent widely used economic indicators of social well-being. Table A-3 presents these socioeconomic data for the three coastal cities, Ventura County, the State of California, and the U.S. In 2011, per capita income in Ventura County was $32,740, exceeding the Statewide level of $29,634. At $31,775, per capita income in the City of Ventura also exceeded the Statewide average. Conversely, per capita incomes in the cities of Oxnard and Port Hueneme were 69.6 percent and 78.9 percent of the Statewide average, respectively.

Median household incomes for the County and cities of Oxnard and Ventura all exceeded the Statewide average in 2011. Only the median household income in Port Hueneme was less than that Statewide average. The median household income in Ventura County was $76,728 in 2011, while that in the cities of Oxnard, Port Hueneme, and Ventura were $60,191, $52,244, and $66,226, respectively.

A third indicator, poverty rate, represents the percentage of an area’s total population living at or below the poverty threshold established by the U.S. Census Bureau. Based on available data for 2011, the poverty rate was 9.9 percent in Ventura County, 15.3 percent in Oxnard, 15.1

percent in Port Hueneme, and 10.5 percent in Ventura. The poverty rate at the State level (14.4 percent) exceeded that for Ventura County and the City of Ventura.

Finally, the unemployment rate represents the percentage of the labor force that is unemployed and is actively seeking employment. In July 2013, Ventura County experienced an unemployment rate (8.0 percent), below the statewide level (8.7 percent). The City of Ventura had an even lower unemployment rate of 7.2 percent. However, the unemployment rate for both the City of Oxnard (10.9 percent) and the City of Port Hueneme (9.4 percent) exceeded the statewide level.

Table A-3: Income, Poverty Rates, and Unemployment Rates

Area	Per Capita Income (2011)	Median Household Income (2011)	Poverty Rate (2011)	Unemployment Rate (July 2013)
City of Oxnard	$20,612	$60,191	15.3%	10.9%
City of Port Hueneme	$23,391	$52,244	15.1%	9.4%
City of Ventura (San Buenaventura)	$31,775	$66,226	10.5%	7.2%
Ventura County	$32,740	$76,728	9.9%	8.0%
California	$29,634	$61,632	14.4%	8.7%
United States	$27,915	$52,762	14.3%	7.4%

Some recent trends and factors affecting the economy of Ventura County are discussed below:

1. The County's median age is 36.2, and nearly half of the population is either under the age of 20 or over the age of 60. This is a key observation for the future of Ventura County.
2. The economy of Ventura County is dependent on the economies of Santa Barbara and Los Angeles counties because of the large proportion of the population that lives in Ventura County, but commutes to these two counties for work because it is more affordable and these dwellers can enjoy a better lifestyle. Due to the economic downturn in these two counties, the economy of Ventura County saw its share of the effects.
3. Based on employment numbers, hospitality and leisure is a major part of the economy of Ventura County (after government and retail). While tourism did get a big hit during the recession, it is recovering now.
4. Generally, the higher income people are still there, but populations of working age and low-income people are shrinking.
5. It did not get hit by the housing bubble too much because there was not much excess housing inventory.
6. While coastal areas tend to do better than the State in terms of job growth in CA, job growth in Ventura County has been surprisingly volatile.

A.5 Cities within the Study Region

This section presents brief discussions of the main cities in coastal Ventura County. In addition to the Naval Base Ventura County (NBVC), which supports significant employment and community as an incorporated city does, the cities of Oxnard, Ventura, and Port Hueneme fall within the study area.

A.5.1 City of Oxnard

The City of Oxnard is Ventura County's largest city, and is located in Western Ventura county midway between Santa Barbara and Los Angeles. Oxnard is situated within easy driving distance of virtually every major visitor attraction in the region. Oxnard combines the sophistication of a modern big city with the easy-going charm of a scenic beach town. Oxnard can boast about many things including, a wonderful climate, great restaurants, beaches, and diverse multicultural population in an ever-evolving community.

Top Employers (2010)

- St. John's Regional Medical Center-Medical (1,393)
- Haas Automation-Engineering (1,200)
- City of Oxnard-Government (1,122)
- Verizon-Communications (860)
- Waterway Plastics Inc-Plastic (700)
- Procter & Gamble-Paper Products Manufacturing (650)
- Boskovich Farms-Produce (600)
- Sysco Food Services of Ventura-Food (500)
- Workrite Uniform Co Inc-Clothing (405)
- Gills Onions-Produce (400)

A.5.2 City of Port Hueneme

The City of Port Hueneme is a small coastal city located 60 miles northwest of Los Angeles and 40 miles south of Santa Barbara. It is generally bounded by Naval Base Ventura County on the west, the City of Oxnard to the north and east, and the Pacific Ocean to the south. The City is nearly completely built-out with approximately one acre of vacant residential land and five acres of vacant commercial land remaining.

Its desirable beach-style living and plentiful business opportunities delight every native and newcomer. Residents and visitors enjoy strolling along the 50-acre Hueneme Beach Park, and businesses benefit from the city being home to the largest commercial deepwater harbor between Los Angeles and San Francisco. Port Hueneme is also home to one of Naval Base Ventura County's three operating facilities. Residents consistently cite the high quality of life offered due to planned development, excellent public facilities and responsive city services as being primary reasons for choosing to live in the city.

Top Employers

- Naval Base Ventura County-Military (15,000)
- Hueneme School District-Public Education (790)
- Pacific Maritime Association-Industry Association (500)
- Pac Foundries-Steel and Aluminum Castings (330)
- City of Port Hueneme-Government (125)

A.5.3 City of Ventura

Ventura is a classic Southern California beach town situated between the Ventura and Santa Clara rivers. Founded as one of nine original California missions, Ventura has miles of uncrowded beaches and bikeways, a commercial harbor that gateways to the Channel Islands National Park, a thriving cultural district and it is evolving as a Smart Growth leader. Ventura is ideally located for businesses involved in domestic and international trade. And, with a new high-tech business incubator, growing a business is easy in Ventura. The City of Ventura is generally built-out along the coast with a few vacant parcels remaining in play.

Top Employers

- County of Ventura-Public Sector (7,191)
- Vons-Grocery (2,406)
- Ventura Unified School District-Public Education (2,340)
- Ventura County Health Care Agency-Health Care (1,877)
- Ventura County Community College District-Public Education (1,877)
- Community Memorial Hospital-Health Care (1,725)
- City of Ventura-Government (1,065)

A.6 Naval Base Ventura County (NBVC)

The Naval Base Ventura County (NVBC) supports more than 80 tenant commands with a base population of more than 19,000 personnel, making it the largest employer in Ventura County.[46] NVBC is composed of three sites, Port Hueneme, Point Mugu, and San Nicolas Island. The facilities are key elements in the Department of Defense (DOD) infrastructure. On-base housing is available at Point Mugu and Port Hueneme. An additional military housing complex is located in the city of Camarillo which is approximately a 20 minute drive from Mugu and 25 minutes from Port Hueneme. Unaccompanied Housing (formerly Bachelor Housing - BH) is conveniently located on Point Mugu and Port Hueneme. UH houses approximately 1,900 service members in 23 buildings.[47]

[46] (http://www.cnic.navy.mil/regions/cnrsw/installations/navbase_ventura_county.html)
[47] (http://navylifesw.com/ventura/housing/unaccompanied/)

Appendix B

Figures for Hazard Modeling

B. Figures for Hazard Modeling

Scenario Codes

Adaptation measures within each scenario were assigned unique identifiers (codes) based on the naming convention below to simplify cost estimating and mapping.

Prefix:

EBA – A measure that is part of the Engineering Based Adaption scenario

NBA – A measure that is part of the Nature Based Adaption scenario

Suffix:

AN – Construction of new coastal armoring (seawalls, revetments, or bulkheads[48])

AR – Reinforcement/maintenance of existing coastal armoring

BD – Measure related to beach and/or dune restoration

EL – Elevate homes and/or commercial buildings

LV – Construction of a levee

MR – Managed retreat action

TB – Construction of a tidal barrier/lock/gate

WL – Measure related to wetlands (restoration, transgression, etc.)

Numbers:

Letters (a, b, c…) reflect the same measure being implemented in different location. For example, Dune enhancement activities (NBA-BD2) are implemented in two locations, so the two regions of dune enhancement activities are labeled “NBA-BD2a” and “NBA-BD2b”. If a specific activity is only implemented in once place, no letter is included in the code.

B.1 Nature Based Adaptation or NBA Scenarios

Nature based adaptation scenarios were developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. NBA options evaluated include a set of management tools including restoration of wetlands, dunes, and other natural processes, and managed retreat.

Restricting flooding in one area, does not eliminate the threat of inundation, it simply moves it. Managed retreat is the concept whereby areas that are naturally prone to flooding and were once protected with levees, barriers and other structures, are allowed to return to a state where flooding is allowed to occur. This is most often accomplished through the removal of structures and assets that require flood protection. Allowing the return to a natural process in an area where it is naturally disposed to occur, will, in principle, lessen the probability of flood damage in adjacent areas.

Areas where open land is available, and where restoration of natural functions and processes could take place, were considered most appropriate for application of “natural processes”. In

[48] Bulkhead is a structural barrier that serves to protect a beach against erosion from waves and other actions. The bulkhead is usually made of wood pilings, steel sheet pile, commercially developed vinyl products, large boulders stacked to form a wall, or a seawall built of concrete or another hard substance.

areas where public infrastructure was located, managed retreat options were considered most appropriate as these tend to fall within the jurisdiction of the state, county, or city governments. In the case of private property, selected adaptation options were chosen based on the criteria that they would allow homeowners to retain their location for the present time and to the extent possible, the integrity of the oceanfront home values.

The elements of the proposed NBA scenario are presented in Figure 2a through c. It consists of beach and dune restoration projects, wetland restoration projects, managed retreat areas, and elevated neighborhoods. The relevant lengths and areas of proposed adaptation scenarios are also shown in Table .

B.1.1 Beach and Dune Restoration

NBA-BD1: Beach nourishment with cobbles and construction of back beach dunes. Beach nourishment is recognized as a natural way of preventing beach erosion and is implemented at different locations, except in the areas designated for “managed retreat” action. Nourishing beach cobbles will preserve natural beach armoring. This strategy would also include all the dune enhancement activities described in **NBA-BD2**, below.

Location: Between the Ventura River Levee and the Ventura Pier (approx. 1 mile).

NBA-BD2: Dune enhancement activities. Activities include:

- Dune augmentation (adding sand to dunes to provide protection during storm events), especially to raise low-lying beach access paths to prevent flood waters from flowing into the neighborhoods behind the dunes.
- Ceasing any activity that adversely affects the sediment supply of the dunes.
- Ceasing beach grooming. This would encourage dune vegetation establishment and dune formation. Beach grooming removes driftwood and wrack and reduces vegetative growth and dune formation.
- Planting vegetation. Planting native dune vegetation, together with wind action, will help build up and stabilize dunes.
- Fencing off sensitive areas and creating dune walkways
- Informational signs and other outreach activities to educate about the importance of maintaining stable sand dunes.

Location: (a) Ventura Pier to the Ventura Harbor.
(b) Between Port Hueneme and Ormond Beach Lagoon
(c) Mandalay Shores to Channel Islands Harbor
(d) Between Channel Islands Harbor and Port Hueneme Harbor

B.1.2 Wetlands

NBA-WL1: Restoration of Ormond Beach wetlands, just west of Naval Base Ventura County. The NBA approach would include 1190 acres of unconstrained seasonally open tidal wetlands (Alternative 2U), just west of Naval Base Ventura County.

NBA-WL2: Conversion of managed ponds to wetlands. These low lying basins are expected to be overtopped under the high SLR scenario and the abandonment (or lack of improvements) would convert this habitat from freshwater managed wetlands to salt marsh.

Location: (**a**) The southern set of ponds. This restoration is closely related to NBA-WL1 as restoration of the managed ponds has been proposed in tandem with Alternative 2U.
(**b**) The northern set of ponds.

NBA-WL3: Conversion of agricultural lands as wetlands transgress west and east of NBVC. This action assumes abandoning the existing land and purchasing the real-estate equivalent land elsewhere,[49] demolition of the existing structures, and natural transgression of wetlands in the same area (without any additional cost).

Location: (**a**) West of the NBVC runway
(**b**) East of NBVC and south of HWY 1

NBA-WL4: Improvement of tidal connectivity through Mugu Lagoon by daylighting existing culverts under roads to be abandoned (e.g. end of the NBVC runway, Laguna Rd) to improve the habitat quality and resilience to SLR throughout the marsh. This would be conducted in collaboration with **NBA-MR6**, below.

NBA-WL5: Retreat of shoreline and transgression of wetlands north of Highway 1 adjacent to Calleguas Creek. This action assumes abandoning the existing agricultural land. No structures exist in this zone.

NBA-WL6: Restore wetland and lagoon at the southern end of Sanjon Road and sliver wetland north of Hwy 101 and Alessandro Drive. Restore connectivity between the sliver wetland and the ocean by raising the road (up to 800' of road) along the back of the beach. Restoration of these wetlands would filter pollutants in flood waters. The wetlands would not act as a significant buffer against SLR, but would mitigate climate change impacts to the ecosystem service of water quality and habitat.

B.1.3 Coastal Armoring, Levees, and Tide Barriers

NBA-LV1: Construction of a ring levee surrounding the airfield at Mugu and tying into Highway 1, which is raised. This measure is considered reasonable as the Mugu airport would only flood under some SLR flood hazard scenarios, and sometimes not until year 2100. The ring levee is assumed to be constructed with clay and protected with geotechnical membranes. Existing culverts and other water conveyance structures across the levee alignment would have to be closed or modified to close during high tides.

NBA-LV2: Construction of a levee along the north side of the Ormond Beach Wetland Restoration (**NBA-WL1**).

[49] This assumes a fee simple acquisition approach as opposed to other cheaper management/land use planning tools like conservation or rolling easement

NBA-TG1: Construction of a tide gate along channel flowing through the Ormond Beach Wetland Restoration (**NBA-WL1**), near Ocean View Drive.

NBA-AR1: Reinforce and raise bulkheads around ports and harbor. Ports and harbors would not be relocated under this alternative, and preservation of bulkheads would prevent increasing water levels (both during high tides and storms) from flooding the adjacent low-lying neighborhoods.

Location: (**a**) Ventura Harbor
(**b**) Channel Islands Harbor
(**c**) Port Hueneme Harbor

NBA-AR2: Reinforcement of the **existing** revetment and/or seawall.

Location: (**a**) West side of Port Hueneme Harbor
(**b**) East side of Port Hueneme Harbor

B.1.4 Managed Retreat

NBA-MR1: Managed retreat between Surfer's Point the eastern edge of Promenade Park. Removal/realignment of existing bike path/promenade. This would be conducted in conjunction with beach and dune restoration (**NBA-BD1**).

Location: (**a**) Between Surfer's Point and the western end of the Ventura Promenade (the round-about. This section was included in the second phase of managed retreat at Surfer's Point. The first phase, which included realignment of the bike path, cobble and sand nourishment, and dune construction, was completed in 2012. The Phase II design is complete and permitted, but political issues and a lack of funding are currently preventing the project from being completed.

(**b**) Between the round-about and the eastern side of Promenade Park.

NBA-MR2: Removal of parking lot and HWY 101 on-ramps east of the Ventura Pier and south of HWY 101, replaced with back beach dunes. This is consistent with the Ventura Beach +Town Project[50]. The larger project includes capping of the existing freeway just north of the Ventura Pier and construction of a retail/business conference center with a train hub and pedestrian walkways. These additional elements (which are assumed to have no effect on the coastal hazards analysis) are not shown in the scenario figure.

NBA-MR3: Relocation of the Ventura Water Reclamation Facility (VWRF). While construction of/improvements to bulkheads around Ventura Harbor (**NBA-AR1a**) will reduce some of the flooding originating from the harbor, relocation is recommended for plant functioning. The plant relocation cost includes purchase of the land, construction, and demolition of the existing structures.

[50] http://www.cityofventura.net/page/beachtown.

NBA-MR4: Relocate McGrath State Beach Park and Campground from (**a**) its current location to (**b**) the east of Harbor Boulevard. This will maintain or improve public use, camping, and access and remove the park from the coastal flood hazard zone (but not the fluvial flood hazard zone).

NBA-MR5: Decommission the Mandalay Power Plant. This power plant, located just south of McGrath State Beach Park, would be subjected to frequent flooding even under the medium SLR scenario.

NBA-MR6: Removal of Halaco Superfund site.

NBA-MR7: Decommission of Ormond Beach Generating Station. This plant, located 900 feet from the shoreline and 7 to 9 feet above the sea level would be subjected to frequent flooding under all hazard scenarios. The plant decommission cost includes purchase of the land, and demolition of the existing structures.

NBA-MR8: Decommission roads and other remaining NBVC infrastructure outside proposed ring levee to the west of the airport runway. This would occur in tandem with **NBA-WL1**, **NBA-WL2a&b**, and **NBA-WL3a**.

NBA-MR9: Remove revetment fronting the NBVC runway and extend runway to the north, if necessary.

NBA-MR10: Relocate Electronics building and other infrastructure (including revetment) on spit at NBVC.

NBA-MR11: Lower levees along Calleguas Creek and Revelon Slough. This project would be done in conjunction with **NBA-WL5**.

NBA-MR12: Managed Retreat from selected parts of the beach, Retreat from the beach assumes abandoning existing residential structure on the beach and purchasing residential structures of a similar value (cost) outside the projected hazard zone.[51] The Managed Retreat concept is generally used to improve coastal stability, relying entirely on management of natural 'soft' coastal landforms (i.e. dune management, cobble beaches). These natural defenses protect inland areas by absorbing or reducing the force of waves. The abandoned residential or commercial areas uphill of the beach becomes the new beach with its own ecological system.

Location: **(a)** Marina Park north of the Ventura Harbor
(b) San Buenaventura State Beach

B.1.5 Elevate Beachfront Neighborhoods

NBA-EL1: Raise roads to remove from hazard zones. Roads would be raised to remove them from regular tidal inundation or also during coastal storms if the access way is required during an emergency.

[51] This assumes a fee simple acquisition approach as opposed to other cheaper management/land use planning tools like conservation or rolling easements

Location: (**a**) Beach frontage road (East Harbor Blvd) behind San Buenaventura State Beach
(**b**) Access roads to NBVC

NBA-EL2: Raise selected residential houses and commercial buildings to elevations comparable to those at Mandalay Shores (7 to 10 m NAVD or 23 – 33 ft. NAVD). Elevating private residences or commercial infrastructure assumes re-construction of buildings on either piles or piers (costs for elevating residences are obtained from similar structures raised and/or reconstructed following Hurricane Sandy).

Location: (**a**) In the canals in Ventura Harbor
(**b**) In the canals in Channel Islands Harbor

B.1.6 Coastal Armoring Adaptation (CAA) Scenario*[52]

An engineering based adaptation scenario was developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. The CAA options included a set of management tools that focused on protection through construction of sea walls, levees, and other armoring. The overall goal of the engineered based scenario was to protect built property and infrastructure as they currently exist in Ventura County. The EBA elements are shown in Figure 3 and summarized below, with the relevant lengths and areas reported in Table 2 (attached).

The EBA approach includes coastal armoring along most of the study area between the Ventura River and Point Mugu. Revetments and/or seawalls would be reinforced or placed along the backshore toe of the existing shoreline to protect it against erosion. The armoring options below are separated into “reinforce existing” or “construct new” armoring, based on an existing geospatial coastal armoring inventory.[53] Revetment[54] is an accepted shoreline protection method as long as it is designed to sustain impact from wave and floodwaters without erosion and without jeopardizing its structural integrity. Three common types of revetments/seawalls are considered in this analysis:

1. Rubble-mound revetment: Boulders and rocks placed atop the shoreline. Revetment cost assumes a density of 3 tons of rock per one linear foot of the revetment.
2. H-soldier (steel or timber) piles filled with concrete (panels).

[52] For the remainder of this document, the CAA scenario is referred to as the “EBA” for Engineering-Based Adaptation. The EBA language has been maintained here to provide consistency with the figures showing the adaptation strategies.

[53] In 2005, NOAA Coastal Service Center Fellow Jennifer Dare developed a statewide coastal armoring GIS database for the CCC by using a combination of oblique aerial images from the California Coastal Records Photo website (www.californiacoastline.org) and georeferenced orthoimages to identify and locate shoreline protective structures (seawalls, revetments, etc.) along the entire California coast. This database represents structure extents along a single California shoreline. This dataset was used to identify study blocks backed by at least 50% shoreline armoring. Stretches of coast characterized by sporadically-spaced private structures are designated as “construct new seawall/revetment”.

[54] Revetment is a coastal structure made of large rock armorstone placed on a slope (typically 2:1) over the bank or cliff to absorb the energy from waves and floodwaters. River or coastal revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion. Revetments typically do not stop flooding.

3. Steel sheet pile bulkhead (a continuous steel seawall structure).

Escalating maintenance costs were assessed by increasing levels of wave attack on the structure as the beach width was lost. Shoreline armoring is known to result in a long term narrowing of the beach in front of these structures (i.e. passive erosion). Additionally, some beach is lost to the footprint of the structure (i.e. placement loss). Both passive erosion and placement loss were evaluated in the beach width analysis.

EBA-AR1: Reinforcement of the **existing** revetment and/or seawall.

Location: (**a**) West end of the Ventura Promenade to the Ventura Pier
(**b**) Greenock Lane to Ventura Marina
(**c**) Ventura Marina to Santa Clara River Mouth (includes maintaining existing VWRF)
(**d**) Channel Islands Harbor to Port Hueneme
(**e**) Port Hueneme to South Ventura Road
(**f**) NBVC runway (waterproof)
(**g**) I Avenue to mouth of Mugu Lagoon (waterproof)

EBA-AN1: Construction of a **new** revetment and/or seawall along the backshore toe of the existing shoreline. These new sections of revetments would result in a continuous structure (including along public parks) to avoid erosion and flooding through gaps. The continuity is important, and if properly designed, would provide uniform protection to the land behind the revetment, without any adjacent erosion.

Location: (**a**) Surfer's Point (Ventura River Levee to round-about)
(**b**) Ventura Pier to San Pedro Street
(**c**) San Pedro Street to Greenock Lane in Ventura
(**d**) Santa Clara River Mouth to Mandalay Generating Station (includes maintaining McGrath State Beach Park in existing location)
(**e**) Mandalay Generating Station to Channel Islands Harbor
(**f**) South Ventura Road to Ormond Beach Wetland Restoration
(**g**) Ormond Beach Wetland Restoration to NBVC runway (waterproof)
(**h**) NBVC runway to I Avenue (waterproof)
(**i**) Inside mouth of Mugu Lagoon (waterproof)
(**j**) East arm of Mugu Lagoon (tie into existing revetment along HWY 1) (waterproof)

EBA-TB1: Construction of tidal barrier/lock system at the mouth of the harbors. The barrier would consist of symmetrically placed floodwalls on each side of the harbor entrance, and a bottom-hinged tidal gate in the middle.[55]

Location: (**a**) Ventura Harbor
(**b**) Channel Islands Harbor
(**c**) Port Hueneme Harbor

[55] For example, An Obermeyer-type barrier with inflatable gates was suggested for Newport Beach: http://www.newportbeachca.gov/Modules/ShowDocument.aspx?documentid=15057.

EBA-TB2: Construction of a tide gate near the western arm of Mugu Lagoon.

EBA-LV1: Ring levee and armoring around power plants. The ring levees are assumed to be constructed with clay and protected with geotechnical membranes. Armoring (e.g. revetment would be included along the shore-facing side of the power plants to protect levee from erosion).

Location: (**a**) Mandalay Power Plant

(**b**) Ormond Beach Generating Station (in tandem with **EBA-EL1a**)

EBA-LV2: Construction of a **new** levee. The levee construction cost assumes hauling, filling, and compaction from a locally available sediment source.

Location: (**a**) Around NBVC to protect runways and facilities. NBVC would only flood under some SLR flood hazard scenarios, and sometimes not until year 2100.

(**b**) Along the inland edge of the Ormond Beach Wetland Restoration (**EBA-WL1**)

EBA-LV3: Strengthen/raise existing levee along Calleguas Creek between HWY1 and Hueneme Road. This is the EBA alternative to **NBA-MR9**, which involves lowering the levees and creating riparian habitat along the sides of Calleguas Creek.

B.1.7 Additional Elements

EBA-EL1: Raise roads to remove from hazard zones. Roads would be raised to remove them from regular tidal inundation or also during coastal storms if the access way is required during an emergency.

Location: (**a**) Access road to Ormond Beach Generating Station

EBA-WL1: Small scale restoration of Ormond Beach (Alternative 3C: Enhance existing non-tidal wetlands (constrained)) along TNC and Coastal Conservancy properties. Even the small-scale restoration (e.g. alt 3c) would still enable some habitat migration to occur.

- Figure 1. Tiles for Adaptation Strategy Maps
- Figure 2. Nature Based Adaptation Maps
- Figure 3. Engineering Based Adaptation Maps
- Table 1. Lengths and Areas of Nature Based Adaptation Components
- Table 2. Lengths and Areas of Engineering Based Adaptation Components

Appendix C

Sea Level Affecting Marshes Model (SLAMM)

Appendix D

Beach Width Analysis

Appendix E

Brief Annotated Bibliography of Literature Related to Costs and Benefits of Climate Change Adaptation

Brief Annotated Bibliography of Literature Related to the Costs and Benefits of Adaptation

This section summarizes some of the research and guidance that has been developed describing how benefits and costs of climate change, and climate change adaptation have been evaluated. This review covers the impacts of SLR, potential adaptation costs, and models that are already in place to facilitate quantification of economic impacts.

Nicholls et al. (2007) Coastal Systems and Low-lying Areas. Climate Change 2007: Impacts, Adaptation and Vulnerability

This is one chapter (Chapter 6) of a larger global study by the Intergovernmental Panel on Climate Change (IPCC); "IPCC Fourth Assessment Report (AR4), Climate Change 2007: Impacts, Adaptation and Vulnerability." In addition to presenting tools for assessing types of adaptation, it presents the costs of adaptation, covering the range from specific interventions to global aggregations, based on available literature on the topic. Selected comparative costs of coastal adaptation measures are presented in Table 6.11 of the report. The authors observe that financial cost is not the only criterion on which adaptation should be judged – local conditions and circumstances might result in a more expensive option being favored, especially where multiple benefits result.

UNFCC (2009) United Nations Framework Convention on Climate Change: Potential Costa and Benefits of Adaption Options: A Review of Existing Literature

This study provides an assessment of literature on costs and benefits of adaptation. Three aggregation levels were assessed: global studies, national studies, and a brief selection of local studies. It assesses the approaches and methods used, their applications and outputs, and their strengths and weaknesses. Where possible, it also compares the studies. The paper investigates the costs of adaptation, defined as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs." It also investigates the benefits of adaptation, defined as "the avoided damage costs or the accrued benefits following the implementation of adaptation measures." For both of these aspects, this paper considers the economic costs and benefits of adaptation, considering the wider costs and benefits to society as a whole, rather than financial ones alone. The document provides a synthesis of global-, national-, and local-level studies in tabular forms (for example, Table 11). The authors observe that there is a continued lack of detailed analyses of the costs and benefits of adaptation, including in a form that is relevant to decisions on public funding.

Nicholls (2003) Case Study on Sea Level Rise Impacts

This work examines the potential impacts of human-induced sea-level rise in the context of the evolving coastal system, rather than simply imposing sea-level rise on today's coastal zone and its activities. The observed and likely changes in sea level are considered over the 20th and 21st Century and beyond to illustrate the long time scales associated with this issue. The paper includes a consideration of the effects of mitigation on sea-level rise. The paper also presents and discusses an appropriate conceptual framework for considering the impacts of sea-level rise. Further, the paper reviews the impacts of sea-level rise, including the potential for adaptation. The potential costs of adaptation/protection based on country studies (including the

US) and costs associated with sea-level rise in the US based on various studies are presented in Tables 2 and 3, respectively, in Chapter 4. Further discussion on adaptation is provided in Chapter 5.

Watkiss et al (2010) The Costs and Benefits of Adaptation in Europe: Review Summary and Synthesis

This policy brief summarizes the review and synthesis work on the costs and benefits of adaptation to climate change in Europe. The review covers about 50 European, sectorial, regional, and national studies, as well as global studies that report information for Europe. Among other findings, the authors observe that the coverage of the adaptation cost estimates is limited, though the evidence base in now growing (though it is primarily in the gray literature). The briefing reports the estimates for adaptation costs from the various studies, and also provides examples of different decision support tools in adaptation in Europe.

Cooley et al. (2012) Social Vulnerability to Climate Change in California

This work presents the development of a new climate vulnerability index to indicate the social vulnerability of a region's population to climate-related harm. The index combines 19 indicators into one overall climate vulnerability score and includes factors specifically related to climate impacts, such as air conditioner ownership, childhood obesity, and percentage of tree cover, pre-term births, workers in outdoor occupations, and others.

Cayan et al. (2012) Climate Change Scenarios and SLR Estimates for California 2008 Climate Change Scenarios Assessment

This analysis provides an evaluation of physical elements of climate change and SLR that are contained in the California Climate Change Vulnerability and Adaptation Assessment. Section 6 in particular discusses sea-level rise.

Garzon et al. (2012) Community Based Climate Action Planning: A Case Study of Oakland California.

The authors provides a detailed analysis of climate impacts, vulnerabilities, and adaptation options in Oakland, California. The goal of this study was to inform the development of a comprehensive and equitable climate adaptation plan effort. This research project engaged active members of the Oakland Climate Action Coalition, including community-based organizations and resident leaders, in analyzing both the impacts of, and social vulnerabilities to, climate change. Further, adaptation strategies that can be implemented at the local level, and their advantages and disadvantages are discussed. It also identifies social equity concerns. Finally, it identifies trends and best practices in climate adaptation planning processes.

Grannis (2011) Threat of Seal Level Rise Costs and Benefits of Adaptation in European Coastal Countries.

This work is geared towards local and state governments and their citizens and provides them with practical knowledge to help adapt to sea-level rise. The Tool Kit offers a menu of generally used legal devices that can reduce future effects.

Perez (2009) Potential Impacts of Climate Change on California's Energy Infrastructures and Identification of Adaptation Measures

This work presents a brief discussion about potential impacts to California's energy infrastructure and concludes with the identification of adaptation or coping strategies that the State could implement in the near future.

Appendix F

Extrapolation of SLAMM Results

Appendix G

Elements of Adaptation Costs

Appendix A

Current Conditions in Ventura County

A. Current Conditions in Ventura County

This Chapter outlines the current conditions in the area of analysis. It provides a brief overview of the location of the study area, coastal Ventura County. This is followed by summarized socioeconomic profile of the area.

A.1 Location and Geographic Features

Ventura County is located in the southern part of California on California's Pacific coast. It is part of the Greater Los Angeles Area. The County's diverse geography ranges from rugged mountain terrain to coastal plains. The County's ten cities lie in the southern portion of the County. The major cities in coastal Ventura County are Oxnard, Port Hueneme, and Ventura (San Buenaventura). The County has a total area of 2,208.20 square miles, of which 1,845.30 square miles (or 83.6 percent) is land and 362.90 square miles (or 16.4 percent) is water.

Ventura County has many natural assets that are valuable to Southern California. These assets include: Ventura River, Santa Clara River, and Ormond Beach. The Ventura River is the only major watershed in Southern California that does not rely on imported water.[40] Climate change and land use changes could impact this water supply and the communities that depend on water from this source. Preserving the watershed and areas to the north intact as 'green capital' allows the watershed to function naturally and can prove to sustain valuable water sources that are continuously growing scarce in California. Similarly, the Santa Clara River is the one of the largest natural river remaining in Southern California stretching from its headwaters in Mountains until it meets the Pacific Ocean. The Ormond Beach region is considered by wetland experts to be the most important wetland restoration opportunity in southern California. The ongoing restoration of the Ormond Beach wetlands and associated habitat is capable of creating a self-sustaining biological system that can be the largest coastal wetland in Southern California.[41] The location of Ventura County, the major cities within the County, and the natural amenities provided in the county are conveniently viewed in an online mapping tool for coastal resilience provided by TNC.[42]

A.2 Socioeconomic Profile

This section describes the existing socioeconomic environment in the cities of Oxnard, Port Hueneme, and Ventura (San Buenaventura), Ventura County, the State of California, and the U.S. The section is organized into three main components: (1) population trends and projections; (2) income-related measures of social well-being; and (3) discussion of cities and county. The focus of this section is on those socioeconomic parameters most likely to be affected by SLR. These key parameters include demographic characteristics of local residents, and employment and income levels in the cities and county. The data used for the economic

[40] Gardner, R. N. Iqbal, A. Love, B. Ponton, J. Sahl, D. Yocum. 2012. Sustainable Water Use in the Ventura River Watershed. Bren School of Environmental Science and Management. Available online at: http://venturariver.weebly.com/uploads/1/5/9/2/15923202/ventura_river_group_project_proposal_2012.pdf

[41] State of California. Coastal Conservancy. Ormond Beach Wetlands Restoration Project. Available online at: http://scc.ca.gov/2010/01/07/ormond-beach-wetlands-restoration-project/

[42] The mapping tool shows forecasted future storm surges, wave action, and erosion from present conditions through the year 2100. These geographic features may be viewed at: http://maps.coastalresilience.org/ventura/#

and socioeconomic analyses are the most recent available or published data from reliable sources. All efforts are made to ensure that these data are updated to their latest release year.

A.3 Population Trends and Projections

The total population of the County is 823,318 based on the 2010 Census. This number represents a 9.3 percent increase over the County's 2000 population, which is a faster growth rate than either Los Angeles County or Orange County during the same period.

The cities of Oxnard, Port Hueneme, and Ventura (San Buenaventura) together account for about 40 percent of the total population of Ventura County, while Ventura County makes up a little over two percent of the population of the State of California. The City of Oxnard is the most populous city in the county, with a population of 197,899 in 2010.[43] The 2010 population for Ventura County was 823,318, while populations for the cities of Port Hueneme and Ventura were 21,723 and 106,433 individuals, respectively.[44]

As shown in Table A-1, each city and the county experienced growth between 1990 and 2010. The largest rate of population growth in the cities analyzed was in the City of Oxnard, which grew at a rate of over 16 percent between 2000 and 2010, and by more than 39 percent between 1990 and 2009. The other two cities experienced slower, but still some population growth between 1990 and 2010. However, while population in the City of Port Hueneme did increase by about seven percent between 1990 and 2010, it actually had negative population growth between 2000 and 2010. The population of Ventura County grew by over 23 percent between 1990 and 2010.[45]

The population in Ventura County is aging because the potential for economic growth is less, leading to less people moving in and younger people moving out. The economy of the County is also dependent on the economies of Santa Barbara and Los Angeles counties because there is a big part of the population that lives in Ventura County, but commutes to these two counties for work because it is more affordable and these people can enjoy a better lifestyle. The economic downturn in Santa Barbara and Los Angeles counties has, in turn, affected the economy and population growth in Ventura County.

---

[43] United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

[44] United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

[45] United States Census Bureau, American Fact Finder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

United States Census Bureau, Census 2000 Gateway. Website (http://www.census.gov/main/www/cen2000.html) accessed August 20, 2013.

United States Census Bureau, 1990 Census of Population and Housing. Website (http://censtats.census.gov/cgi-bin/pl94/pl94data.pl) accessed August 20, 2013.

Table A-1: Population and Population Growth

Area	Population			Population Growth		
	1990	2000	2010	1990-2000	2000-2010	1990-2010
City of Oxnard	142,216	170,358	197,899	19.8%	16.2%	39.2%
City of Port Hueneme	20,319	21,845	21,723	7.5%	-0.6%	6.9%
City of Ventura (San Buenaventura)	92,575	100,916	106,433	9.0%	5.5%	15.0%
Ventura County	669,016	753,197	823,318	12.6%	9.3%	23.1%
California	29,760,021	33,871,648	37,253,956	13.8%	10.0%	25.2%
United States	248,709,873	281,421,906	308,745,538	13.2%	9.7%	24.1%

Sources:
United States Census Bureau, American Fact Finder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

United States Census Bureau, Census 2000 Gateway. Website (http://www.census.gov/main/www/cen2000.html) accessed August 20, 2013.

United States Census Bureau, 1990 Census of Population and Housing. Website (http://censtats.census.gov/cgi-bin/pl94/pl94data.pl) accessed August 20, 2013.

Population projections through 2040 for the three cities and the State of California are shown in Table A-2. It is projected that the population in Oxnard will continue to increase, with a rate of growth of 9.8 percent between 2010 and 2020. Beyond 2020, this population is expected to increase by 11.3 percent between 2020 and 2040, and by 22.2 percent between 2010 and 2040. The population in Port Hueneme is expected to increase by 10.1 percent from 2010 to 2040. At 24.8 percent, the City of Ventura is projected to have the highest growth rate among the three coastal cities between 2010 and 2040. Overall for Ventura County, the population growth rate between 2010 and 2040 is projected at 16.7 percent, which is much lower than that for the State of California for the same period (28 percent).

Table A-2: Population Projections* (2010-2040)

Area	Population			Population Growth		
	2010	2020	2040	2010-2020	2020-2040	2010-2040
City of Oxnard	197,899	217,293	241,834	9.8%	11.3%	22.2%
City of Port Hueneme	21,723	21,313	23,920	-1.9%*	12.2%	10.1%
City of Ventura (San Buenaventura)	106,433	112,913	132,783	6.1%	17.6%	24.8%
Ventura County	823,318	867,535	960,528	5.4%	10.7%	16.7%
California	37,253,956	40,643,643	47,690,186	9.1%	17.3%	28.0%

Note:

* Projections for Ventura County and the State of California are available through DoF 2013. The most reliable projections for the cities are available in VCOG 2008. However, the VCOG projections are older and based on the 2000 Census populations. These were updated for each city by adjusting the total county projection to the 2013 DoF projection and parsing out the cities based on the share of the county population in the VCOG projection. This approach may have resulted in some discrepancies, such as a negative growth rate for City of Port Hueneme between 2010 and 2020.

Sources:

United States Census Bureau, American FactFinder. Website (http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml###) accessed August 20, 2013.

California Department of Finance (DoF), Demographic Research Unit. January 31, 2013. Report P-1 (County) - State and County Population Projections - July 1, 2010-2060 (5-year increments). Available at (http://www.dof.ca.gov/research/demographic/reports/projections/) accessed August 27, 2013.

Ventura Council of Governments (VCOG). May 2008. 2040 Population Forecast - Ventura Cities and County. Available at (http://www.ventura.org/rma/planning/pdf/demograghics/2040_revised_Decapolis%205_23_08_Final.pdf) accessed August 27, 2013.

A.4 Income-related Measures of Social Well-Being

As derivatives of total personal income, per capita and median household income, poverty rates, and unemployment rates represent widely used economic indicators of social well-being. Table A-3 presents these socioeconomic data for the three coastal cities, Ventura County, the State of California, and the U.S. In 2011, per capita income in Ventura County was $32,740, exceeding the Statewide level of $29,634. At $31,775, per capita income in the City of Ventura also exceeded the Statewide average. Conversely, per capita incomes in the cities of Oxnard and Port Hueneme were 69.6 percent and 78.9 percent of the Statewide average, respectively.

Median household incomes for the County and cities of Oxnard and Ventura all exceeded the Statewide average in 2011. Only the median household income in Port Hueneme was less than that Statewide average. The median household income in Ventura County was $76,728 in 2011, while that in the cities of Oxnard, Port Hueneme, and Ventura were $60,191, $52,244, and $66,226, respectively.

A third indicator, poverty rate, represents the percentage of an area’s total population living at or below the poverty threshold established by the U.S. Census Bureau. Based on available data for 2011, the poverty rate was 9.9 percent in Ventura County, 15.3 percent in Oxnard, 15.1

percent in Port Hueneme, and 10.5 percent in Ventura. The poverty rate at the State level (14.4 percent) exceeded that for Ventura County and the City of Ventura.

Finally, the unemployment rate represents the percentage of the labor force that is unemployed and is actively seeking employment. In July 2013, Ventura County experienced an unemployment rate (8.0 percent), below the statewide level (8.7 percent). The City of Ventura had an even lower unemployment rate of 7.2 percent. However, the unemployment rate for both the City of Oxnard (10.9 percent) and the City of Port Hueneme (9.4 percent) exceeded the statewide level.

Table A-3: Income, Poverty Rates, and Unemployment Rates

Area	Per Capita Income (2011)	Median Household Income (2011)	Poverty Rate (2011)	Unemployment Rate (July 2013)
City of Oxnard	$20,612	$60,191	15.3%	10.9%
City of Port Hueneme	$23,391	$52,244	15.1%	9.4%
City of Ventura (San Buenaventura)	$31,775	$66,226	10.5%	7.2%
Ventura County	$32,740	$76,728	9.9%	8.0%
California	$29,634	$61,632	14.4%	8.7%
United States	$27,915	$52,762	14.3%	7.4%

Some recent trends and factors affecting the economy of Ventura County are discussed below:

1. The County's median age is 36.2, and nearly half of the population is either under the age of 20 or over the age of 60. This is a key observation for the future of Ventura County.
2. The economy of Ventura County is dependent on the economies of Santa Barbara and Los Angeles counties because of the large proportion of the population that lives in Ventura County, but commutes to these two counties for work because it is more affordable and these dwellers can enjoy a better lifestyle. Due to the economic downturn in these two counties, the economy of Ventura County saw its share of the effects.
3. Based on employment numbers, hospitality and leisure is a major part of the economy of Ventura County (after government and retail). While tourism did get a big hit during the recession, it is recovering now.
4. Generally, the higher income people are still there, but populations of working age and low-income people are shrinking.
5. It did not get hit by the housing bubble too much because there was not much excess housing inventory.
6. While coastal areas tend to do better than the State in terms of job growth in CA, job growth in Ventura County has been surprisingly volatile.

A.5 Cities within the Study Region

This section presents brief discussions of the main cities in coastal Ventura County. In addition to the Naval Base Ventura County (NBVC), which supports significant employment and community as an incorporated city does, the cities of Oxnard, Ventura, and Port Hueneme fall within the study area.

A.5.1 City of Oxnard

The City of Oxnard is Ventura County's largest city, and is located in Western Ventura county midway between Santa Barbara and Los Angeles. Oxnard is situated within easy driving distance of virtually every major visitor attraction in the region. Oxnard combines the sophistication of a modern big city with the easy-going charm of a scenic beach town. Oxnard can boast about many things including, a wonderful climate, great restaurants, beaches, and diverse multicultural population in an ever-evolving community.

Top Employers (2010)

- St. John's Regional Medical Center-Medical (1,393)
- Haas Automation-Engineering (1,200)
- City of Oxnard-Government (1,122)
- Verizon-Communications (860)
- Waterway Plastics Inc-Plastic (700)
- Procter & Gamble-Paper Products Manufacturing (650)
- Boskovich Farms-Produce (600)
- Sysco Food Services of Ventura-Food (500)
- Workrite Uniform Co Inc-Clothing (405)
- Gills Onions-Produce (400)

A.5.2 City of Port Hueneme

The City of Port Hueneme is a small coastal city located 60 miles northwest of Los Angeles and 40 miles south of Santa Barbara. It is generally bounded by Naval Base Ventura County on the west, the City of Oxnard to the north and east, and the Pacific Ocean to the south. The City is nearly completely built-out with approximately one acre of vacant residential land and five acres of vacant commercial land remaining.

Its desirable beach-style living and plentiful business opportunities delight every native and newcomer. Residents and visitors enjoy strolling along the 50-acre Hueneme Beach Park, and businesses benefit from the city being home to the largest commercial deepwater harbor between Los Angeles and San Francisco. Port Hueneme is also home to one of Naval Base Ventura County's three operating facilities. Residents consistently cite the high quality of life offered due to planned development, excellent public facilities and responsive city services as being primary reasons for choosing to live in the city.

Top Employers

- Naval Base Ventura County-Military (15,000)
- Hueneme School District-Public Education (790)
- Pacific Maritime Association-Industry Association (500)
- Pac Foundries-Steel and Aluminum Castings (330)
- City of Port Hueneme-Government (125)

A.5.3 City of Ventura

Ventura is a classic Southern California beach town situated between the Ventura and Santa Clara rivers. Founded as one of nine original California missions, Ventura has miles of uncrowded beaches and bikeways, a commercial harbor that gateways to the Channel Islands National Park, a thriving cultural district and it is evolving as a Smart Growth leader. Ventura is ideally located for businesses involved in domestic and international trade. And, with a new high-tech business incubator, growing a business is easy in Ventura. The City of Ventura is generally built-out along the coast with a few vacant parcels remaining in play.

Top Employers

- County of Ventura-Public Sector (7,191)
- Vons-Grocery (2,406)
- Ventura Unified School District-Public Education (2,340)
- Ventura County Health Care Agency-Health Care (1,877)
- Ventura County Community College District-Public Education (1,877)
- Community Memorial Hospital-Health Care (1,725)
- City of Ventura-Government (1,065)

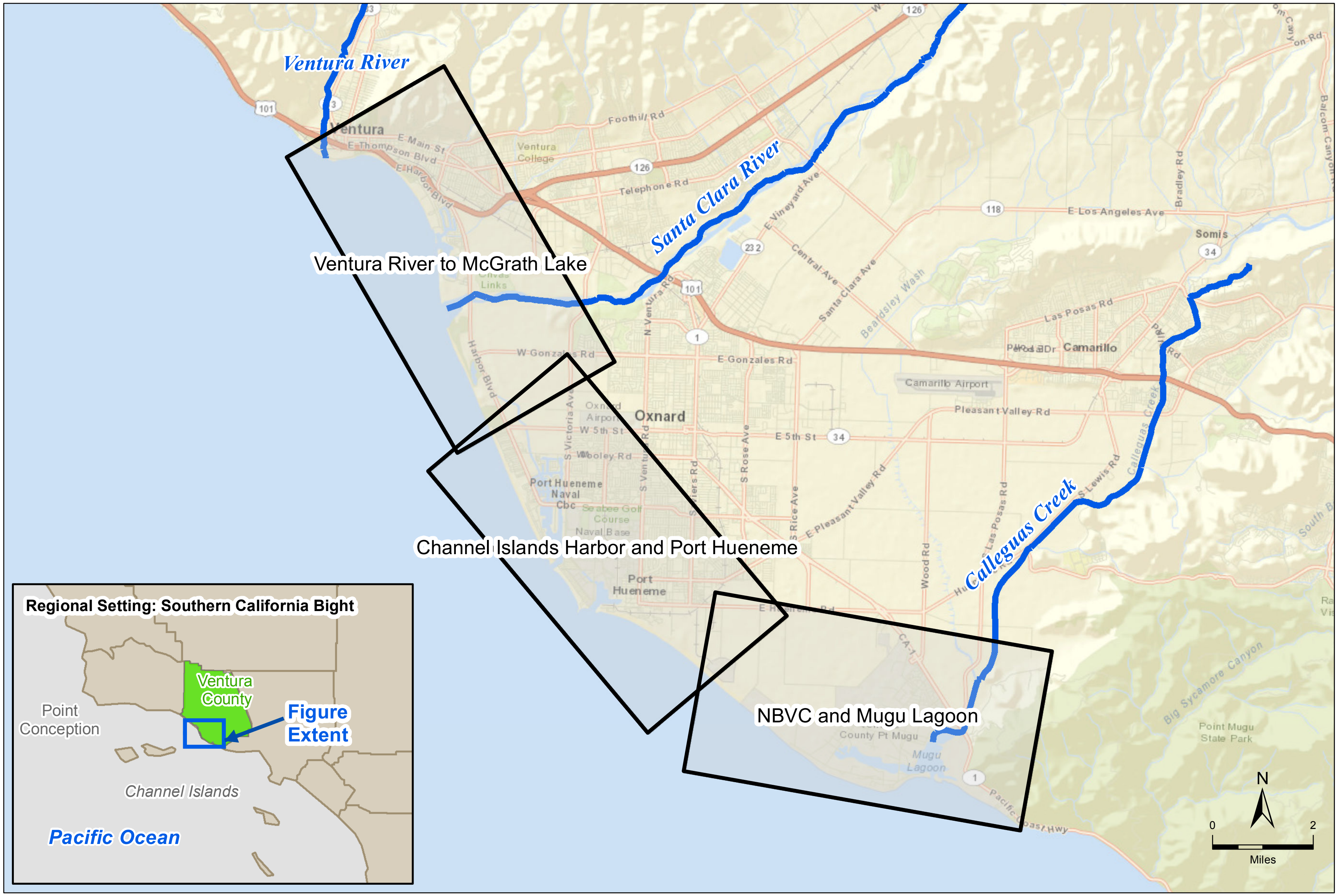
A.6 Naval Base Ventura County (NBVC)

The Naval Base Ventura County (NVBC) supports more than 80 tenant commands with a base population of more than 19,000 personnel, making it the largest employer in Ventura County.[46] NVBC is composed of three sites, Port Hueneme, Point Mugu, and San Nicolas Island. The facilities are key elements in the Department of Defense (DOD) infrastructure. On-base housing is available at Point Mugu and Port Hueneme. An additional military housing complex is located in the city of Camarillo which is approximately a 20 minute drive from Mugu and 25 minutes from Port Hueneme. Unaccompanied Housing (formerly Bachelor Housing - BH) is conveniently located on Point Mugu and Port Hueneme. UH houses approximately 1,900 service members in 23 buildings.[47]

[46] (http://www.cnic.navy.mil/regions/cnrsw/installations/navbase_ventura_county.html)
[47] (http://navylifesw.com/ventura/housing/unaccompanied/)

Appendix B

Figures for Hazard Modeling



Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure X
Tiles for Adaptation Strategy Maps

Path: G:\Projects\130257_VenturaTNC_Adapt\MXDs\Figures\T1_ScenarioShapefiles.mxd, 6/9/2014

Figure 2a
Nature Based Adaptation (Ventura River to McGrath Lake)

Path: G:\Projects\130257_VenturaTNC_Adapt\MXDs\Figures\T1_ScenarioShapefiles.mxd, 6/9/2014

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 2b

Nature Based Adaptation (Channel Islands Harbor and Port Hueneme)

Path: G:\Projects\130257_VenturaTNC_Adapt\MXDs\Figures\T1_ScenarioShapefiles.mxd, 6/9/2014

Figure 2c
Nature Based Adaptation (NBVC and Mugu Lagoon)

Path: S:\GIS\Projects\130257_VenturaTNC_Adapt\MXDs\Working\T1_ScenarioShapefiles_v2.mxd, 4/10/2014

SOURCE: Air Photo from NAIP 2012

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 3a

Engineering Based Adaptation (Ventura River to McGrath Lake)

Path: S:\GIS\Projects\130257_VenturaTNC_Adapt\MXDs\Working\T1_ScenarioShapefiles_v2.mxd, 4/10/2014

SOURCE: Air Photo from NAIP 2012

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 3b

Engineering Based Adaptation (Channel Islands Harbor and Port Hueneme)

Path: S:\GIS\Projects\130257_VenturaTNC_Adapt\MXDs\Working\T1_ScenarioShapefiles_v2.mxd, 4/10/2014

SOURCE: Air Photo from NAIP 2012

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 3c

Engineering Based Adaptation (NBVC and Mugu Lagoon)

Table 6. Lengths and Areas of Nature Based Adaptation Components (6/9/2014, Subject to Revision)

Shape	Code	Category	Description (brief)	Description (longer)	Area (acres)	Length (ft)
Polyline	NBA-AR1a	Elevate Bulkhead	Elevate bulkheads at Ventura Harbor		--	30,834
Polyline	NBA-AR1b	Elevate Bulkhead	Elevate bulkheads at Channel Islands Harbor		--	54,547
Polyline	NBA-AR1c	Elevate Bulkhead	Elevate bulkheads at Port Hueneme Harbor		--	15,549
Polyline	NBA-AR2a	Reinforce Seawall and/or Revetment	Reinforce Seawall and/or Revetment		--	1,754
Polyline	NBA-AR2b	Reinforce Seawall and/or Revetment	Reinforce Seawall and/or Revetment	Port Hueneme to Market St	--	3,606
Polygon	NBA-BD1	Beach and Dune Restoration	Nourish with cobbles and backbeach dunes	From the Ventura River levee to the Ventura Pier.	17	--
Polygon	NBA-BD2a	Beach and Dune Restoration	Dune enhancement activities		84	--
Polygon	NBA-BD2b	Beach and Dune Restoration	Dune restoration/maintenance	Between Port Hueneme and Ormond Beach Lagoon	45	--
Polygon	NBA-BD2c	Beach and Dune Restoration	Dune restoration/maintenance	Along Oxnard Shores	170	
Polygon	NBA-BD2d	Beach and Dune Restoration	Dune restoration/maintenance	In front of Port Hueneme	42	
Polygon	NBA-EL1a	Elevate Roads	Elevate East Harbor Blvd	At San Buenaventura State Beach	1.4	--
Polygon	NBA-EL2a	Elevate Harbor Neighborhoods	In Ventura Harbor		147	--
Polygon	NBA-EL2b	Elevate Harbor Neighborhoods	In Channel Islands Harbor		365	--
Polyline	NBA-LV1	Construct Levee	Ring levee surrounding airfield at NBVC		--	44,779
Polyline	NBA-LV2	Construct Levee	Along north side of OB wetland restoration		--	8,883
Polygon	NBA-MR1a	Managed Retreat	Removal of parking lot and revetment	Consistent with Surfer's Point Phase II	1.9	--
Polygon	NBA-MR1b	Managed Retreat	Between the round-about and Promenade Park		3.3	--
Polygon	NBA-MR2	Managed Retreat	Removal of roads/parking lot, dune restoration	Consistent with the Ventura Beach+Town Project	2.5	--
Polygon	NBA-MR3	Managed Retreat	Relocation of Ventura Water Reclamation Facility		65	--
Polygon	NBA-MR4a	Managed Retreat	Existing McGrath State Beach Park	Starting Location. To east of Harbor Boulevard	58	--
Polygon	NBA-MR4b	Managed Retreat	Relocated McGrath State Beach Park	Ending Location. Very approximate.	49	--
Polygon	NBA-MR5	Managed Retreat	Decommission Mandalay Generating Station	Current Location	44	--
Polygon	NBA-MR6	Managed Retreat	Removal of Halaco Superfund site		25	--
Polygon	NBA-MR7	Managed Retreat	Decomission Ormond Beach Generating Station	Current Location	50	--
Polygon	NBA-MR8	Managed Retreat	Decommission of roads and NBVC infrastructure		53	--
Polygon	NBA-MR9	Managed Retreat	Remove revetment fronting the NBVC runway		2.4	--
Polygon	NBA-MR10	Managed Retreat	Removal of revetment and all infrastructure		196	--
Polyline	NBA-MR11	Lower Levee	Lower levee		--	11,543
Polygon	NBA-MR12a	Managed Retreat	Managed retreat with erosion through time		10	--
Polygon	NBA-MR12b	Managed Retreat	Managed retreat at San Buenaventura State Beach		5.2	--
Polygon	NBA-WL1	Wetland Restoration	Ormond Beach wetland restoration, Alt 2U		1,120	--
Polygon	NBA-WL2a	Wetland Restoration	Duck ponds to tidal wetlands/OB Rest Alt 2U		568	--
Polygon	NBA-WL2b	Wetland Restoration	Duck ponds to tidal wetlands		229	--
Polygon	NBA-WL3a	Wetland Restoration	Agricultural lands convert as wetlands transgress		1,403	--
Polygon	NBA-WL3b	Wetland Restoration	Agricultural lands convert as wetlands transgress		490	--
Polygon	NBA-WL5	Wetland Restoration	Floodplain/wetland restoration	Adjacent to Revelon Slough and Calleguas Creek	60	--
Polygon	NBA-WL6	Wetland Restoration	Restore wetland and lagoon	Southern end of Sanjon Road and sliver between Hwy 101 and Alessandro Dr.	20	--

Table 7. Lengths and Areas of Engineering Based Adaptation Components (6/9/2014, Subject to Revision)

Shape	Code	Category	Description (brief)	Description (longer)	Area (acres)	Length (ft)
Polyline	EBA-AN1a	New Seawall and/or Revetment	New seawall and/or revetment	Surfer's Point	--	2,150
Polyline	EBA-AN1b	New Seawall and/or Revetment	New seawall and/or revetment	Ventura Pier to San Pedro Street	--	5,126
Polyline	EBA-AN1c	New Seawall and/or Revetment	New seawall and/or revetment	San Pedro Street to Greenock Lane in Ventura	--	5,255
Polyline	EBA-AN1d	New Seawall and/or Revetment	New seawall and/or revetment	Santa Clara River to Mandalay Generating Station	--	11,768
Polyline	EBA-AN1e	New Seawall and/or Revetment	New seawall and/or revetment	Mandalay Generating Station to Channel Islands Harbor	--	18,782
Polyline	EBA-AN1f	New Seawall and/or Revetment	New seawall and/or revetment	South Ventura Road to Ormond Beach Wetland Restoration	--	6,292
Polyline	EBA-AN1g	New Seawall and/or Revetment	New seawall and/or revetment	Ormond Beach Wetland Restoration to NBVC runway	--	8,272
Polyline	EBA-AN1h	New Seawall and/or Revetment	New seawall and/or revetment	NBVC runway to I Avenue	--	6,860
Polyline	EBA-AN1i	New Seawall and/or Revetment	New seawall and/or revetment	Inside mouth of Mugu Lagoon	--	2,746
Polyline	EBA-AN1j	New Seawall and/or Revetment	New seawall and/or revetment	East arm of Mugu - ties into existing revetment along HWY1	--	9,987
Polyline	EBA-AR1a	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	West end of Ventura Promenade to Ventura Pier	--	3,233
Polyline	EBA-AR1b	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	Greenrock Lane to Ventura Marina	--	1,682
Polyline	EBA-AR1c	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	Ventura Marina to Santa Clara River	--	3,979
Polyline	EBA-AR1d	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	Channel Islands Harbor to Port Hueneme	--	6,920
Polyline	EBA-AR1e	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	Port Hueneme to S Ventura Road	--	5,022
Polyline	EBA-AR1f	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	NBVC runway	--	2,227
Polyline	EBA-AR1g	Reinforce Seawall and/or Revetment	Reinforce seawall and/or revetment	I Avenue to mouth of Mugu Lagoon	--	8,841
Polyline	EBA-EL1a	Raise Road	Raise road to Ormond Beach Generating Station		--	1,961
Polyline	EBA-LV1a	Construct Levee	Ring levee around Mandalay Power Plant		--	4,227
Polyline	EBA-LV1a	Construct Levee	Ring levee/revetment across Mandalay Power Plant		--	1,938
Polyline	EBA-LV1b	Construct Levee	Ring levee around Ormond Beach Generating Station		--	7,113
Polyline	EBA-LV2a	Construct Levee	Ring levee surrounding airfield at NBVC		--	44,779
Polyline	EBA-LV2b	Construct Levee	Levee backing the Ormond Beach Wetland Restoration		--	23,563
Polyline	EBA-LV3	Raise Levee	Raise levee along Revelon Slough		--	14,766
Polyline	EBA-TB1a	Tidal Barrier/Lock	Tidal barrier/lock at mouth of harbor	Mouth of Ventura Harbor	--	570
Polyline	EBA-TB1b	Tidal Barrier/Lock	Tidal barrier/lock at mouth of harbor	Mouth of Channel Islands Harbor	--	506
Polyline	EBA-TB1c	Tidal Barrier/Lock	Tidal barrier/lock at mouth of harbor	Mouth of Port Hueneme Harbor	--	668
Polyline	EBA-TB2	Tidal Barrier/Lock	Tidal barrier/lock across bridge at Laguna Rd	Mouth of west Mugu Lagoon	--	413
Polygon	EBA-WL1	Wetland Restoration	Ormond Beach Wetland Restoration (Alt 3C)		695	--

B. Figures for Hazard Modeling

Scenario Codes

Adaptation measures within each scenario were assigned unique identifiers (codes) based on the naming convention below to simplify cost estimating and mapping.

Prefix:

EBA – A measure that is part of the Engineering Based Adaption scenario
NBA – A measure that is part of the Nature Based Adaption scenario

Suffix:

AN – Construction of new coastal armoring (seawalls, revetments, or bulkheads[48])
AR – Reinforcement/maintenance of existing coastal armoring
BD – Measure related to beach and/or dune restoration
EL – Elevate homes and/or commercial buildings
LV – Construction of a levee
MR – Managed retreat action
TB – Construction of a tidal barrier/lock/gate
WL – Measure related to wetlands (restoration, transgression, etc.)

Numbers:

Letters (a, b, c…) reflect the same measure being implemented in different location. For example, Dune enhancement activities (NBA-BD2) are implemented in two locations, so the two regions of dune enhancement activities are labeled "NBA-BD2a" and "NBA-BD2b". If a specific activity is only implemented in once place, no letter is included in the code.

B.1 Nature Based Adaptation or NBA Scenarios

Nature based adaptation scenarios were developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. NBA options evaluated include a set of management tools including restoration of wetlands, dunes, and other natural processes, and managed retreat.

Restricting flooding in one area, does not eliminate the threat of inundation, it simply moves it. Managed retreat is the concept whereby areas that are naturally prone to flooding and were once protected with levees, barriers and other structures, are allowed to return to a state where flooding is allowed to occur. This is most often accomplished through the removal of structures and assets that require flood protection. Allowing the return to a natural process in an area where it is naturally disposed to occur, will, in principle, lessen the probability of flood damage in adjacent areas.

Areas where open land is available, and where restoration of natural functions and processes could take place, were considered most appropriate for application of "natural processes". In

[48] Bulkhead is a structural barrier that serves to protect a beach against erosion from waves and other actions. The bulkhead is usually made of wood pilings, steel sheet pile, commercially developed vinyl products, large boulders stacked to form a wall, or a seawall built of concrete or another hard substance.

areas where public infrastructure was located, managed retreat options were considered most appropriate as these tend to fall within the jurisdiction of the state, county, or city governments. In the case of private property, selected adaptation options were chosen based on the criteria that they would allow homeowners to retain their location for the present time and to the extent possible, the integrity of the oceanfront home values.

The elements of the proposed NBA scenario are presented in Figure 2a through c. It consists of beach and dune restoration projects, wetland restoration projects, managed retreat areas, and elevated neighborhoods. The relevant lengths and areas of proposed adaptation scenarios are also shown in Table .

B.1.1 Beach and Dune Restoration

NBA-BD1: Beach nourishment with cobbles and construction of back beach dunes. Beach nourishment is recognized as a natural way of preventing beach erosion and is implemented at different locations, except in the areas designated for "managed retreat" action. Nourishing beach cobbles will preserve natural beach armoring. This strategy would also include all the dune enhancement activities described in **NBA-BD2**, below.

Location: Between the Ventura River Levee and the Ventura Pier (approx. 1 mile).

NBA-BD2: Dune enhancement activities. Activities include:

- Dune augmentation (adding sand to dunes to provide protection during storm events), especially to raise low-lying beach access paths to prevent flood waters from flowing into the neighborhoods behind the dunes.
- Ceasing any activity that adversely affects the sediment supply of the dunes.
- Ceasing beach grooming. This would encourage dune vegetation establishment and dune formation. Beach grooming removes driftwood and wrack and reduces vegetative growth and dune formation.
- Planting vegetation. Planting native dune vegetation, together with wind action, will help build up and stabilize dunes.
- Fencing off sensitive areas and creating dune walkways
- Informational signs and other outreach activities to educate about the importance of maintaining stable sand dunes.

Location: (a) Ventura Pier to the Ventura Harbor.
(b) Between Port Hueneme and Ormond Beach Lagoon
(c) Mandalay Shores to Channel Islands Harbor
(d) Between Channel Islands Harbor and Port Hueneme Harbor

B.1.2 Wetlands

NBA-WL1: Restoration of Ormond Beach wetlands, just west of Naval Base Ventura County. The NBA approach would include 1190 acres of unconstrained seasonally open tidal wetlands (Alternative 2U), just west of Naval Base Ventura County.

NBA-WL2: Conversion of managed ponds to wetlands. These low lying basins are expected to be overtopped under the high SLR scenario and the abandonment (or lack of improvements) would convert this habitat from freshwater managed wetlands to salt marsh.

Location: (**a**) The southern set of ponds. This restoration is closely related to NBA-WL1 as restoration of the managed ponds has been proposed in tandem with Alternative 2U.
(**b**) The northern set of ponds.

NBA-WL3: Conversion of agricultural lands as wetlands transgress west and east of NBVC. This action assumes abandoning the existing land and purchasing the real-estate equivalent land elsewhere,[49] demolition of the existing structures, and natural transgression of wetlands in the same area (without any additional cost).

Location: (**a**) West of the NBVC runway
(**b**) East of NBVC and south of HWY 1

NBA-WL4: Improvement of tidal connectivity through Mugu Lagoon by daylighting existing culverts under roads to be abandoned (e.g. end of the NBVC runway, Laguna Rd) to improve the habitat quality and resilience to SLR throughout the marsh. This would be conducted in collaboration with **NBA-MR6**, below.

NBA-WL5: Retreat of shoreline and transgression of wetlands north of Highway 1 adjacent to Calleguas Creek. This action assumes abandoning the existing agricultural land. No structures exist in this zone.

NBA-WL6: Restore wetland and lagoon at the southern end of Sanjon Road and sliver wetland north of Hwy 101 and Alessandro Drive. Restore connectivity between the sliver wetland and the ocean by raising the road (up to 800' of road) along the back of the beach. Restoration of these wetlands would filter pollutants in flood waters. The wetlands would not act as a significant buffer against SLR, but would mitigate climate change impacts to the ecosystem service of water quality and habitat.

B.1.3 Coastal Armoring, Levees, and Tide Barriers

NBA-LV1: Construction of a ring levee surrounding the airfield at Mugu and tying into Highway 1, which is raised. This measure is considered reasonable as the Mugu airport would only flood under some SLR flood hazard scenarios, and sometimes not until year 2100. The ring levee is assumed to be constructed with clay and protected with geotechnical membranes. Existing culverts and other water conveyance structures across the levee alignment would have to be closed or modified to close during high tides.

NBA-LV2: Construction of a levee along the north side of the Ormond Beach Wetland Restoration (**NBA-WL1**).

[49] This assumes a fee simple acquisition approach as opposed to other cheaper management/land use planning tools like conservation or rolling easement

NBA-TG1: Construction of a tide gate along channel flowing through the Ormond Beach Wetland Restoration (**NBA-WL1**), near Ocean View Drive.

NBA-AR1: Reinforce and raise bulkheads around ports and harbor. Ports and harbors would not be relocated under this alternative, and preservation of bulkheads would prevent increasing water levels (both during high tides and storms) from flooding the adjacent low-lying neighborhoods.

Location: (**a**) Ventura Harbor
(**b**) Channel Islands Harbor
(**c**) Port Hueneme Harbor

NBA-AR2: Reinforcement of the **existing** revetment and/or seawall.

Location: (**a**) West side of Port Hueneme Harbor
(**b**) East side of Port Hueneme Harbor

B.1.4 Managed Retreat

NBA-MR1: Managed retreat between Surfer's Point the eastern edge of Promenade Park. Removal/realignment of existing bike path/promenade. This would be conducted in conjunction with beach and dune restoration (**NBA-BD1**).

Location: (**a**) Between Surfer's Point and the western end of the Ventura Promenade (the round-about. This section was included in the second phase of managed retreat at Surfer's Point. The first phase, which included realignment of the bike path, cobble and sand nourishment, and dune construction, was completed in 2012. The Phase II design is complete and permitted, but political issues and a lack of funding are currently preventing the project from being completed.

(**b**) Between the round-about and the eastern side of Promenade Park.

NBA-MR2: Removal of parking lot and HWY 101 on-ramps east of the Ventura Pier and south of HWY 101, replaced with back beach dunes. This is consistent with the Ventura Beach +Town Project[50]. The larger project includes capping of the existing freeway just north of the Ventura Pier and construction of a retail/business conference center with a train hub and pedestrian walkways. These additional elements (which are assumed to have no effect on the coastal hazards analysis) are not shown in the scenario figure.

NBA-MR3: Relocation of the Ventura Water Reclamation Facility (VWRF). While construction of/improvements to bulkheads around Ventura Harbor (**NBA-AR1a**) will reduce some of the flooding originating from the harbor, relocation is recommended for plant functioning. The plant relocation cost includes purchase of the land, construction, and demolition of the existing structures.

[50] http://www.cityofventura.net/page/beachtown.

NBA-MR4: Relocate McGrath State Beach Park and Campground from (**a**) its current location to (**b**) the east of Harbor Boulevard. This will maintain or improve public use, camping, and access and remove the park from the coastal flood hazard zone (but not the fluvial flood hazard zone).

NBA-MR5: Decommission the Mandalay Power Plant. This power plant, located just south of McGrath State Beach Park, would be subjected to frequent flooding even under the medium SLR scenario.

NBA-MR6: Removal of Halaco Superfund site.

NBA-MR7: Decommission of Ormond Beach Generating Station. This plant, located 900 feet from the shoreline and 7 to 9 feet above the sea level would be subjected to frequent flooding under all hazard scenarios. The plant decommission cost includes purchase of the land, and demolition of the existing structures.

NBA-MR8: Decommission roads and other remaining NBVC infrastructure outside proposed ring levee to the west of the airport runway. This would occur in tandem with **NBA-WL1**, **NBA-WL2a&b**, and **NBA-WL3a**.

NBA-MR9: Remove revetment fronting the NBVC runway and extend runway to the north, if necessary.

NBA-MR10: Relocate Electronics building and other infrastructure (including revetment) on spit at NBVC.

NBA-MR11: Lower levees along Calleguas Creek and Revelon Slough. This project would be done in conjunction with **NBA-WL5**.

NBA-MR12: Managed Retreat from selected parts of the beach, Retreat from the beach assumes abandoning existing residential structure on the beach and purchasing residential structures of a similar value (cost) outside the projected hazard zone.[51] The Managed Retreat concept is generally used to improve coastal stability, relying entirely on management of natural 'soft' coastal landforms (i.e. dune management, cobble beaches). These natural defenses protect inland areas by absorbing or reducing the force of waves. The abandoned residential or commercial areas uphill of the beach becomes the new beach with its own ecological system.

Location: **(a)** Marina Park north of the Ventura Harbor
(b) San Buenaventura State Beach

B.1.5 Elevate Beachfront Neighborhoods

NBA-EL1: Raise roads to remove from hazard zones. Roads would be raised to remove them from regular tidal inundation or also during coastal storms if the access way is required during an emergency.

[51] This assumes a fee simple acquisition approach as opposed to other cheaper management/land use planning tools like conservation or rolling easements

Location: (**a**) Beach frontage road (East Harbor Blvd) behind San Buenaventura State Beach
(**b**) Access roads to NBVC

NBA-EL2: Raise selected residential houses and commercial buildings to elevations comparable to those at Mandalay Shores (7 to 10 m NAVD or 23 – 33 ft. NAVD). Elevating private residences or commercial infrastructure assumes re-construction of buildings on either piles or piers (costs for elevating residences are obtained from similar structures raised and/or reconstructed following Hurricane Sandy).

Location: (**a**) In the canals in Ventura Harbor
(**b**) In the canals in Channel Islands Harbor

B.1.6 Coastal Armoring Adaptation (CAA) Scenario*[52]

An engineering based adaptation scenario was developed based on feasible engineering options, stakeholder comments/suggestions, and overall options that were considered realistic in terms of implementation and relative public acceptance. The CAA options included a set of management tools that focused on protection through construction of sea walls, levees, and other armoring. The overall goal of the engineered based scenario was to protect built property and infrastructure as they currently exist in Ventura County. The EBA elements are shown in Figure 3 and summarized below, with the relevant lengths and areas reported in Table 2 (attached).

The EBA approach includes coastal armoring along most of the study area between the Ventura River and Point Mugu. Revetments and/or seawalls would be reinforced or placed along the backshore toe of the existing shoreline to protect it against erosion. The armoring options below are separated into “reinforce existing” or “construct new” armoring, based on an existing geospatial coastal armoring inventory.[53] Revetment[54] is an accepted shoreline protection method as long as it is designed to sustain impact from wave and floodwaters without erosion and without jeopardizing its structural integrity. Three common types of revetments/seawalls are considered in this analysis:

1. Rubble-mound revetment: Boulders and rocks placed atop the shoreline. Revetment cost assumes a density of 3 tons of rock per one linear foot of the revetment.
2. H-soldier (steel or timber) piles filled with concrete (panels).

[52] For the remainder of this document, the CAA scenario is referred to as the “EBA” for Engineering-Based Adaptation. The EBA language has been maintained here to provide consistency with the figures showing the adaptation strategies.

[53] In 2005, NOAA Coastal Service Center Fellow Jennifer Dare developed a statewide coastal armoring GIS database for the CCC by using a combination of oblique aerial images from the California Coastal Records Photo website (www.californiacoastline.org) and georeferenced orthoimages to identify and locate shoreline protective structures (seawalls, revetments, etc.) along the entire California coast. This database represents structure extents along a single California shoreline. This dataset was used to identify study blocks backed by at least 50% shoreline armoring. Stretches of coast characterized by sporadically-spaced private structures are designated as “construct new seawall/revetment”.

[54] Revetment is a coastal structure made of large rock armorstone placed on a slope (typically 2:1) over the bank or cliff to absorb the energy from waves and floodwaters. River or coastal revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion. Revetments typically do not stop flooding.

3. Steel sheet pile bulkhead (a continuous steel seawall structure).

Escalating maintenance costs were assessed by increasing levels of wave attack on the structure as the beach width was lost. Shoreline armoring is known to result in a long term narrowing of the beach in front of these structures (i.e. passive erosion). Additionally, some beach is lost to the footprint of the structure (i.e. placement loss). Both passive erosion and placement loss were evaluated in the beach width analysis.

EBA-AR1: Reinforcement of the **existing** revetment and/or seawall.

Location: (**a**) West end of the Ventura Promenade to the Ventura Pier
(**b**) Greenock Lane to Ventura Marina
(**c**) Ventura Marina to Santa Clara River Mouth (includes maintaining existing VWRF)
(**d**) Channel Islands Harbor to Port Hueneme
(**e**) Port Hueneme to South Ventura Road
(**f**) NBVC runway (waterproof)
(**g**) I Avenue to mouth of Mugu Lagoon (waterproof)

EBA-AN1: Construction of a **new** revetment and/or seawall along the backshore toe of the existing shoreline. These new sections of revetments would result in a continuous structure (including along public parks) to avoid erosion and flooding through gaps. The continuity is important, and if properly designed, would provide uniform protection to the land behind the revetment, without any adjacent erosion.

Location: (**a**) Surfer's Point (Ventura River Levee to round-about)
(**b**) Ventura Pier to San Pedro Street
(**c**) San Pedro Street to Greenock Lane in Ventura
(**d**) Santa Clara River Mouth to Mandalay Generating Station (includes maintaining McGrath State Beach Park in existing location)
(**e**) Mandalay Generating Station to Channel Islands Harbor
(**f**) South Ventura Road to Ormond Beach Wetland Restoration
(**g**) Ormond Beach Wetland Restoration to NBVC runway (waterproof)
(**h**) NBVC runway to I Avenue (waterproof)
(**i**) Inside mouth of Mugu Lagoon (waterproof)
(**j**) East arm of Mugu Lagoon (tie into existing revetment along HWY 1) (waterproof)

EBA-TB1: Construction of tidal barrier/lock system at the mouth of the harbors. The barrier would consist of symmetrically placed floodwalls on each side of the harbor entrance, and a bottom-hinged tidal gate in the middle.[55]

Location: (**a**) Ventura Harbor
(**b**) Channel Islands Harbor
(**c**) Port Hueneme Harbor

[55] For example, An Obermeyer-type barrier with inflatable gates was suggested for Newport Beach: http://www.newportbeachca.gov/Modules/ShowDocument.aspx?documentid=15057.

EBA-TB2: Construction of a tide gate near the western arm of Mugu Lagoon.

EBA-LV1: Ring levee and armoring around power plants. The ring levees are assumed to be constructed with clay and protected with geotechnical membranes. Armoring (e.g. revetment would be included along the shore-facing side of the power plants to protect levee from erosion).

Location: (**a**) Mandalay Power Plant

(**b**) Ormond Beach Generating Station (in tandem with **EBA-EL1a**)

EBA-LV2: Construction of a **new** levee. The levee construction cost assumes hauling, filling, and compaction from a locally available sediment source.

Location: (**a**) Around NBVC to protect runways and facilities. NBVC would only flood under some SLR flood hazard scenarios, and sometimes not until year 2100.

(**b**) Along the inland edge of the Ormond Beach Wetland Restoration (**EBA-WL1**)

EBA-LV3: Strengthen/raise existing levee along Calleguas Creek between HWY1 and Hueneme Road. This is the EBA alternative to **NBA-MR9**, which involves lowering the levees and creating riparian habitat along the sides of Calleguas Creek.

B.1.7 Additional Elements

EBA-EL1: Raise roads to remove from hazard zones. Roads would be raised to remove them from regular tidal inundation or also during coastal storms if the access way is required during an emergency.

Location: (**a**) Access road to Ormond Beach Generating Station

EBA-WL1: Small scale restoration of Ormond Beach (Alternative 3C: Enhance existing non-tidal wetlands (constrained)) along TNC and Coastal Conservancy properties. Even the small-scale restoration (e.g. alt 3c) would still enable some habitat migration to occur.

- Figure 1. Tiles for Adaptation Strategy Maps
- Figure 2. Nature Based Adaptation Maps
- Figure 3. Engineering Based Adaptation Maps
- Table 1. Lengths and Areas of Nature Based Adaptation Components
- Table 2. Lengths and Areas of Engineering Based Adaptation Components

Appendix C

Sea Level Affecting Marshes Model (SLAMM)

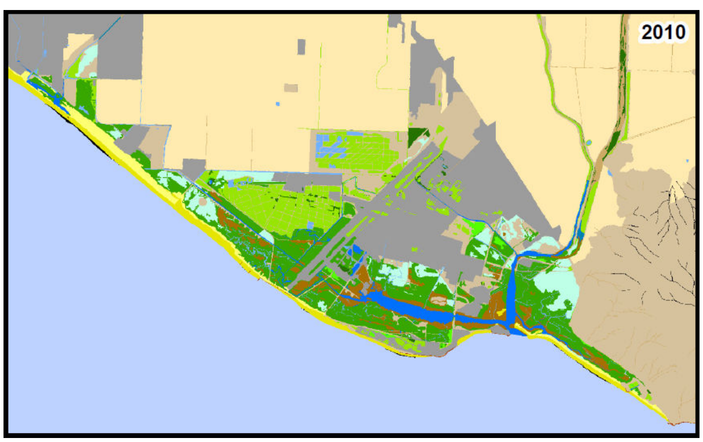
Final

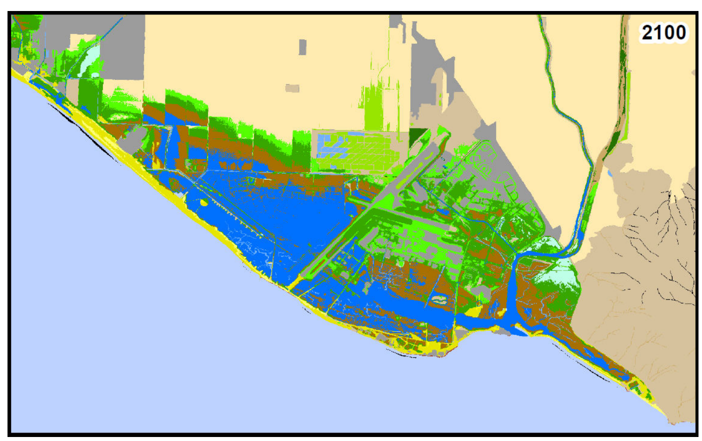
COASTAL RESILIENCE VENTURA

Technical Report for Sea Level Affecting Marshes Model (SLAMM)

Prepared for
The Nature Conservancy

March 18, 2014





Final

COASTAL RESILIENCE VENTURA

Technical Report for Sea Level Affecting Marshes Model (SLAMM)

Prepared for
The Nature Conservancy

March 18, 2014

550 Kearny St

Suite 800

San Francisco, CA 94108

www.esassoc.com

Los Angeles
Oakland
Olympia
Petaluma
Portland
San Francisco
San Diego
Santa Cruz
Seattle
Tampa
Woodland Hills

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

1. Introduction

1.1 Purpose

This report presents technical documentation of the methods used to assess the evolution and vulnerability of the major wetland habitats under various future climate and management scenarios for the Ventura County, California coast from Ormond Beach to Point Mugu. The data that result from this work will be part of The Nature Conservancy's Coastal Resilience Ventura project. This report documents data sources and technical methods used in the ecological vulnerability assessment.

1.2 Project Background

The Nature Conservancy is leading Coastal Resilience Ventura – a partnership to provide science and decision-support tools to aid conservation and planning projects and policymaking to address conditions brought about by climate change. The primary goals of Coastal Resilience Ventura are to assess the vulnerabilities of human and natural resources and identify solutions that help nature help people.

Steering Committee

The Coastal Resilience Ventura project has been guided directly by stakeholders and local decision-makers to develop tools and information to answer questions related to local climate change impacts. The steering committee consists of city, regional, state, and national government agencies and public and private organizations[1]. The committee provided input to the methods and results described in this report as well as provided data and input on deliverables throughout the project including four in-person meetings in Ventura.

Science Advisory Committee

The Science Advisory Committee (SAC) is a group of local and regional technical experts that was developed to provide scientific and technical input to the Coastal Resilience Ventura project. The foundation of the SAC was the Ormond Beach Science Advisory Committee, which was formed as part of the joint efforts of The Nature Conservancy and the California State Coastal Conservancy to Restore the Ormond Beach Wetlands[2]. A number of additional experts were added to the group for the Coastal Resilience Ventura project. The committee provided input to the following SLAMM modeling aspects during a web-conference (December 2011) and three in-person meetings (August 2012 and February 2013 in Ventura, August 2013 in Los Angeles):

- Availability and quality of ecological datasets
- SLAMM study area boundaries
- Reclassification and peer review of disparate habitat and vegetation data sets
- The level of taxonomic detail and spatial explicitness necessary for maps to prove useful for supporting land management decisions related to conservation and restoration of biodiversity and ecosystem function along the Ventura coastline

[1] A complete list of the agencies and organizations represented on the steering committee can be found on the Coastal Resilience Ventura website at http://coastalresilience.org/geographies/ventura-county/partners (Accessed 3 April 2013).

[2] More information available at http://scc.ca.gov/2010/01/07/ormond-beach-wetlands-restoration-project/ (Accessed 20 May 2013).

- Review of preliminary SLAMM results and recommendations for subsequent model runs based on knowledge of Ventura County wetlands systems.
- Input on the management strategies and climate scenarios used in the analysis

Previous Modeling for Coastal Resilience Ventura

ESA PWA conducted modeling of the precipitation and sea level rise impacts of climate change to coastal and fluvial hazards as a previous phase of Coastal Resilience Ventura. These methods are described in a separate technical report titled Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping (ESA PWA 2013). Results and interim data sets generated during that modeling were incorporated whenever possible into the SLAMM model. For example, the SLAMM model used erosion rates generated in the coastal erosion analysis.

1.3 Model Background and Summary

This is one of the first detailed applications of Sea Level Affecting Marshes Model (SLAMM) to the California coastline[3]. SLAMM was first developed in the mid-1980s with EPA funding to evaluate changes to east coast habitats and wetlands and has evolved over time with support from many other funding sources, including TNC. SLAMM was chosen for use in this study because it is well known by policymakers and has been applied widely in the U.S. The software is open source and freely available.

SLAMM simulates the dominant processes involved in wetland conversions during long-term sea level rise: inundation, erosion, overwash, saturation, and accretion. A complex decision tree incorporates both geometric and qualitative relationships to model habitat conversions in coastal habitats through spatial relationships (e.g. adjacency, elevation). It is important to note that while the dominant processes are represented, this is not a hydrodynamic or sediment transport model. The following model processes are applied at each time step:

- Inundation: As sea level rises, land elevations lower relative to mean sea level. This causes habitats to convert to habitats found lower in the tide frame. Inundation is calculated based on the minimum elevation and slope of a cell. Figure 1 shows the decision tree for inundation, as understood from the SLAMM technical documentation.

- Erosion: Horizontal erosion triggered given a minimum fetch threshold and proximity of the marsh to estuarine water or open ocean.

- Saturation: Migration of coastal swamps and fresh marshes onto adjacent uplands as driven by a rising water table.

- Accretion: Vertical rise of marsh due to buildup of organic and inorganic matter on the marsh surface.

- Overwash: Overwash occurs at a specified interval (i.e. every 20 years) causing barrier islands to migrate inland over time. The overwash module has been disabled for this project since barrier islands and the associated overwash by major U.S. East Coast storms (i.e. hurricanes) are not applicable to the Ventura County study areas.

[3] SLAMM has also been applied in South San Francisco Bay, Elkhorn Slough in Monterey County, Tijuana Estuary in San Diego, and Carpinteria Marsh in Santa Barbara.

The primary inputs to SLAMM include a high resolution digital elevation model, a map of current wetland habitats, future sea level rise projections, marsh accretion rates, tide ranges, and erosion rates. These inputs and many others are described later in Sections 4 and 5. This project used SLAMM version 6.2 beta.

1.4 Mugu Lagoon Study Area

The initial SLAMM study areas were selected during the first in-person Science Advisory Committee meeting (see Section 1.2). The study area limits are shown in Figure 2. This final ecological vulnerability study focuses on the Mugu Lagoon site, which includes the coastal wetland habitats from Ormond Beach to Point Mugu. Two other major coastal wetland systems exist in Ventura County: The Santa Clara River and Ventura River Estuaries. Both of these lagoon systems are bar built estuaries that are seasonally closed. Water levels in these systems are determined more by coastal and beach processes than tide levels. During initial efforts to apply SLAMM to these estuaries it became clear that the conceptual model in SLAMM version 6.2 (the most recent version) does not account for many of the dominant processes occurring in these highly dynamic, seasonally closed systems. Therefore, subsequent effort was focused on Mugu Lagoon, a large open tidal system where wetland extent and habitats have been relatively stable through time. Section 6 describes the modeling efforts and limitations at the Santa Clara River and Ventura River Estuaries.

Ventura County is located within the southern California Bight, where the north-south trending U.S. West Coast takes an abrupt turn to a west-east trending shoreline. Point Conception in the northwest and the Channel Islands to the south, create a narrow swell window that shelters much of the Ventura coast from extreme wave events. The Mediterranean climate of southern California results in mild annual temperatures and low precipitation punctuated by episodic and often extreme events frequently associated with El Niños. The sand found on these beaches moves eastward along the coast of southern Santa Barbara and Ventura Counties to the Point Mugu submarine canyon at the mouth of Mugu Lagoon. Tidal fluctuations in this area range from ~3 feet during a neap cycle and up to ~7.5 feet on a spring tide cycle.

Mugu Lagoon lies within Naval Base Ventura County (NBVC) and is bordered by approximately 900 acres of salt marsh with a network of tidal channels (Figure 3). The Ventura County Game Preserve maintains a series of artificially-managed ponds for duck habitat northwest of NBVC. Calleguas Creek, which drains part of the Santa Monica Mountains National Recreation Area, flows into the northeast corner of Mugu Lagoon. This stream is currently a perennial stream[4] fed continuously by treated wastewater flows, groundwater infiltration, and urban/agricultural run-off. The volume of this daily flow, however, is negligible compared to stormwater during rainfall events. While large freshwater flow events occur periodically, the wetland habitats in Mugu Lagoon are generally saline. The lagoon mouth, which is partially controlled by armoring constructed by the Navy, is tidally dominated, with a large diurnal tidal prism compared to overall volume. This results in an open lagoon mouth, year-round. Wetland habitats are driven primarily by their elevation relative to the tides (duration of inundation), which is the primary wetland process modeled by SLAMM. Salinity, coastal winds, morning fog, mild air temperatures, and variable rainfall affect habitats to a lesser extent, but these processes are not modeled in SLAMM.

[4] Historically, Calleguas Creek flow was intermittent, flowing in the wet winters and drying in the summers (Beller et al 2011).

2. Summary of GIS Deliverables

This section summarizes the GIS deliverables developed as a result of this work and points to the sections in this document that describe how they were developed in more detail. All GIS deliverables are provided in WGS 1984 Web Mercator Auxiliary Sphere projected coordinates[5]. Horizontal units are meters. SLAMM was run with a 10-year time step, and results were provided at each time step from 2010 to 2100. This includes the same planning horizons (2030, 2060, and 2100) that were used in the coastal hazards analysis.

2.1 Future Scenarios

The following scenarios were developed in discussions with TNC, the Science Advisory Committee, and the Steering Committee to provide the most utility to decision making. Section 6 explains how these scenarios were implemented in SLAMM by modifying the input maps (Section 4) and site parameters (Section 5). Each combination was modeled, for a total of 24 model runs.

Table 1. SLAMM Scenarios

Type	Scenarios
Sea Level Rise	• High (1.47 meters between 2010 and 2100) • Low (0.44 meters between 2010 and 2100)
Management	• Allow marshes to transgress into dry land • Fortify developed dry land (excluding agricultural land) • Fortify developed dry land (including agricultural land) • Fortify developed dry land (including agricultural land and managed ponds)
Accretion/Sedimentation Rate	• High • Low (half of high rates)
Erosion of New Inlet[6]	• No erosion of new inlet west of the NBVC runway • With erosion of new inlet west of the NBVC runway

Sea Level Rise

The sea level rise scenarios used in this study are based on recent National Research Council (NRC, 2012) and U.S. Army Corps of Engineers (USACE, 2011) guidance[7]. The USACE medium curve was selected as the low curve in this study because it is the lowest of all the USACE and NRC projections that incorporates future increases in the rate of sea level rise. It was also included because steering committee members acknowledged that some future projects may require federal funding, and any analysis used for such project funding sources must use the USACE methodology. The high end curve is based on the high end range of models discussed in the NRC 2012 report. Both curves include an

[5] All SLAMM analysis was conducted in NAD 1983 UTM Zone 11N meters. The final results were projected at the request of TNC for simplifying web display and incorporation into the online decision support tool (maps.coastalresilience.org/ventura/).

[6] It is unlikely that given the longshore sand transport in the area and/or the existing tidal prism that both inlets would be maintained without active management. ESA PWA recommends that this management scenario NOT be included in the data layers available to the public.

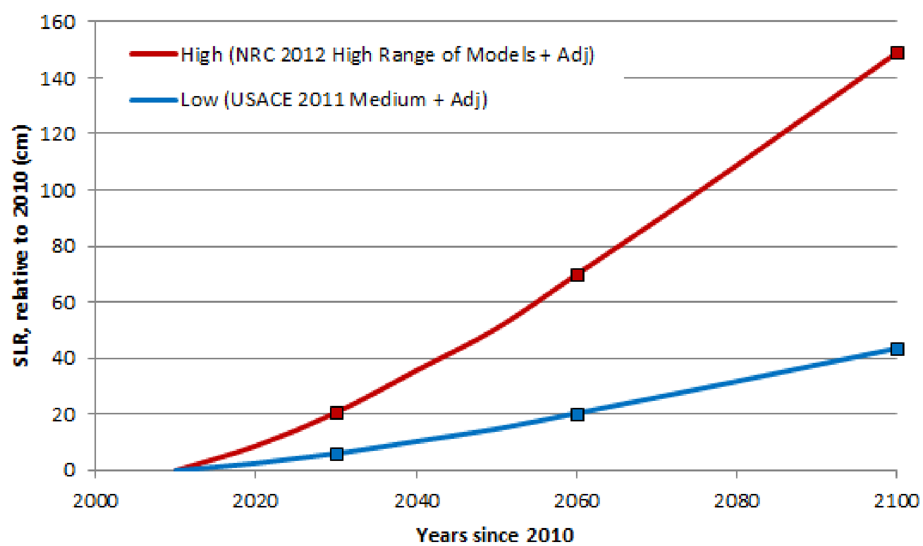
[7] While the state of California guidance on sea level rise prescribed the use of 55 inches of rise by 2100, this present study attempted to combine federal and scientific guidance in anticipation of revised guidance expected to be issued by the state shortly after the completion of this study.

adjustment for local vertical land motion using the Santa Monica tide station (NOAA #9410840). The sea level rise at each planning horizon is shown in Table 2 and marked in Figure 4.

Table 2. Sea Level Rise Projections, relative to 2010

Year	*Low SLR*	*High SLR*
2030	6 cm (2.3 inches)	20 cm (8.0 inches)
2060	19 cm (7.4 inches)	64 cm (25.3 inches)
2100	44 cm (17.1 inches)	148 cm (58.1 inches)

Figure 4 – Sea Level Rise Scenarios (Local SLR, relative to 2010)



Management

The management scenarios presented in Table 1 represent a wide range of trade-offs between allowing marshes to transgress inland with sea level rise and holding the line or “fortifying” current development or agricultural land (e.g. by building levees and seawalls). The fortification scenarios are modeled by preventing marshes from transgressing into developed areas, agriculture, and the managed ponds, as applicable. This study does not assess the feasibility of these scenarios from a cost/engineering perspective. Rather, it focuses on how wetland habitats are likely to develop in response to future management.

Normally, SLAMM is only used to model the “allow marshes to transgress” and the “protect developed area” scenarios. However, the Mugu Lagoon study area includes large expanses of low lying agricultural land that will be at risk with future sea level rise. Additionally, two stretches of ponds, managed by the Ventura County Game Preserve for duck habitat, are already at or below tide levels and will require increasing levels of management to protect in place with sea level rise. The implications of these low-salinity ponds on greenhouse gas emissions are assessed in a separate memo (ESA PWA 2014). In discussions with TNC and the SAC it became clear that it was important to differentiate between developed areas (such as the Navy Base and residential areas), agricultural land, and the managed ponds.

Accretion/Sedimentation

Marshes build vertically through two processes: inorganic surface sedimentation and organic growth and accretion. Both processes are controlled by flooding patterns and duration of inundation, among other factors. Rising sea levels affect these processes by increasing the time of inundation. Accretion rates in Mugu Lagoon are highly dependent on sediment supply and can vary widely based on location in the marsh. Since the response of accretion rate to sea level rise (and other climate changes) is not well understood, high and a low accretion[8] scenarios were modeled. The high and low values were selected based on a literature review of accretion studies in Mugu Lagoon and other Southern California wetlands and with input from the Science Advisory Committee. Section 5.4 describes this process and explains how the feedback between inundation time and accretion rates was implemented in SLAMM.

Erosion

In the SAC and stakeholder meetings, participants asked what could happen if accelerating erosion caused a breach in the beach/dune system and increased the hydraulic connection with the back barrier wetlands. This was investigating by modeling the “erosion of new inlet” scenario, which assumed a breach somewhere west of the NBVC runway. This would bypass the tidal damping caused by the series of culverts and result in a wider tide range across the western portion of the Mugu site.

Geomorphically, however, it is unlikely that a new inlet would persist. Since an additional inlet would only breach during an extreme storm event, and given the high rates of alongshore sand transport in this region, we do not anticipate that a new inlet would persist. There are no other examples of multiple-inlet systems along the Southern or Central California coast. In addition, the current lagoon mouth discharges near the head of the Mugu Submarine Canyon, which geologically controls the inlet location. In recent years, the head of this submarine canyon has been headcutting, migrating across the continental shelf toward the entrance to Mugu Lagoon (Xu et al 2010). As a result of these factors, ESA PWA recommends that this scenario (“Erosion of a New Inlet”, e2) NOT be presented on the CRV website as a viable future scenario.

2.2 File Naming Convention

The naming conventions for the GIS deliverables are based on future scenarios and planning horizons, as follows:

Sea level rise scenarios:
ec – Existing conditions (2010)
s1 – Low sea level rise
s3 – High sea level rise

Accretion/Sedimentation scenarios:
a1 – Low accretion/sedimentation
a2 – High accretion/sedimentation

Erosion scenarios:
e1 – No erosion of new inlet
e2 – With erosion of new inlet

Management scenarios:
m1 – Allow marshes to transgress into all dry land
m2 – Fortify developed dry land (excluding agricultural land)
m3 – Fortify developed dry land (including agricultural land)
m4 – Fortify developed dry land (including agricultural land and managed ponds)

[8] The terms “accretion” and “sedimentation” are used somewhat interchangeably in this report because SLAMM does not differentiate between organic accretion and inorganic sedimentation.

Years:
The SLAMM outputs are provided at 10 year intervals from 2010 to 2100.

Example: The model output at 2100 with low sea level rise (s1), high accretion/sedimentation (a2), no erosion of a new inlet (e1), and fortification of developed dry land (including agricultural land) (m3) is named s1a2e1m32100.

A complete list of GIS deliverables is provided in Appendix A.

2.3 Recommended Map Display

There are 26 different habitat types in SLAMM. Displaying all of these habitats in the Coastal Resilience online tool would result in a very large legend and make the map difficult to interpret. Below we recommend a classification that will simplify display and make the maps easier to understand. The SLAMM outputs were post processed to include these simplified categories in an attribute called “SimpCat” for easy display on the web map.

SLAMM Habitat IDs	General Category
1	Developed Dry Land
2	Undeveloped Dry Land
100	Agricultural Land
3, 5, 22	Freshwater Non-Tidal
6, 23	Freshwater Tidal
7, 26	Transitional
8, 20	Salt Marsh
11	Mud Flat
10, 12, 14, 22	Beach or Gravel Shore
15, 16, 17, 18, 19	Open Water

3. Disclaimer and Use Restrictions

Funding Agencies

These data and this report were prepared as the result of work funded by The Nature Conservancy, and the County of Ventura (collectively "the funding agencies"). It does not necessarily represent the views of the funding agencies, their respective officers, agents and employees, subcontractors, or the State of California. The funding agencies, the State of California, and their respective officers, employees, agents, contractors, and subcontractors make no warranty, express or implied, and assume no responsibility or liability, for the results of any actions taken or other information developed based on this report; nor does any party represent that the uses of this information will not infringe upon

4. Input Maps

This section describes the original data sources and post processing used to develop map inputs for SLAMM. All model inputs and outputs have 5 meter cell size. This resolution was selected based on review of SLAMM applications in other regions, input from the Science Advisory Committee, and computational time. The majority of existing SLAMM studies covered areas 2 to 100 times as large as the Mugu Lagoon study area and used 10 to 30 meter resolution (Clough and Larson 2010, Clough and Larson 2009a,b, Glick et al 2007, Warren Pinnacle Consulting 2011). A smaller resolution was selected for the Ventura project due to the small study area, high resolution (1 meter) topography, and availability of detailed vegetation studies. Table 3 summarizes optional map inputs that were not used and explains the purpose for each input and the rationale for excluding it in this analysis.

Table 3. Map inputs excluded from the Ventura SLAMM

Model Input	Purpose	Rationale for Exclusion
Map of percent impervious	This input can be used when a good habitat map is not available to identify "developed" areas.	Many high resolution datasets of land cover and habitats were available in Ventura County, making this input unnecessary.
Raster output sites	This creates outputs for specific output sites within the overall modeled region.	The SLAMM study area is already small compared to typical SLAMM models, so the site was not subdivided into smaller output sites.
VDATUM map	This map allows for spatial variations in the conversion between the NAVD88 and MTL vertical datums.	Because each of the individual sites was modeled separately, and because the sites are small, we assume that the conversion between NAVD88 and MTL does not vary spatially.
Uplift/Subsidence map	Allows for spatial variation of relative sea level rise.	While uplift of the mountainous areas within Ventura County is relatively well documented, the amount and spatial distribution of vertical land motion within the Oxnard Plain was not available. Relative land motion is partially considered in the long term local sea level trend at the Santa Monica tide gage, which was used to develop the sea level rise scenarios (see Section 2.1). This scenario does not, however, consider localized subsidence.

4.1 Topography

Elevation and land cover maps are the two most important inputs to SLAMM. The relationship between elevation (relative to the tide range) and habitat is what drives habitat changes under sea level rise. The 2009 – 2011 California Coastal Conservancy Coastal LiDAR Project Hydro-Flattened Bare Earth DEM was downloaded from the NOAA Digital Coast Data Access Viewer (NOAA, 2012a). This data was collected in November 2009 for the Ventura study area and has 1 meter resolution with a horizontal accuracy of ± 50 cm and a vertical accuracy of ± 9 cm. The LiDAR data was reclassified, filtered, edited, and hydro-flattened by the DEM creators using 3D hydro breaklines to develop the final DEM[9]. This was the primary DEM used for conducting topographic analysis and mapping coastal erosion and flood hazard zones.

The DEM was modified in a few ways to address connectivity and resolution issues.

1. In order to improve the mapped projections of future habitat transgression it was important to represent the hydraulic connectivity not apparent from the digital elevation model (e.g. through culverts or under bridges). Within the Ventura County study area, this is most relevant for the Mugu Lagoon area, which is characterized by a series of low-lying ponds, interconnected by underground culverts. Martin Ruane at Naval Base Ventura County (NBVC) provided culvert data as a GIS polyline shapefile. This dataset covered the extent of the NBVC Point Mugu property, which includes Mugu Lagoon. These polylines were buffered in GIS, assigned a low

[9] Detailed metadata describing DEM development is available on the NOAA Digital Coast Data Access Viewer at this link: http://csc.noaa.gov/dataviewer/webfiles/metadata/ca2010_coastal_dem.html (Accessed April 2, 2013).

elevation (0 m NAVD88), and overlaid on the above DEM. This ensures that the low-lying areas connected by culverts are considered connected in the SLAMM model.

2. The dike elevations around the managed ponds in the Mugu study area were modified in the 5 meter DEM, as described in Section 4.3.

3. In the process of hydroflattening, many of the mudflats in Mugu Lagoon were inadvertently lowered below MLW. Since the lower limit for mudflats in SLAMM is MLW, this caused the mudflats to convert to open water in the first timestep. High resolution bathymetry, collected in September 2012, was provided by Sean Anderson at California State University Channel Islands and added to the existing conditions topography to address this problem in many areas. However, the surveyed bathymetry did not cover the entire lagoon. In the other areas a reasonable elevation was assigned to the hydroflattened mudflat areas. The elevation selected, 0.94 m NAVD88, is 1 standard deviation below the mean observed mudflat elevation. This agreed very well with non-hydroflattened mudflats that were close in proximity.

SLAMM also requires a topographic slope map. This was developed by applying the ArcGIS spatial analyst slope function to the above digital elevation model.

4.2 Habitat Map (SLAMM Categories)

Multiple datasets were combined to create an existing conditions habitat layer, which is the main input to SLAMM. The datasets are described in order of prioritization (first is highest priority) in Table 4.

SLAMM (version 6.2) accepts land cover data in the form of 24 habitat classes. Each of the sources described in Table 4 uses a different vegetation/land cover classification scheme. Kirk Klausmeyer at The Nature Conservancy reviewed each classification scheme and developed a “crosswalk” for each source that linked each source’s habitat class to a SLAMM habitat class. The SLAMM technical documentation includes a crosswalk between some (but not all) of the NWI classes and the SLAMM classes. Since many of the SLAMM habitat names are specific to the East and Gulf Coasts, the habitats were renamed to better reflect the naming conventions in Ventura County. The Science Advisory Committee (see Section 1.2) provided input to the habitat map during two review meetings. The committee provided input and peer review to the habitat crosswalk, renaming of habitats, and SLAMM’s assumptions about habitat conversions with sea level rise. For clarity, all subsequent references to habitats use the Ventura name with the SLAMM ID number in parentheses. Table 5 provides a summary of the SLAMM habitats, corresponding Ventura names, and acreage in the Ormond Beach and Mugu Lagoon study area. Figure 3 shows a map of the Mugu Lagoon and Ormond Beach habitats. Agricultural land is not modeled in SLAMM, but was added in after modeling as this is an important upland classification in the vicinity of Mugu Lagoon.

Table 4. Data Sources for SLAMM Habitat Map

Habitat Data Source	Description
1. Expert input	The Science Advisory Committee provided significant input to the habitat map during two meetings.
2. Dune habitats	Brian Cohen at The Nature Conservancy digitized dunes in Ventura County using recent aerial imagery.
3. WRA vegetation map	Vegetation mapping conducted by WRA in 2007 at Ormond Beach
4. Santa Clara River estuary habitat map[10]	Detailed habitat mapping conducted by Stillwater Sciences (2010) at the mouth of the Santa Clara River. This field survey was conducted in September 2009.
5. Southern California Wetlands[11] Mapping Project	This project builds on NWI mapping in Southern California and uses NWI methodology. Mapping is based on 2005 aerial imagery and covers the Santa Clara River Estuary and Mugu Lagoon study areas.
6. U.S. Fish & Wildlife Service National Wetlands Inventory (NWI)[12]	This dataset is based on 2002 aerial imagery and covers the Ventura River Estuary study area.
7. Farmland Mapping and Monitoring Program (FMMP)[13]	This dataset covers upland (non-wetland) areas and is based on 2010 aerial imagery.

Note: Shaded datasets do not apply to the Mugu Lagoon study area, but were used to develop a county-wide existing habitats map that is currently displayed on the Coastal Resilience Ventura web map.

[10] Obtained from Scott Dusterhoff at Stillwater Sciences in November, 2012.
[11] Available at http://www.socalwetlands.com/website/main.htm (Downloaded February 2012).
[12] Available at http://www.fws.gov/wetlands/Data/index.html (Downloaded February 2012).
[13] Available at: http://www.conservation.ca.gov/dlrp/fmmp/Pages/Index.aspx (Downloaded November 2012).

Table 5. SLAMM Habitats and Acreages in the Ormond Beach/Mugu Lagoon Study Area

ID	SLAMM Name	Ventura Name	Approximate Area, acres (%)
1	Developed Dry Land	Developed Uplands	2446.7 (10.3%)
100*	N/A (Added after SLAMM)	Agricultural Land	6314 (26.6%)
2	Undeveloped Dry Land	Undeveloped Uplands	2897.2 (12.2%)
3	Swamp	Freshwater Wetland with Trees/Shrubs/ Riparian Forest	82.8 (0.3%)
4	Cypress Swamp	N/A – Not Present	Not Present
5	Inland Fresh Marsh	Inland Fresh Marsh	737.7 (3.1%)
6	Tidal Fresh Marsh	Tidal Fresh Marsh	4.2 (0%)
7	Trans. Salt Marsh (Scrub Shrub)	Tidal Estuarine Wetland with Trees/Shrubs	31.1 (0.1%)
8	Regularly Flooded Marsh	Emergent Salt Marsh	1224 (5.2%)
9	Mangrove	N/A – Not Present	Not Present
10	Estuarine Beach	N/A – Not Present	Not Present
11	Tidal Flat	Mud Flat	322.3 (1.4%)
12	Ocean Beach	Coastal Strand	267.3 (1.1%)
13	Ocean Flat	N/A – Not Present	Not Present
14	Rocky Intertidal	Rocky Intertidal	6.9 (0.03%)
15	Inland Open Water	Open Water	85.3 (0.4%)
16	Riverine Tidal Open Water	Riverine Tidal	16.9 (0.1%)
17	Estuarine Water	Open Water Subtidal	230 (1%)
18	Tidal Creek	Tidal Channel	80 (0.3%)
19	Open Ocean	Open Ocean	8266.8 (34.8%)
20	Irreg. Flooded Marsh	Rarely Flooded Salt Marsh / Salt Pans	411.9 (1.7%)
21	Not Used	N/A – Not Present	Not Present
22	Inland Shore	Arroyo / Gravel / Shore	123.7 (0.5%)
23	Tidal Swamp	Tidal Wetland with Trees/Shrubs	5.7 (0.02%)
24	Not Used	N/A – Not Present	Not Present
25	Vegetated Tidal Flat	N/A – Not Present	Not Present
26	Backshore	Dunes	183.2 (0.8%)
		TOTAL	23,738 (100%)

**Agricultural Land is not recognized in SLAMM. An ID of 100 was arbitrarily assigned to this classification. Agricultural land was added to the SLAMM results after modeling was completed to differentiate between developed dry land, undeveloped dry land, and agricultural land.*

4.3 Diked Areas

Diked areas are considered in SLAMM using two mechanisms: high resolution topography or a spatial map of diked areas. The first option requires that the DEM be detailed enough to delineate the crest of a levee around a diked area. One low point (which can sometimes happen inadvertently when converting the 1-meter DEM to the 5-meter resolution used in this analysis) can cause the entire diked area to be flooded when in fact it is still protected by dikes. The second option uses a spatial map of diked areas to represent areas that are protected from sea level rise and intrusion of saline water.

Areas are designated as either diked (1) or not diked (0 or No Data). In this option, the diked areas are assumed protected until 2 meters of sea level rise has occurred, at which point the protected areas become inundated.

Four data sources were considered in identifying the locations of diked areas:

1. Expert consultation with Martin Ruane at Ventura County Naval Base. He reviewed and provided input to the dike map for the Mugu Lagoon study area. He also provided the alignment of the flood control levee along Calleguas Creek.

2. National Wetlands Inventory (NWI). The NWI wetlands classification scheme includes a modifier, “h” that indicates that an area is diked.

3. Southern California Wetlands Mapping Project. This dataset is a more recent version of the NWI map for Ventura County, with the same “h” modifier.

4. USACE National Levee Database[14]. This database primarily showed areas protected from fluvial flood events and was not used in identifying areas protected from coastal inundation and sea level rise.

Ultimately, only expert consultation with Martin Ruane was used. Most of the “diked areas” identified in the NWI and Southern California Wetlands Map occur in the Mugu Lagoon area. According to Martin Ruane, many of these areas are actually connected by culverts. He provided a culvert dataset as a GIS polyline shapefile that covered the extent of the Naval Base Ventura County Point Mugu property, which includes Mugu Lagoon. He delineated two stretches of diked managed ponds on the northeast side of the airport runway. The rest of the “diked areas” have some connectivity with the ocean and are assumed unprotected by dikes for this analysis. The high resolution (1 meter) DEM was inspected to identify the approximate minimum crest elevation of the dikes around the managed ponds. The coarser DEM was then modified as needed to ensure that these ponds were diked to this elevation. Therefore, no “diked areas” map was used. This approach is far more reasonable than assuming the diked ponds will not be inundated until 2-meters of sea level rise will occur. The crest elevation for the southern ponds is currently only ~ 65 cm above mean tide level at the ocean.

5. Input Site Parameters

5.1 Overview

This section discusses non-map inputs to SLAMM, such as water levels, tide ranges, erosion rates, and accretion/sedimentation rates. Four sub-sites were delineated within the larger study area to account for differences in tide range, source data, likely accretion/sedimentation rates, and erosion rates:

- Mugu Lagoon West 1 (MLW1): Wetlands and agricultural land west of the NBVC airport runway. This region currently has the smallest tide range and includes the managed ponds.

- Mugu Lagoon West 2 (MLW2): Wetlands and Navy Base infrastructure between the runway and Laguna Road.

---

[14] Available online: http://nld.usace.army.mil/egis/f?p=471:32:559674793604701::NO (Accessed May 21, 2013).

- Mugu Lagoon Center (MLC): Adjacent to the mouth of Mugu Lagoon, this area has the largest tide range (with the exception of open ocean) and includes the downstream portion of Calleguas Creek.

- Mugu Lagoon East (MLE): This is the eastern arm of Mugu Lagoon, which has a large tide range and no other inflows. Wetland evolution is constrained by steep mountains along the north side.

These sites are delineated in Figure 3. Global parameters were specified for areas not included in one of these sub-sites.

Table 6. Summary of SLAMM input parameters for Ormond Beach and Mugu Lagoon

Parameter	***Global***	***MLW1***	***MLW2***	***MLC***	***MLE***
Habitat Map Year	2005	2005	2005	2005	2005
DEM Year	2009	2009	2009	2009	2009
Offshore Direction	South	South	South	South	South
Frequency of Overwash	Not used.				
Use Elev Pre-Processor?	No				
Water Levels					
Historic Sea Level Trend (mm/yr)	1.7 mm/year for all (see discussion in Section 6.1)				
MTL to NAVD88 (m)	0.798	0.85	0.85	0.82	0.82
Great Diurnal Tide Range (m)	1.65	0.66	1.01	1.37	1.37
Salt Elevation (m above MTL)	1.20	0.46	0.68	1.05	1.05
Horizontal Erosion Rates (horizontal meters/year, + is erosion)					
Marsh (5, 6, 7, 8, 18, 20, 23)	0.1	0.1	0.1	0.1	0.1
Freshwater Wetland with Shrubs (3)	0.1	0.1	0.1	0.1	0.1
Mud Flat (11) & Coastal Strand (12)	0.9	0.1	0.1	0.1	0.1
Constant Accretion/Sedimentation Rates (mm/year)					
Emergent Salt Marsh (8)	Elevation/accretion-sedimentation feedback relationship used instead, see below.				
Rarely Flood Salt Marsh/Pan (20)					
Tidal Fresh Marsh (6)					
Inland Fresh Marsh (5)					
FW Wetland w/ Trees/Shrubs (3)	1	1	1	1	1
Tidal Wetland w/ Trees/Shrubs (23)	1	1	1	1	1
Coastal Strand (12)	1	1	1	1	1
Accretion/Sedimentation Rate Extremes for Elevation Feedback* (see Section 5.4) (mm/year)					
Emergent Salt Marsh (8), min	1	1	2	3	2
Emergent Salt Marsh (8), max	4	4	6	8	6
Rare Flood Salt Marsh (20), min	1	1	2	3	2
Rare Flood Salt Marsh (20), max	4	4	6	8	6
Tidal Flat (11), min	1	1	2	3	2
Tidal Flat (11), max	4	4	6	8	6
Tidal Fresh Marsh (6), min	1	1	2	3	2
Tidal Fresh Marsh (6), max	5	5	7	9	7

**These accretion rates represent the “high accretion” scenario (described in Section 2.1). The “low accretion” scenario used half the rates presented here (e.g. the Emergent Salt Marsh (8), Global min for “low accretion” was 0.5 mm/year).*

5.2 Water Levels and Salt Elevation

Elevation ranges for each habitat type in SLAMM are specified based on three water level parameters:

- Conversion between Mean Tide Level (MTL) and the vertical datum NAVD88
- Great Diurnal Tide Range
- Salt Elevation

Mean Tide Level (MTL) is the vertical datum used in SLAMM. As sea level rises, the land elevations are lowered relative to MTL. The SLAMM technical documentation describes how habitat categories switch with rising sea level and changes to the above three water level parameters (WPC 2012). This section describes how these parameters were selected using existing studies. Table 6 reports values selected for each study area.

The “salt elevation” is a threshold elevation that determines when dry lands and freshwater wetlands convert to salt marsh (unless a freshwater influence is identified, as described in Section 5.5). This is the elevation below which salt water has an influence on the habitat type. This elevation is defined as the elevation that is inundated by salt water less than every 30 days, or approximately a one month. This value was estimated for each nearby tide station by calculating the average maximum monthly water level (Table 7).

Table 7. Regional Tidal Datums

Tide	**Rincon Island**** #9411270 *m NAVD88*	**Santa Barbara** #9411340 *m NAVD88*	**Santa Monica** #9410840 *m NAVD88*	**Los Angeles** #9410660 *m NAVD88*
Highest Observed Water Level	2.350	2.213	2.533	2.352
Salt Elevation*	1.997	1.990	2.002	2.003
Mean Higher High Water	1.634	1.606	1.596	1.611
Mean High Water	1.404	1.376	1.371	1.386
Mean Tide Level***	0.838	0.818	0.798	0.805
Mean Sea Level	0.831	0.811	0.792	0.799
Mean Low Water	0.271	0.260	0.226	0.224
Mean Lower Low Water	-0.030	-0.039	-0.057	-0.062
Lowest Observed Water Level	-0.737	-0.921	-0.924	-0.894

*Salt Elevation was calculated by calculating the median of the maximum monthly high water for all available data from each tide station. This is the water level that is reached approximately once per month.
** Rincon Island station has was decommissioned in 1990
*** This is the MTL-NAVD88 conversion, one of the inputs to SLAMM.

The Great Diurnal Tide Range is important in SLAMM because it associates the habitat and elevation relationship with the tidal variability across the site. Across the Mugu wetlands, substantial tidal variations exist because of the complex hydraulic connections between various basins, bridges, and culverts. In 2003, RMA conducted a numerical modeling study that provided many of the tide range inputs for the Mugu Lagoon study area (RMA 2003). Water levels were collected at two locations in Mugu Lagoon for model calibration. Figure 5 shows the locations of the gages (“Mugu West” and “Mugu

North") and compares the various tidal water levels observed during the month-long period to the Santa Monica tide gage. "Mugu North" is located north of the central lagoon channel. It experienced approximately 80% of the Santa Monica gage tide range. For subsite MLC we use 83% of the GDTR from the Santa Monica tide gage (1.37 meters). This value was also applied to subsite MLE, which is not separated from the main lagoon by any water control structures. "Mugu West" is located just east (ocean-side) of five 30" culverts under L Avenue (Figure 3). This gage is located past a 30' box culvert under Laguna Road, which probably causes much of the damping observed in the gage data. Subsite MLW2 was assigned a GDTR of 61% of the Santa Monica GDTR (1.01 meters). While gage data was not available inside of the culverts under the airport runway, we assume that the tide range will be further reduced in this region. A GDTR of 40% of the Santa Monica tide range was assigned to sub-site MLW1.

The RMA water level comparison also found that mean sea level was slightly different between the three tide gages. The Mugu West and Mugu North gages experienced a MSL 5 and 2 cm higher than the Santa Monica gage, respectively. The MTL-NAVD88 conversion from the Santa Monica tide gage was adjusted to account for this difference. The salt elevation in each sub-site was estimated by reducing the salt elevation at the Santa Monica gage by the observed % reduction of high tides shown in Figure 5 (56% for Mugu West and 87% for Mugu North).

CH2M Hill (2008) collected water level data in the Ormond Beach Lagoon over a 3-month period during which the lagoon breached multiple times (Figure 6). When the lagoon is open, the high water levels match the tide level at the ocean and the lower tides are clipped, likely due to water ponding in the lagoon at low tides. Based on this dataset it appears that Ormond Lagoon experiences high tides similar to those at the ocean, so no reductions in high tide range were applied to this site.

5.3 Horizontal Erosion Rates

SLAMM requires estimates of horizontal erosion (e.g. shoreline or bank erosion) for coastal strand, marshes, freshwater wetlands, and mudflats. Mudflats and coastal strand are assumed to erode continuously at a specified rate (unless using the Bruun rule, as described in the next paragraph). Marshes are predicted to undergo erosion if they directly interface open water with over 9 km of fetch available for wind setup. This minimum fetch distance is hardcoded in SLAMM and, based on discussions with the Science Advisory Committee, may not accurately represent the rates of marsh erosion in Ventura's wetland systems. Model results (acreages of habitats) are relatively insensitive to horizontal erosion rates compared to vertical accretion/sedimentation rates. Table 6 presents a summary of input parameters, including the horizontal erosion rates.

By default, SLAMM uses the Bruun rule for beach erosion with an assumed beach slope of 1:100. This means that for every meter of sea level rise, the beach erodes by 100 meters. While this may be applicable to natural, flat, East Coast beaches, the beaches along the Ventura shoreline are far steeper. This module causes the beaches to disappear by 2020, which is not anticipated based on the prior erosion analysis. Therefore, this module was disabled. Instead, coastal strand and mudflat erosion rates (SLAMM uses the same rate for these two habitats) were based on a shoreline change analysis conducted for the Coastal Resilience Ventura coastal hazards analysis (ESA PWA 2013). This prior study calculated average short term (1970s to 2010) and long term (1850s to 2010) shoreline erosion rates for 500 meter or smaller along-shore study "blocks". The erosion rates used in the erosion study were averaged within each SLAMM study area (Figure 2) as the global Coastal Strand (12) erosion rate. In either case the beaches narrow significantly in SLAMM, and the dunes slowly disappear.

Marsh erosion rates were not readily available within the Ventura study areas, so estimates from Elkhorn Slough in Monterey Bay were implemented. Elkhorn Slough, which is an actively eroding system, has experienced 15 – 35 cm/year of marsh bank erosion over the past 10 years (Wasson 2011). Therefore, a marsh erosion rate of 10 cm/year was assumed for all study areas, as these systems are not known to be actively eroding.

5.4 Vertical Accretion and Sedimentation Rates

Vertical accretion/sedimentation[15] is a key factor in determining whether or not a marsh can persist in the face of sea level rise and will be increasingly important with accelerated sea level rise. Vertical accretion is driven by a variety of factors such as sediment supply, duration of tidal inundation, and rate of plant growth. SLAMM incorporates average annual marsh accretion and beach sedimentation rates for various habitat types into estimates of relative sea level rise. Vertical marsh growth is a combination of inorganic sediment deposition and organic soil production (bioaccumulation). Our literature review found a wide range of accretion rates in estuaries in Central/Southern California, which are summarized below. The subsequent section describes how accretion rates were modeled in the Ventura SLAMM.

Literature Review

Deposition in southern California estuaries tends to be episodic and storm-driven rather than continuous and tidally-driven as observed in larger estuaries like South San Francisco Bay (Wallace et al 2005, Weis et al 2001, Cahoon et al 1996, and Onuf 1987). Major storms in 1978 and 1980 filled nearly 40% of the volume of Mugu Lagoon, which had previously been dredged by the Navy (Onuf 1987). Chan and Ambrose (unpublished, as cited in Rosencranz 2012) found accretion rates of 2 mm/year over a 13-year period. In contrast, a recent study in Mugu Lagoon (Rosencranz 2012) observed no net vertical accretion during an unusually dry monitoring period (August 2011 to May 2012). Few studies exist that report long term average annual sedimentation/accretion rates in Ventura County wetland systems.

Accretion measurements do exist for some nearby estuaries. Most understanding of marsh accretion in southern California comes from studies at the Tijuana Estuary National Estuarine Research Reserve, which lies just south of San Diego Bay. Mudie & Byrne (1980) estimate that the vertical accretion rate in Tijuana estuary has been approximately 1 mm/year over the last 1100 years, which is comparable to the rate of sea level rise over that period (1-3 mm/yr). Cahoon et al (1996) observed 1-2 mm of accretion in the high marshes and 85 mm of accretion in the low marshes of Tijuana Estuary during a 17 month monitoring period (October 1992 – March 1994). Almost all of this accretion occurred due to mineral sedimentation during a 2 month period of storm-induced river flows. Wallace et al (2005) monitored a restoration site in Tijuana Estuary for 3.5 years and measured 4 to 11 mm/year net accretion.

Elkhorn Slough, in the center of the Monterey Bay coast, has no major rivers providing pulses of sediment and has experienced gradual accretion. Watson (2008) measured 2 to 3 mm/year of salt marsh accretion since 1950, when the Army Corp of Engineers dredged a navigational channel and built a pair of entrance jetties. Before construction, accretion was << 1mm/year. More recent measurements suggest that the average marsh surface elevation gain has averaged about 1 mm/yr since 2006 (Van Dyke 2012).

---

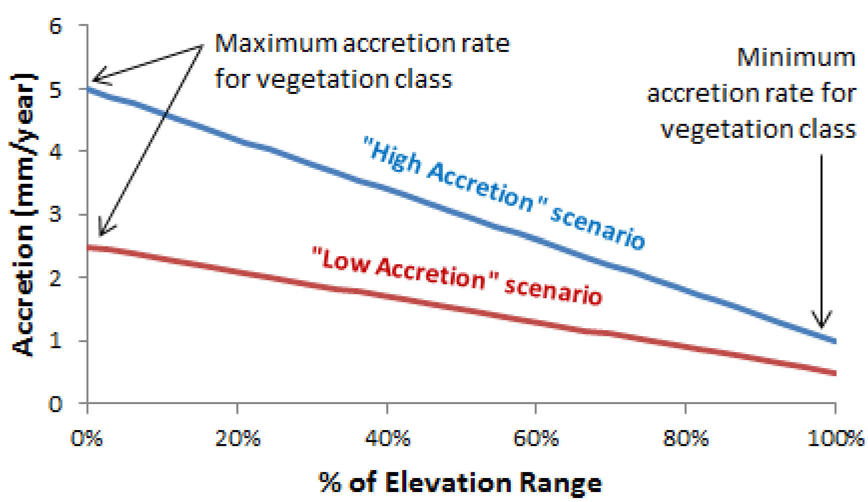
[15] Vertical growth of the marsh or wetland.

Model Implementation

Land management practices, sediment supply, ecology, and many other factors influence accretion rates and vary among southern California systems. For the purposes of predicting future accretion rates in the Ventura County SLAMM study areas, we implemented an elevation-accretion relationship where wetlands that are higher in the tide range and inundated less often experience lower accretion rates. This inverse relationship between elevation and accretion has been measured (Cahoon et al 1996, Cahoon and Reed 1995, Stoddart et al. 1989, Marion et al 2009) and observed in physical models (Krone 1985). This inverse relationship appears to be true for both storm-induced sedimentation and long term tidal deposition. This feedback would cause wetlands to accrete more quickly as the rate of sea level rise increases, up to a threshold (Morris et al 2002, Friedrichs and Perry 2001). This outcome relies heavily on the amount of sediment available for sedimentation. Here we make the assumption that the feedback relationship, which is based on historic trends and historic sediment supply, remains the same into the future.

For simplicity, we assume a linear relationship between accretion rate and elevation. Figure 7 shows an example of such a relationship with a maximum and minimum accretion rate of 5 and 1 mm/year and 2.5 and 0.5 mm/year for the “High” and “Low” accretion scenarios, respectively. Maximum and minimum accretion rates were selected based on regional accretion rates (at Elkhorn Slough and Tijuana Estuary) and relative sediment supply from each fluvial system (Inman and Jenkins 1999), with some judgment and input from the SAC to select rates for each wetland type. The rates selected for each study area and marsh type are reported in Table 6. The elevation feedback curve is only available for four habitat types which are subject to the greatest variability in inundation depth. A long term accretion rate of 1 or 2 mm/year was selected for the other wetland types, depending on the sediment supply. These wetland types occur at higher elevations and are inundated less frequently.

Figure 7 – Conceptual Relationship between Elevation and Accretion Rate



The low accretion limit for each habitat type was set at 1 mm/year or 2 mm/year as this tends to be the lower limit of longer term studies that included some storm events. The upper limit for tidal fresh marsh was set higher than salt marsh as freshwater wetlands tend to be more productive and experience higher rates of organic accretion.

While the rates of accretion were selected after this literature compilation and discussion with the Science Advisory Committee, there have been few long term measurements in Mugu Lagoon. However, another way to view these “assigned” accretion rates is that various sediment management or restoration practices could be implemented to support higher accretion rates and thus improve the resiliency of these various wetland habitats in the face of accelerating sea level rise. It should also be noted that precipitation projections in the region show a slight increase in precipitation to 2030 and then a steady decline through 2100 (ESA PWA 2013). Reduced precipitation and river run-off can reduce fluvial sediment delivery to coastal marshes. However, changes to accretion rates driven by changes in river flows were not modeled in this SLAMM study due to high uncertainty in future watershed management, river flows, and amount of sediment delivery.

5.5 Freshwater Flows

Freshwater runoff into Mugu Lagoon tends to occur rapidly and for short periods of time between November to April. During these periods the lagoon is essentially flushed and becomes fresh for short periods of time (Onuf 1987). Except for immediately at the junction between Calleguas Creek and Mugu Lagoon, the lagoon experiences marine salinities during the rest of the year, when flows from Calleguas Creek are very low. The wetlands in Mugu Lagoon are dominated by salt-tolerant plants. With future sea level rise and the possibility for decreased freshwater runoff, we anticipate that this condition will persist.

The existing wetlands at Ormond Beach are also dominated by salt water vegetation, so no “freshwater-influenced” area was delineated. There is some Freshwater Marsh (5), but it occurs at higher elevations and is expected to convert to salt marsh as sea level rises and salt water inundation occurs more frequently. No major source of constant freshwater feeds and maintains these freshwater marshes.

For these reasons, no SLAMM freshwater module was applied to the Mugu Lagoon and Ormond Beach study area. The freshwater module was, however, considered in the Ventura and Santa Clara River models, as described in Section 7.2.

6. Modeling Implementation of Future Scenarios

This section explains how the future scenarios (described in Section 2.1) were implemented in SLAMM by adjusting the input maps (Section 4) and/or site parameters (Section 5).

Sea Level Rise

SLAMM (version 6.2) calculates sea level rise based on projections that start in 1990. Since the Ventura sea level rise projections are taken relative to 2010, it was necessary to input a higher sea level rise relative to 2010 to “trick” SLAMM into implementing the correct amount of sea level rise between 2010 and 2100. Taking the high sea level rise scenario as an example, the “Custom SLR by 2100” input in the SLAMM execution options was set to 1.66 meters by 2100, relative to 1990, to obtain 1.48 meters by 2100, relative to 2010. SLAMM then uses the custom sea level rise amount to scale the A1B scenario curve to obtain the custom SLR by 2100. Additionally, SLAMM adjusts the global sea level rise to a local sea level rise using the difference between historic local and historic global (1.7 mm/year, from IPCC 2007). Since these corrections were done outside of SLAMM for the Ventura project, we set the “Historic Trend” site parameter to 1.7 mm/year to remove this unnecessary adjustment.

Management

As described in Section 2.1, SLAMM was used to model four future management scenarios: allow wetlands to transgress into all dry land, fortify developed dry land (excluding agricultural land), fortify developed dry land (including agricultural land), and fortify developed dry land (including agricultural land and managed ponds). SLAMM focuses on wetland habitats and does not model upland habitats, other than to convert them to wetlands when sea level rise causes high tides to inundate new areas. SLAMM only recognizes two types of upland areas: developed and undeveloped. Since the two fortification scenarios protect different expanses of developed dry land, two input habitat maps were created. One mapped agricultural land as “Undeveloped Dry Land” and another mapped it as “Developed Dry Land”. In the “Fortify developed dry land (including agriculture and managed ponds)” scenario, the two stretches of diked ponds are assumed to be protected. This would require fortifying/raising the levees around the ponds and extensive water management in the future, as they are currently low-lying compared to the tide frame. This scenario was implemented in SLAMM by adding a dike raster with a value of 1 in diked and “No Data” other areas. SLAMM does not allow diked areas to change habitats with sea level rise.

Accretion

Model implementation of the “High” accretion scenario is described in Section 5.4, with accretion rates presented in Table 6. The low scenario was implemented by halving the “maximum” and “minimum” accretion rates presented in Table 6.

Erosion

The “erosion of new inlet west of the NBVC” scenario was implemented by setting the tide range in site MLW1 equal to the tide range in site MLC, which is located near the main inlet.

7. The Santa Clara and Ventura River Estuaries

The Ventura River and Santa Clara River Estuaries are the two other major wetland systems in Ventura County. These regions were originally included as part of the ecological vulnerability modeling (Figure 2). This section summarizes the approach taken and explains why SLAMM was not sufficient for modeling wetland evolution with future sea level rise in these estuaries.

7.1 Site Descriptions

The Ventura River Estuary (VRE) is a bar built estuary supplied by the Ventura River (watershed area = 224 mi^2) with perennial flow and occasional extreme flood events. The lagoon is separated (closed) from the ocean by a cobble/sand bar except during and shortly after storms. The lagoon is brackish when the mouth is open, but stratifies during periods of closure (fresh on top and brackish on the bottom). Figure 8 shows an aerial photo and habitat map of this study area, and Table 8 reports habitat acreages.

The Santa Clara River Estuary (SCRE) is a bar built estuary at the end of the Santa Clara River (watershed area = 1600 mi^2). Estuary dynamics are driven by flows from the Santa Clara River (which vary greatly throughout the year), tides, wave overwash, and effluent from the Ventura Water Reclamation Facility (VWRF). The estuary tends to be open during the winter and spring, when the river flows are greatest, and closed by a sandbar during the summer and fall due to low river flows and smaller waves. Figure 9 shows an aerial photo and habitat map of this study area, and Table 8 reports habitat acreages. Both the Ventura and Santa Clara River Estuaries are dominated by freshwater wetland habitats.

Table 8. SLAMM Habitats and Acreages in the Ventura and Santa Clara River Estuaries

			Approximate Acreage (% of total area)	
ID	SLAMM Name	Ventura Name	Ventura River Estuary	Santa Clara River Estuary
1	Developed Dry Land (Including agricultural land)	Developed Uplands	1790.3 (51.2%)	6704.8 (46.9%)
2	Undeveloped Dry Land	Undeveloped Uplands	526.5 (15.1%)	583.3 (4.1%)
3	Swamp	Freshwater Wetland with Trees/Shrubs/ Riparian Forest	72.5 (2.1%)	379.2 (2.6%)
4	Cypress Swamp	N/A – Not Present	*Not Present*	*Not Present*
5	Inland Fresh Marsh	Inland Fresh Marsh	7 (0.2%)	101.3 (0.7%)
6	Tidal Fresh Marsh	Tidal Fresh Marsh	*Not Present*	*Not Present*
7	Trans. Salt Marsh (Scrub Shrub)	Tidal Estuarine Wetland with Trees/Shrubs	0.6 (0.02%)	*Not Present*
8	Regularly Flooded Marsh	Emergent Salt Marsh	6.4 (0.2%)	4.7 (0.03%)
9	Mangrove	N/A – Not Present	*Not Present*	*Not Present*
10	Estuarine Beach	N/A – Not Present	*Not Present*	2.5 (0.02%)
11	Tidal Flat	Mud Flat	1.7 (0%)	1.3 (0.01%)
12	Ocean Beach	Coastal Strand	85.4 (2.4%)	204.2 (1.4%)
13	Ocean Flat	N/A – Not Present	*Not Present*	*Not Present*
14	Rocky Intertidal	Rocky Intertidal	0.4 (0.01%)	4.6 (0.03%)
15	Inland Open Water	Open Water	0.9 (0.02%)	55.9 (0.4%)
16	Riverine Tidal Open Water	Riverine Tidal	1.4 (0.04%)	*Not Present*
17	Estuarine Water	Open Water Subtidal	9.1 (0.3%)	446.1 (3.1%)
18	Tidal Creek	Tidal Channel	*Not Present*	*Not Present*
19	Open Ocean	Open Ocean	933.1 (26.7%)	5245 (36.6%)
20	Irreg. Flooded Marsh	Rarely Flooded Salt Marsh / Salt Pans	0.9 (0.03%)	*Not Present*
21	Not Used	N/A – Not Present	*Not Present*	*Not Present*
22	Inland Shore	Arroyo / Gravel / Shore	14.5 (0.4%)	182.5 (1.3%)
23	Tidal Swamp	Tidal Wetland with Trees/Shrubs	17.9 (0.5%)	*Not Present*
24	Not Used	N/A – Not Present	*Not Present*	*Not Present*
25	Vegetated Tidal Flat	N/A – Not Present	*Not Present*	*Not Present*
26	Backshore	Dunes	26.9 (0.8%)	395.7 (2.8%)
		TOTAL	**3,495 (100%)**	**14,311 (100%)**

7.2 Seasonal Closures and Episodic Disturbances

There are two aspects of the Ventura and Santa Clara River estuaries that make them a challenge to model using SLAMM:

1. Seasonal Closures: Tide range and salinity depend almost entirely on the extent to which the estuaries are open or closed. This is a process that is not considered in SLAMM.

2. Episodic Disturbances: Habitats, geomorphology, and topography are highly dependent on rare storm events rather than a steady-state relationship with the tides. The estuary topography and habitats often change drastically during major storm events, but this is not modeled by SLAMM.

The mouths of these rivers cycle between open and closed tidal conditions and are largely controlled by the elevation of the sand bar at the entrance, which affects the duration of inundation and can cause water levels to far exceed ocean tide levels (Figure 10). These bar built systems differ significantly from Mugu lagoon and the SLAMM conceptual model, which depend on daily tidal fluctuations. Seasonally closed systems are rather unique in the U.S. and found primarily along the Southern and Central California Coast. Constructive long period waves (typically present in summer) steadily rebuild the beach, reducing the tide range and salinity exposure in the lagoon. Incoming river flows gradually raise lagoon water levels behind the beach berm, inundating higher habitats with buoyant freshwater. This results in a shift in habitats vertically relative to the open ocean tidal regime. The SLAMM conceptual model for inundation (Figure 1) assumes that wetland habitats exist in specific elevation ranges, defined by the tides rather than a higher lagoon water level. We attempted to “trick” SLAMM[16] by lifting the tide range within the lagoons to encourage wetland transgression into dry lands, but this only resulted in all the freshwater marshes converting to salt marsh at the first time step.

We anticipate that with a similar wave climate, enough sediment, and similar river flows, the estuary habitats would continue to be largely controlled, by closed lagoon water levels. If we assume that the height of the berm is related to coastal processes (waves and tides) and that the current wave climate and sediment supply persist, the typical summer berm elevation should rise at a rate similar to sea level rise. This, in turn, would likely result in higher summer lagoon water levels, allowing wetland habitats to migrate further inland.

Salinity is a very important factor in vegetation establishment, growth, and habitat function. Once the barrier beach closes, any salt water remaining in the estuary gradually seeps out through the closed beach causing a freshening of the estuary water over the summer of the lagoon. Salinity can be modeled in two ways in SLAMM. The first applies to classic salt wedge estuaries, where a relatively constant source of freshwater flows into a large estuary and a gradual transition occurs between fresh and saltwater. Vegetation type in the estuary depends on the salinity of the water at each location. The VRE and SCRE wetland systems do not function in this way – they tend to be fresh or saline, switching for short periods of time during storms or breaching events. The second option is a simpler approach, in which it is possible to delineate an area as “freshwater influenced”. Within these areas, regardless of connectivity to the ocean, freshwater wetlands follow a separate decision tree of freshwater wetland types before converting to salt marsh. However, this approach still assumes that freshwater habitats are controlled by ocean tides, which is not the case. This module was added in the most recent version of SLAMM, and according to the model developers, is still in development. The elevation that converts dry land to salt marsh (the salt elevation) is the same elevation that converts dry land to freshwater

[16] Since SLAMM is open source, it could be modified to account for the vertical shifts in elevation bands observed in seasonally closed lagoons. However, reprogramming SLAMM would be a substantial effort and likely involve collaboration with the model developers.

marsh. Changing this would require re-coding of SLAMM and a good understanding of the elevation, relative to mean sea level, that leads dry land to convert to wetland.

As a result of the complexities of these two bar built estuaries and the lack of adequate representation of the formative physical processes in SLAMM, these two systems were removed from further analysis after consultation with the Science Advisory Committee and Project Development team.

8. List of Preparers

This report was prepared by Elena Vandebroek, P.E. and David Revell, Ph.D.

9. References

Aquatic Bioassay & Consulting (ABC) (2004). “Santa Clara River Estuary Macroinvertebrate Bioassessment Monitoring: Annual Report 2003.” Prepared for the City of San Buenaventura on March 2004. Ventura, CA.

Barnard, P.L., and D. Hoover, (2010), A seamless, high-resolution coastal digital elevation model (DEM) for southern California. U.S. Geological Survey Data Series 487, 8 p. and database.

Beller, E.E., R.M. Grossinger, M.N. Salomon, S.J. Dark, E.D. Stein, B.K. Orr, P.W. Downs, .T.R Longcore, G.C. Coffman, A.A. Whipple, R.A. Askevold, B. Stanford, J.R. Beagle (2011). Historical ecology of the lower Santa Clara River, Ventura River, and Oxnard Plain: an analysis of terrestrial, riverine, and coastal habitats. Prepared for the State Coastal Conservancy. A report of SFEI’s Historical Ecology Program, SFEI Publication #641, San Francisco Estuary Institute, Oakland, CA.

Bruun, P. (1962), Sea level rise as a cause of shore erosion. Journal Waterways and Harbours Division, 88(1-3), 117-130.

Cahoon, D. R., and D. J. Reed (1995). Relationships among marsh surface topography, hydroperiod, and soil accretion in a deteriorating Louisiana salt marsh, J. Coastal Res., 11, 357–369.

Cahoon, D.R., J.C. Lynch, and A.N. Powell (1996) Marsh vertical accretion in a Southern California estuary, U.S.A. Estuarine, Coastal and Shelf Science 43, 19-32.

Chan, V.A., Ambrose, R.F., Vance, R.R. (2012). Vegetation change and accretion rates after fourteen years at three tidal wetlands in Southern California. Manuscript submitted for publication.

Clough, J.S. and E.C. Larson, Warren Pinnacle Consulting, Inc. (2009a). SLAMM Analysis of Kenai Peninsula and Anchorage, AK: Final Report. Prepared for National Wildlife Federation, Anchorage AK, and U.S. Fish & Wildlife Service, Anchorage AK. December 28, 2009.

Clough, J.S. and E.C. Larson, Warren Pinnacle Consulting, Inc. (2009b). Application of the Sea-Level Affecting Marshes Model (SLAMM 5.1) to Tijuana Slough NWR. Prepared for U.S. Fish and Wildlife Service. October 15, 2009.

Clough, J.S. and E.C. Larson, Warren Pinnacle Consulting, Inc. (2010). Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Don Edwards NWR. Prepared for U.S. Fish and Wildlife Service. March 3, 2010.

ENTRIX, Inc. (2002). “Resident Species Study Santa Clara River Estuary. Ventura Water Reclamation Facility NPDES Permit No. CA0053651, CI-1822.” Prepared for City of San Buenaventura on Sept 17, 2002. Ventura, CA.

ESA PWA (2013). Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping. Prepared by ESA PWA, San Francisco, for The Nature Conservancy. July 2013.

ESA PWA (2014). Coastal Resilience Ventura: Implications of Sea Level Rise Adaptation Strategies on Greenhouse Gas Sequestration at Mugu Lagoon and Ormond Beach. Prepared by ESA PWA, San Francisco, for The Nature Conservancy. March 2014.

Ferren, W.R. et al. (1990). Botanical Resources at Emma Wood State Beach and the Ventura River Estuary, California: Inventory and Management. Santa Barbara, CA : Environmental Research Team, Herbarium, the Department of Biological Sciences, University of California, University of California, Santa Barbara. Environmental Report No. 15. 310 p.

Glick, P., J. Clough, and B. Nunley, National Wildlife Federation (2007). Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. July 2007.

HDR (2008) J Street Drain/Ormond Beach Lagoon Coastal Engineering Report. Prepared for the Ventura County Watershed Protection District. November 2008.

Inman, D.L. and S. A. Jenkins (1999). Climate Change and the Episodicity of Sediment Flux of Small California Rivers. Journal of Geology v.107 p. 251-270.

Krone, R.B. (1985). Simulation of Marsh Growth under Rising Sea Levels. Proceedings of the Specialty Conference sponsored by the Hydraulics Division of the American Society of Civil Engineers. Lake Buena Vista, Florida. August 12-17, 1985.

Marion, C., E. J. Anthony, and A. Trentesaux (2009). Short-term (<= 2 yrs) estuarine mudflat and saltmarsh sedimentation: High-resolution data from ultrasonic altimetery, rod surface elevation table, and filter traps, Estuarine Coastal Shelf Sci., 83, 475–484, doi:10.1016/j.ecss.2009.03.039.

Mudie, P. J. and Byrne, R. (1980). Pollen evidence for historic sedimentation rates in California coastal marshes. Estuarine and Coastal Marine Science 10, 305–316.

NRC (2012). “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.” Prepublication. National Academy Press: Washington, D. C.

NOAA (2005b). “Rincon Island, CA Station Tidal Datum.” NOAA National Ocean Service Tides & Currents. Station ID: 9411270. Available online: http://tidesandcurrents.noaa.gov/.

NOAA (2012a). “2009 – 2011 CA Coastal Conservancy Coastal LiDAR Project: Hydro-flattened Bare Earth DEM.” NOAA Coastal Services Center. Charleston, South Carolina. Available online: http://www.csc.noaa.gov/dataviewer/#.

Onuf, C. (1987). The ecology of Mugu Lagoon, California: an estuarine profile. U.S. Fish and Wildlife Service, Biological Report 85 (7.15), 122 pp.

Resource Management Associates, Inc (RMA) (2003). Mugu Lagoon Numerical Model Development, Final Report. Prepared for U.S. Army Corps of Engineers Los Angeles District. May 2003.

Rosencranz, J. 2012. Accretion, Sediment Deposition, and Suspended Sediment Dynamics in Mugu Lagoon, a Southern California Estuary. Master of Science at University of California, Los Angeles under R. Ambrose.

Stillwater Sciences (2007). Assessment of Geomorphic Processes for the Santa Clara River Watershed, Ventura and Los Angeles counties, California. Final Report. Prepared for The California Coastal Conservancy. August 2007.

Stillwater Sciences (2010). City of Ventura Special Studies: Estuary Subwatershed Study, Draft Year One Data Summary and Assessment. Prepared by Stillwater Sciences, Berkeley California for the City of Ventura. January 2010.

Stoddart, D. R., D. J. Reed, and J. R. French (1989). Understanding salt marsh accretion, Scolt Head Island, Norfolk, England, Estuaries, 12(4), 228–236, doi:10.2307/1351902.

USACE (2011). “Sea-Level Change Considerations for Civil Works Programs.” US Army Corps of Engineers, EC 1165-2-212.

Wallace, K., J. Callaway, and J. Zedler (2005) Evolution of tidal creek networks in a high sedimentation environment: A 5-year experiment at Tijuana Estuary, California. Estuaries Vol. 28, No. 6, p. 795-811.

Warren Pinnacle Consulting, Inc. (WPC) (2011). Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Galveston Bay. Prepared for The Nature Conservancy. June 30, 2011.

Warren Pinnacle Consulting, Inc. (WPC) (2012). SLAMM 6.2 Technical Documentation. December 7, 2012.

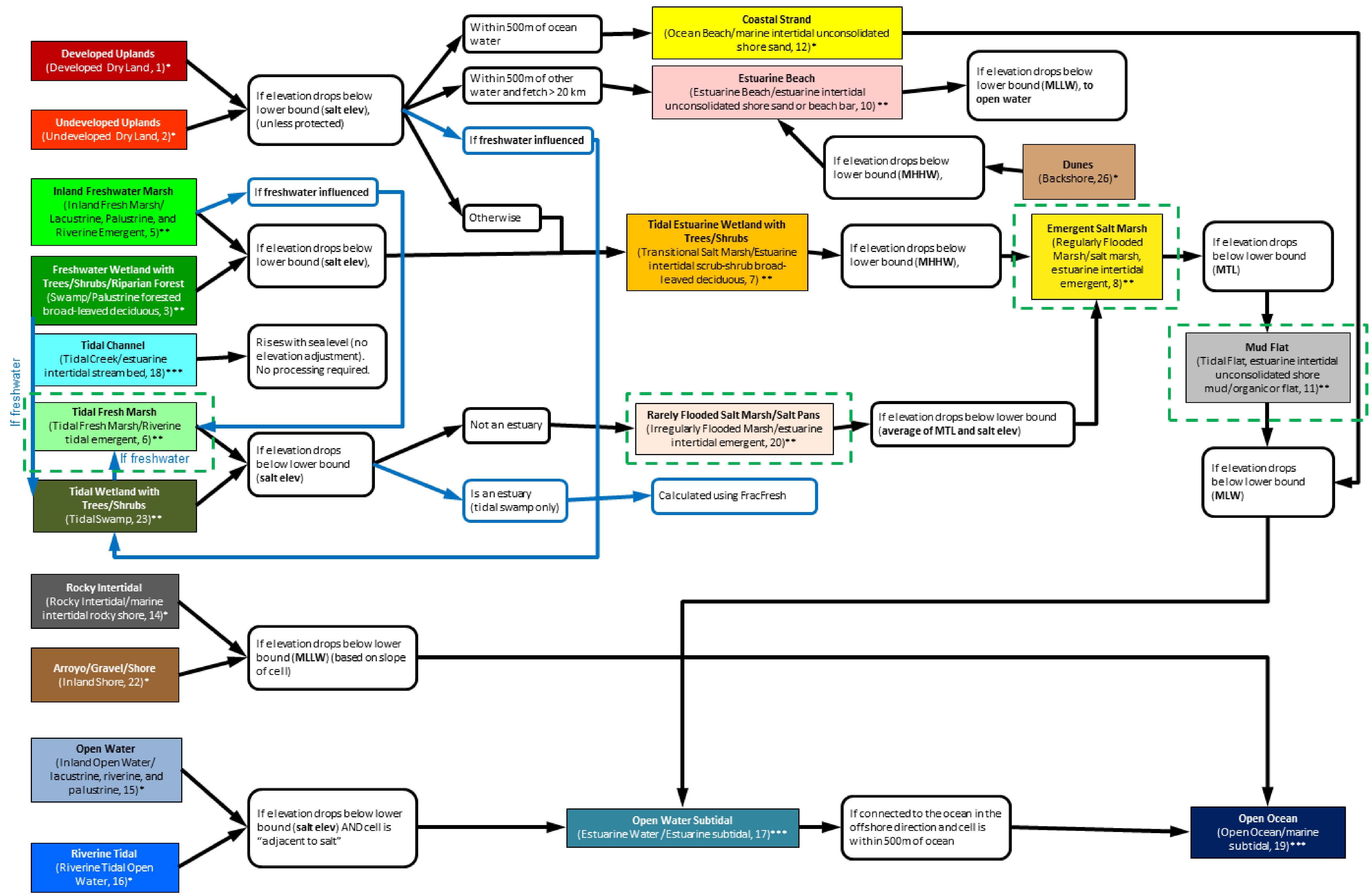
Wasson, K. (2011) Elkhorn Slough Bank Erosion Monitoring: A synthesis of results. Powerpoint Presentation.

Watson, E. (2008) Dating recent sedimentation rates in healthy marsh at Elkhorn Slough using Pb-210 and Cs-137 dating methods. Prepared for Bryan Largay, Tidal Wetland Project Director at Elkhorn Slough National Estuarine Research Reserve.

Weis, D.A., J.C. Callaway, and R.M. Gersberg (2001). Vertical accretion rates an heavy metal chronologies in wetland sediments of the Tijuana Estuary. Estuaries. Vol. 24 No. 6A. p. 840-850. December 2001.

Van Dyke, E. (2012). Water levels, wetland elevations, and marsh loss. Elkhorn Slough Technical Report Series 2012:2.

Xu, J.P., P.W. Swarzenski, M. Noble, and A. Li (2010). Event-driven sediment flux in Hueneme and Mugu submarine canyons, southern California. Marine Geology. Vol. 269, Issues 1-2, 15 February 2010, Pages 74-88. ISSN 0025-3227.



* Adjusted for SLR only
** Adjusted with equations (8) & (9) for SLR and accretion (if not protected by a dike).
*** Assumed to rise with sea level, so no elevation adjustment required.

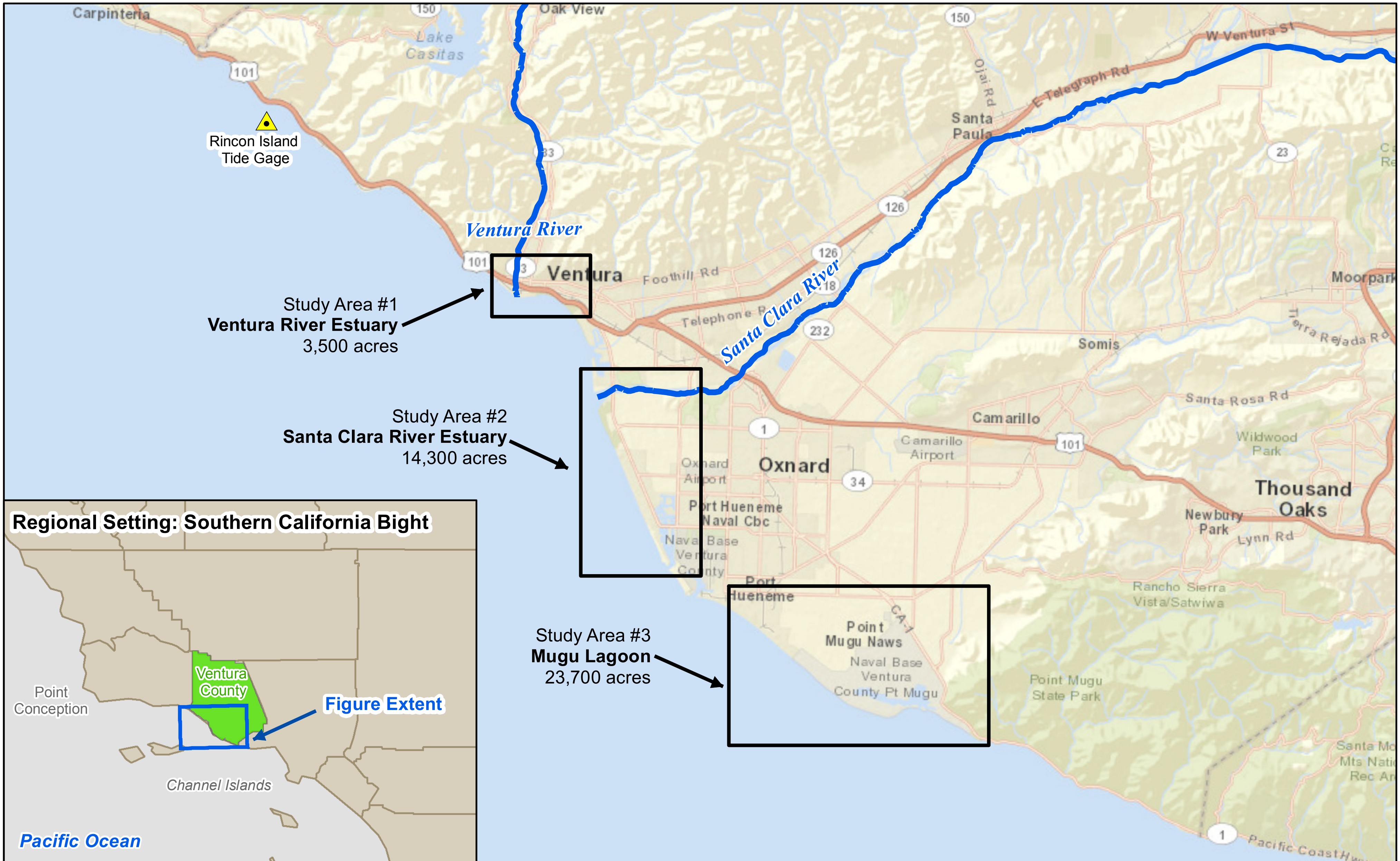
Note: This is one of the decision trees that exist in SLAMM. Others exist for erosion and saturation. This chart was developed by ESA PWA using the SLAMM 6.2 Technical Documentation as the primary reference.

figure 1
Ventura County Climate Change Vulnerability Assessment

SLAMM Conceptual Model for Inundation

ESA PWA Ref# D211452.00

ESA PWA



Basemap Credits: Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

2/24/2014

N

0 2.5 5 Miles

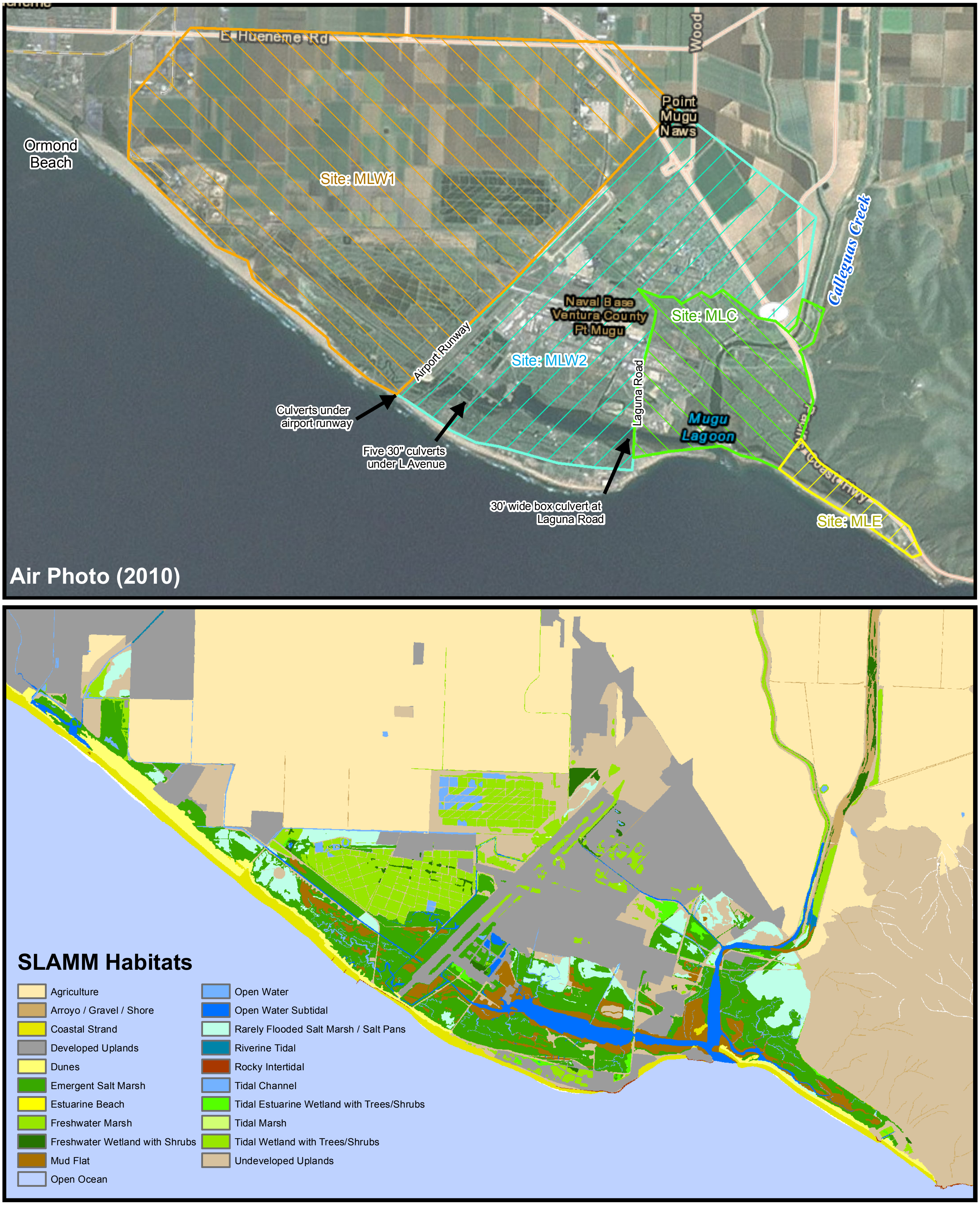
figure 2

Ventura County Climate Change Vulnerability Study

SLAMM Study Areas

ESA PWA Ref# - D211452

ESA PWA



N

0 2,500 5,000 Feet

figure 3

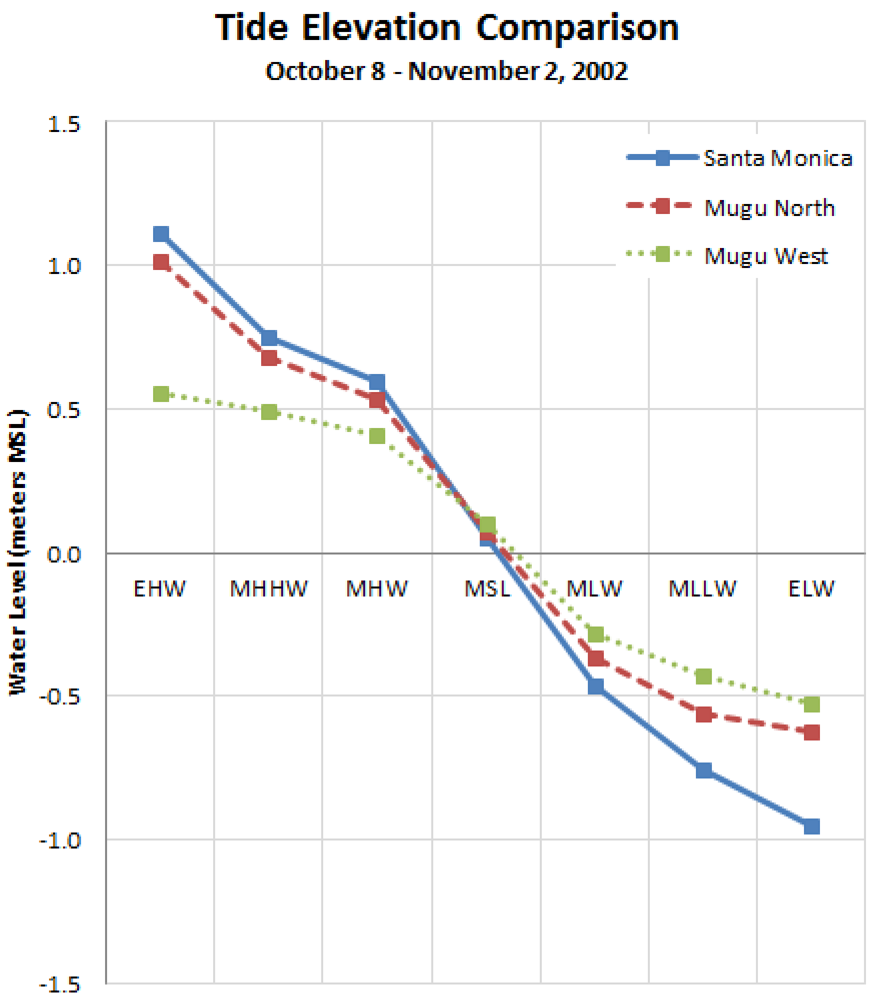
Ventura County Climate Change Vulnerability Study

Site Map: Mugu Lagoon and Ormond Beach

ESA PWA Ref# - D211452

ESA PWA

Relative to Santa Monica	Mugu West	Mugu North
MHHW relative to MSL	56%	87%
Change in Mean Sea Level	+5.2 cm	+2.4 cm
Reduction in GDTR	61%	83%



Source: RMA (2003). Mugu Lagoon Numerical Model Development, Final Report. Prepared for U.S. Army Corps of Engineers Los Angeles District. May 2003.

figure **5**

Ventura County Climate Change Vulnerability Assessment

Mugu Lagoon Tidal Water Level Comparison

ESA PWA Ref# D211452.00

ESA PWA

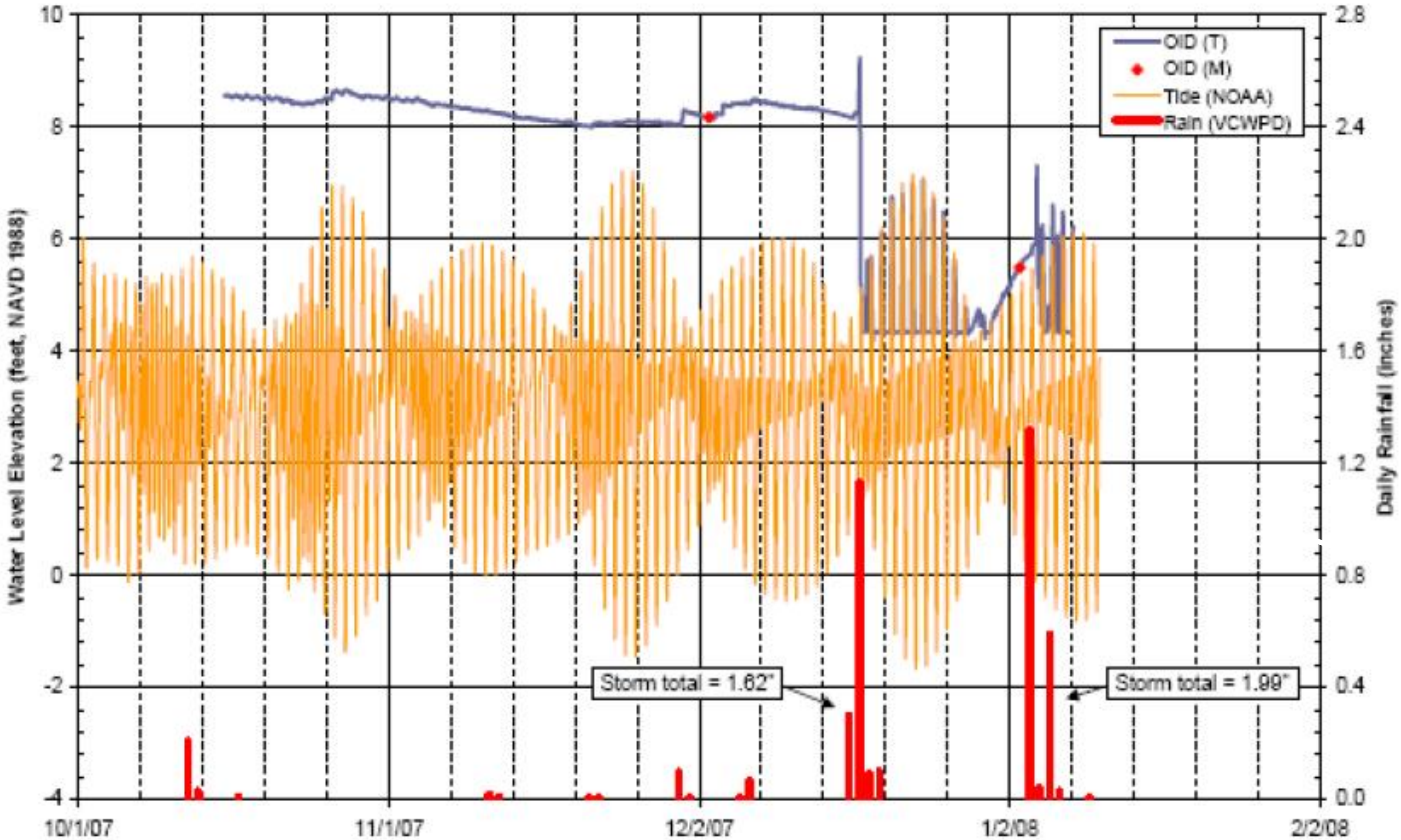


Figure 5.9. Water level in the lagoon 10/2007 – 1/2008 (CH2M Hill 2008).

Source: CH2M Hill (2008) as cited in HDR (2008) J Street Drain/Ormond Beach Lagoon Coastal Engineering Report. Prepared for the Ventura County Watershed Protection District. November 2008.

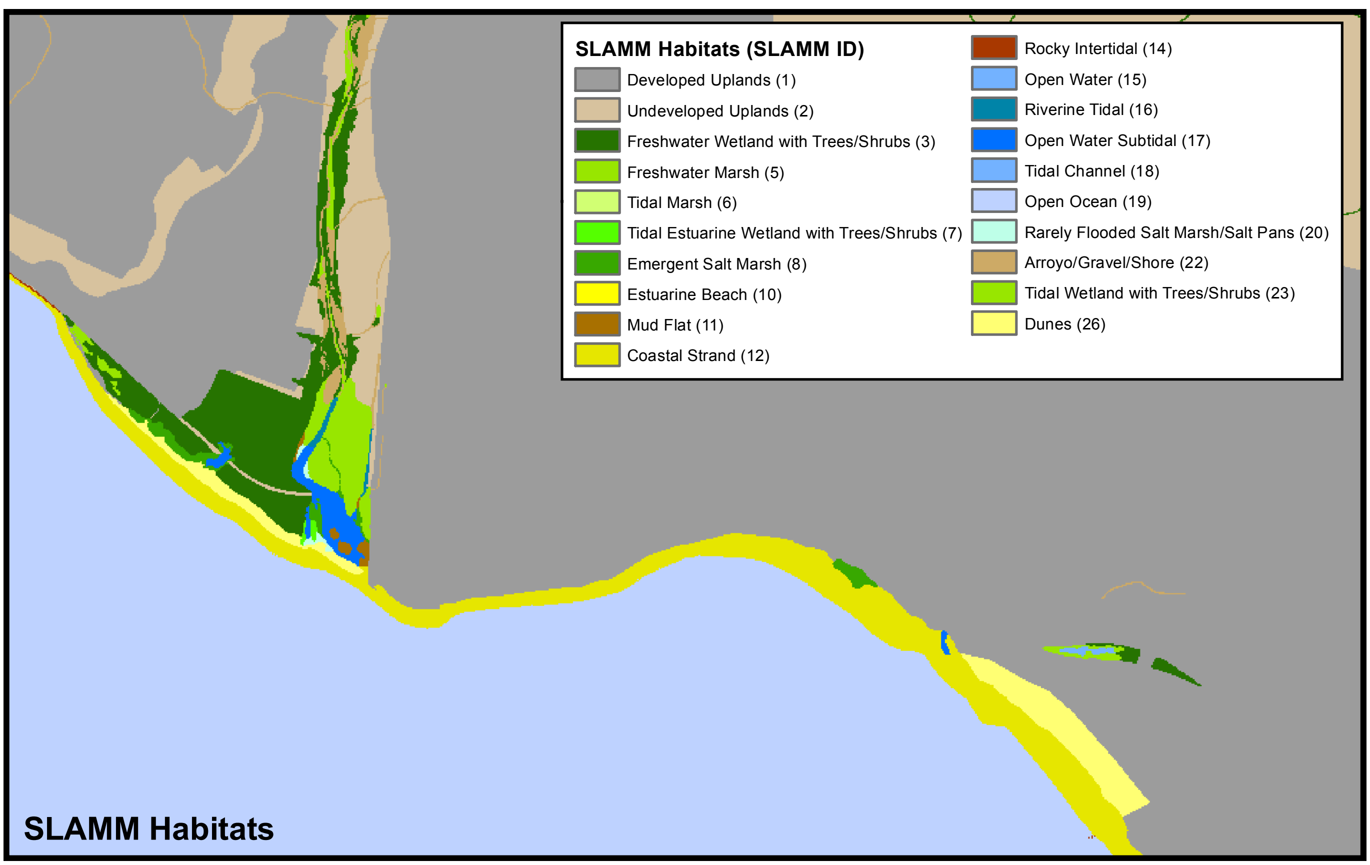
figure ***6***

Ventura County Climate Change Vulnerability Assessment

Ormond Beach Lagoon Water Levels

ESA PWA Ref# D211452.00

ESA PWA



Please see Figure 2 for a regional map.

N

0 1,000 2,000 Feet

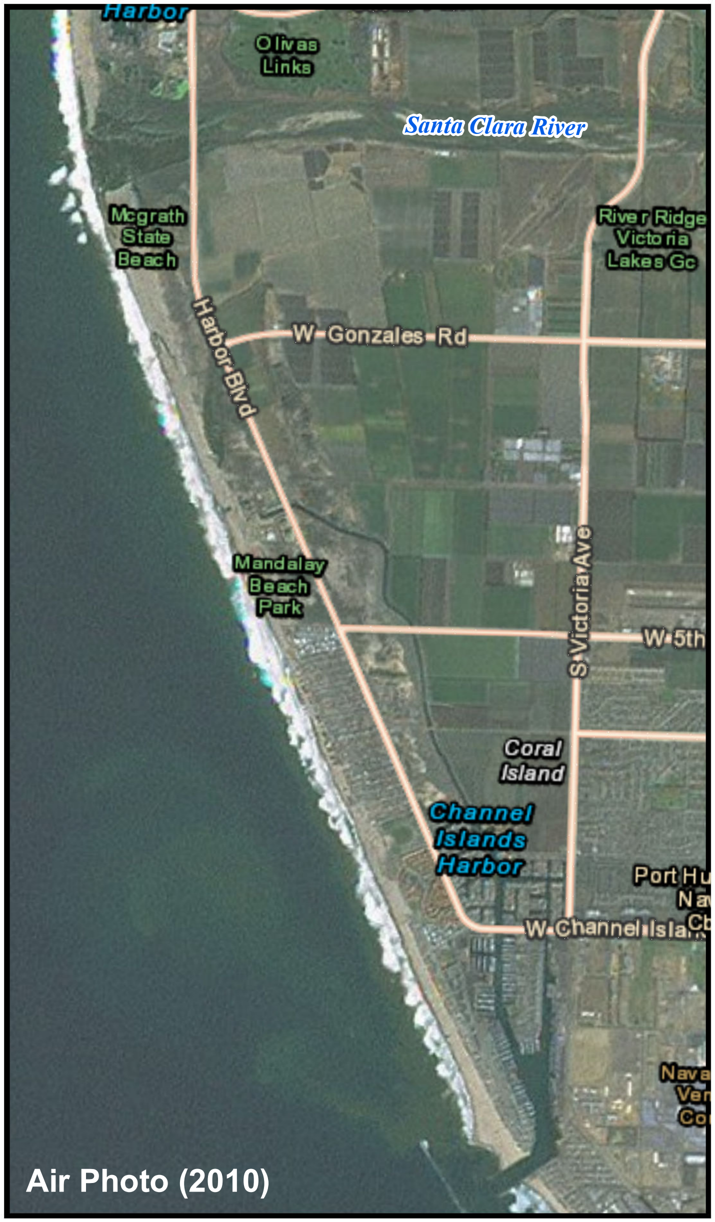
figure ***8***

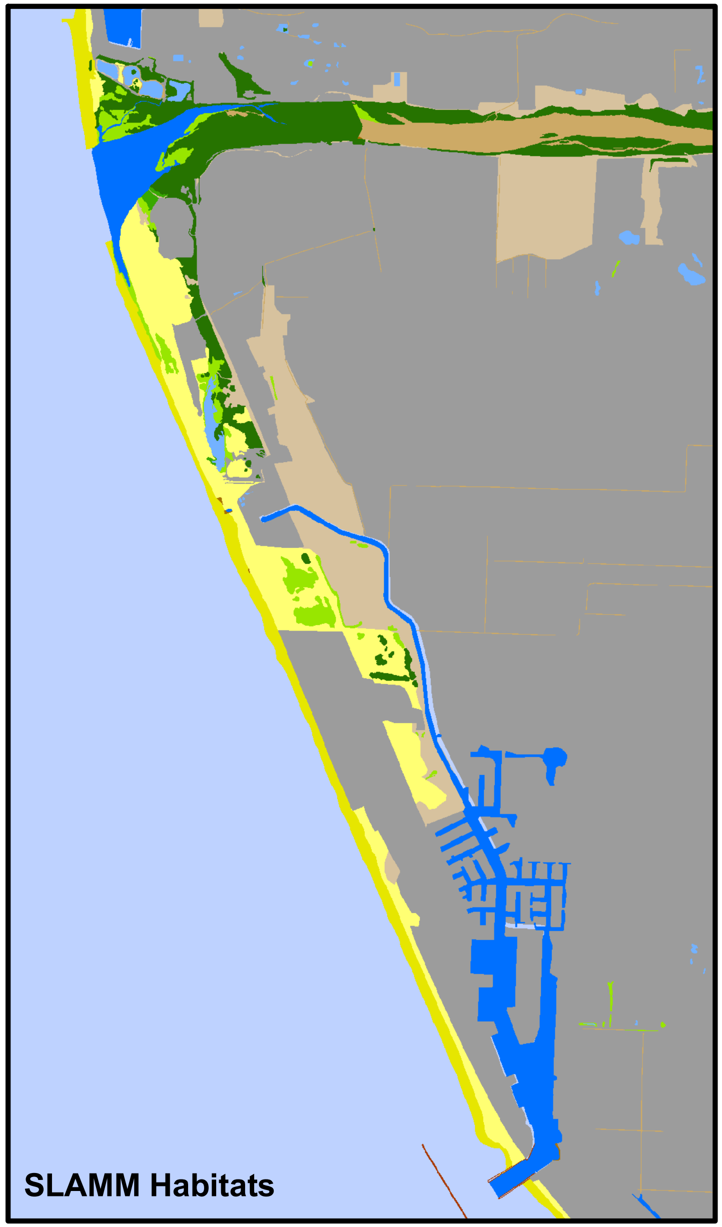
Ventura County Climate Change Vulnerability Study

Site Map: Ventura River Estuary

ESA PWA Ref# - D211452

ESA PWA





SLAMM Habitats (SLAMM ID)

- Developed Uplands (1)
- Undeveloped Uplands (2)
- Freshwater Wetland with Trees/Shrubs (3)
- Freshwater Marsh (5)
- Tidal Marsh (6)
- Tidal Estuarine Wetland with Trees/Shrubs (7)
- Emergent Salt Marsh (8)
- Estuarine Beach (10)
- Mud Flat (11)
- Coastal Strand (12)
- Rocky Intertidal (14)
- Open Water (15)
- Riverine Tidal (16)
- Open Water Subtidal (17)
- Tidal Channel (18)
- Open Ocean (19)
- Rarely Flooded Salt Marsh/Salt Pans (20)
- Arroyo/Gravel/Shore (22)
- Tidal Wetland with Trees/Shrubs (23)
- Dunes (26)

Please see Figure 2 for a regional map.

N

0 2,500 5,000 Feet

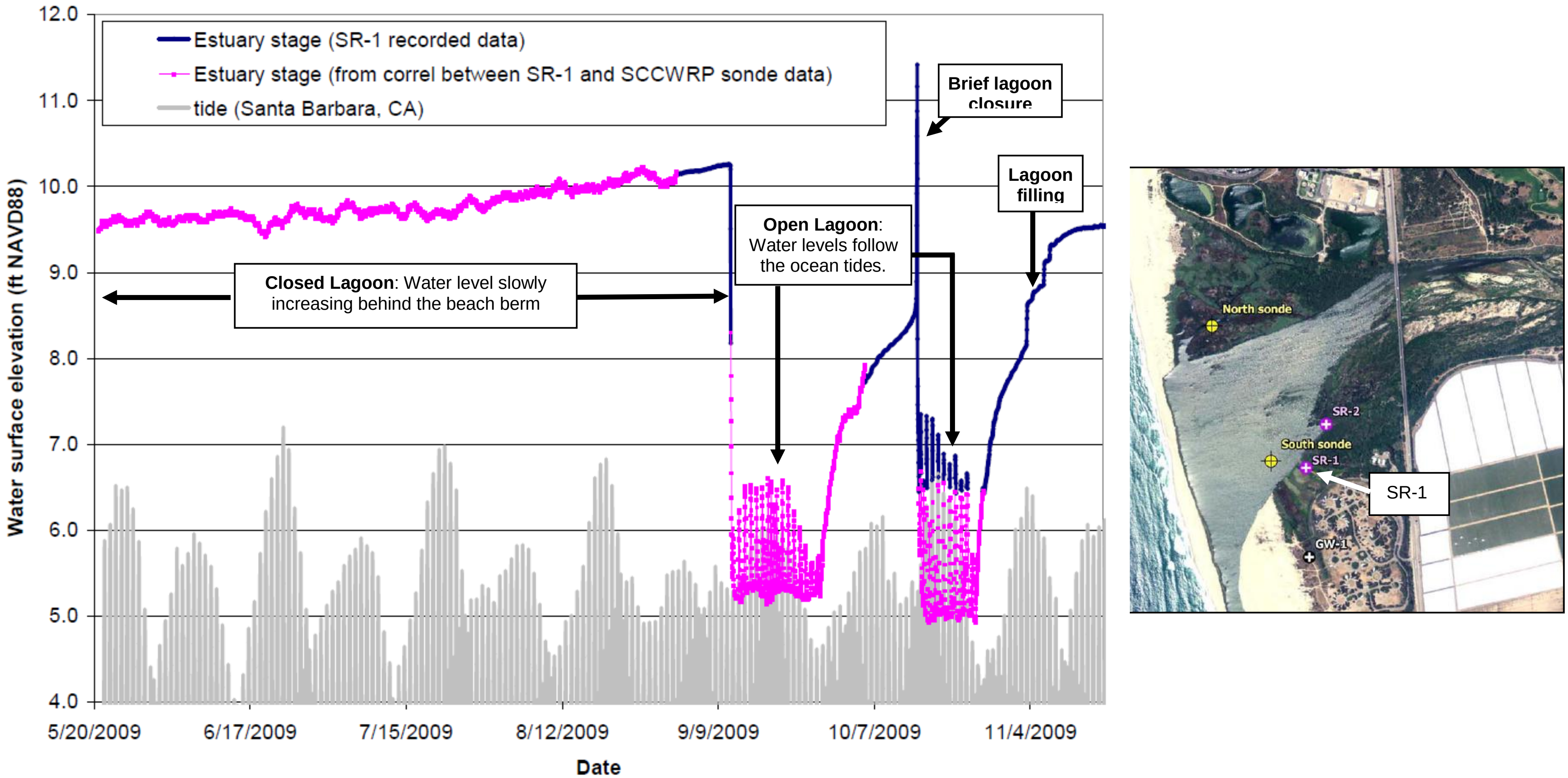
figure 9

Ventura County Climate Change Vulnerability Study

Site Map: Santa Clara River Estuary

ESA PWA Ref# - D211452

ESA PWA



Source: Adapted from Stillwater Sciences (2010). City of Ventura Special Studies: Estuary Subwatershed Study, Draft Year One Data Summary and Assessment. Prepared by Stillwater Sciences, Berkeley California for the City of Ventura. January 2010.

figure ***10***

Ventura County Climate Change Vulnerability Assessment

Water Levels in the Santa Clara River Estuary

ESA PWA Ref# D211452.00

ESA PWA

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		Accretion		Erosion of New Inlet		Management		Planning Horizon	Figure	ESA Model Run
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
ec_2010	GRID Raster	None	ec	N/A	N/A	N/A	N/A	N/A	N/A	2010	All	N/A - input
s1a1e1m12020	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2020	--	Run3-47
s1a1e1m12030	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2030	B.2	Run3-47
s1a1e1m12040	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2040	--	Run3-47
s1a1e1m12050	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2050	--	Run3-47
s1a1e1m12060	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2060	B.2	Run3-47
s1a1e1m12070	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2070	--	Run3-47
s1a1e1m12080	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2080	--	Run3-47
s1a1e1m12090	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2090	--	Run3-47
s1a1e1m12100	GRID Raster	Low	s1	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2100	B.2	Run3-47
s1a1e1m22020	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-47
s1a1e1m22030	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2030	B.3	Run3-47
s1a1e1m22040	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-47
s1a1e1m22050	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-47
s1a1e1m22060	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2060	B.3	Run3-47
s1a1e1m22070	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-47
s1a1e1m22080	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-47
s1a1e1m22090	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-47
s1a1e1m22100	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2100	B.3	Run3-47
s1a1e1m32020	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-47b
s1a1e1m32030	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2030	B.4	Run3-47b
s1a1e1m32040	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-47b
s1a1e1m32050	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-47b
s1a1e1m32060	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2060	B.4	Run3-47b
s1a1e1m32070	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-47b
s1a1e1m32080	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-47b
s1a1e1m32090	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-47b
s1a1e1m32100	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2100	B.4	Run3-47b
s1a1e1m42020	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-47c
s1a1e1m42030	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.5	Run3-47c
s1a1e1m42040	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-47c
s1a1e1m42050	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-47c
s1a1e1m42060	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.5	Run3-47c
s1a1e1m42070	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-47c
s1a1e1m42080	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-47c
s1a1e1m42090	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-47c
s1a1e1m42100	GRID Raster	Low	s1	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.5	Run3-47c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		**Accretion**		**Erosion of New Inlet**		**Management**		**Planning Horizon**	**Figure**	**ESA Model Run**
File Name	**File Type**	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s1a1e2m12020	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2020	--	Run3-51
s1a1e2m12030	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2030	B.6	Run3-51
s1a1e2m12040	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2040	--	Run3-51
s1a1e2m12050	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2050	--	Run3-51
s1a1e2m12060	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2060	B.6	Run3-51
s1a1e2m12070	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2070	--	Run3-51
s1a1e2m12080	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2080	--	Run3-51
s1a1e2m12090	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2090	--	Run3-51
s1a1e2m12100	GRID Raster	Low	s1	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2100	B.6	Run3-51
s1a1e2m22020	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-51
s1a1e2m22030	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2030	B.7	Run3-51
s1a1e2m22040	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-51
s1a1e2m22050	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-51
s1a1e2m22060	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2060	B.7	Run3-51
s1a1e2m22070	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-51
s1a1e2m22080	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-51
s1a1e2m22090	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-51
s1a1e2m22100	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2100	B.7	Run3-51
s1a1e2m32020	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-51b
s1a1e2m32030	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2030	B.8	Run3-51b
s1a1e2m32040	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-51b
s1a1e2m32050	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-51b
s1a1e2m32060	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2060	B.8	Run3-51b
s1a1e2m32070	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-51b
s1a1e2m32080	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-51b
s1a1e2m32090	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-51b
s1a1e2m32100	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2100	B.8	Run3-51b
s1a1e2m42020	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-51c
s1a1e2m42030	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.9	Run3-51c
s1a1e2m42040	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-51c
s1a1e2m42050	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-51c
s1a1e2m42060	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.9	Run3-51c
s1a1e2m42070	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-51c
s1a1e2m42080	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-51c
s1a1e2m42090	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-51c
s1a1e2m42100	GRID Raster	Low	s1	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.9	Run3-51c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red****. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		Accretion		Erosion of New Inlet		Management		Planning Horizon	Figure	ESA Model Run
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s1a2e1m12020	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2020	--	Run3-46
s1a2e1m12030	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2030	B.10	Run3-46
s1a2e1m12040	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2040	--	Run3-46
s1a2e1m12050	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2050	--	Run3-46
s1a2e1m12060	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2060	B.10	Run3-46
s1a2e1m12070	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2070	--	Run3-46
s1a2e1m12080	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2080	--	Run3-46
s1a2e1m12090	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2090	--	Run3-46
s1a2e1m12100	GRID Raster	Low	s1	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2100	B.10	Run3-46
s1a2e1m22020	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-46
s1a2e1m22030	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2030	B.11	Run3-46
s1a2e1m22040	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-46
s1a2e1m22050	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-46
s1a2e1m22060	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2060	B.11	Run3-46
s1a2e1m22070	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-46
s1a2e1m22080	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-46
s1a2e1m22090	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-46
s1a2e1m22100	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2100	B.11	Run3-46
s1a2e1m32020	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-46b
s1a2e1m32030	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2030	B.12	Run3-46b
s1a2e1m32040	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-46b
s1a2e1m32050	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-46b
s1a2e1m32060	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2060	B.12	Run3-46b
s1a2e1m32070	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-46b
s1a2e1m32080	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-46b
s1a2e1m32090	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-46b
s1a2e1m32100	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2100	B.12	Run3-46b
s1a2e1m42020	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-46c
s1a2e1m42030	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.13	Run3-46c
s1a2e1m42040	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-46c
s1a2e1m42050	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-46c
s1a2e1m42060	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.13	Run3-46c
s1a2e1m42070	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-46c
s1a2e1m42080	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-46c
s1a2e1m42090	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-46c
s1a2e1m42100	GRID Raster	Low	s1	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.13	Run3-46c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		Accretion		Erosion of New Inlet		Management		Planning Horizon	Figure	ESA Model Run
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s1a2e2m12020	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2020	--	Run3-50
s1a2e2m12030	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2030	B.14	Run3-50
s1a2e2m12040	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2040	--	Run3-50
s1a2e2m12050	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2050	--	Run3-50
s1a2e2m12060	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2060	B.14	Run3-50
s1a2e2m12070	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2070	--	Run3-50
s1a2e2m12080	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2080	--	Run3-50
s1a2e2m12090	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2090	--	Run3-50
s1a2e2m12100	GRID Raster	Low	s1	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2100	B.14	Run3-50
s1a2e2m22020	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-50
s1a2e2m22030	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2030	B.15	Run3-50
s1a2e2m22040	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-50
s1a2e2m22050	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-50
s1a2e2m22060	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2060	B.15	Run3-50
s1a2e2m22070	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-50
s1a2e2m22080	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-50
s1a2e2m22090	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-50
s1a2e2m22100	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2100	B.15	Run3-50
s1a2e2m32020	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-50b
s1a2e2m32030	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2030	B.16	Run3-50b
s1a2e2m32040	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-50b
s1a2e2m32050	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-50b
s1a2e2m32060	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2060	B.16	Run3-50b
s1a2e2m32070	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-50b
s1a2e2m32080	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-50b
s1a2e2m32090	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-50b
s1a2e2m32100	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2100	B.16	Run3-50b
s1a2e2m42020	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-50c
s1a2e2m42030	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.17	Run3-50c
s1a2e2m42040	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-50c
s1a2e2m42050	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-50c
s1a2e2m42060	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.17	Run3-50c
s1a2e2m42070	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-50c
s1a2e2m42080	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-50c
s1a2e2m42090	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-50c
s1a2e2m42100	GRID Raster	Low	s1	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.17	Run3-50c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		Accretion		Erosion of New Inlet		Management		Planning Horizon	Figure	ESA Model Run
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s3a1e1m12020	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2020	--	Run3-45
s3a1e1m12030	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2030	B.18	Run3-45
s3a1e1m12040	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2040	--	Run3-45
s3a1e1m12050	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2050	--	Run3-45
s3a1e1m12060	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2060	B.18	Run3-45
s3a1e1m12070	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2070	--	Run3-45
s3a1e1m12080	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2080	--	Run3-45
s3a1e1m12090	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2090	--	Run3-45
s3a1e1m12100	GRID Raster	High	s3	Low	a1	No	e1	Allow marshes to transgress into dry land	m1	2100	B.18	Run3-45
s3a1e1m22020	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-45
s3a1e1m22030	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2030	B.19	Run3-45
s3a1e1m22040	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-45
s3a1e1m22050	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-45
s3a1e1m22060	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2060	B.19	Run3-45
s3a1e1m22070	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-45
s3a1e1m22080	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-45
s3a1e1m22090	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-45
s3a1e1m22100	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (excluding agriculture)	m2	2100	B.19	Run3-45
s3a1e1m32020	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-45b
s3a1e1m32030	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2030	B.20	Run3-45b
s3a1e1m32040	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-45b
s3a1e1m32050	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-45b
s3a1e1m32060	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2060	B.20	Run3-45b
s3a1e1m32070	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-45b
s3a1e1m32080	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-45b
s3a1e1m32090	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-45b
s3a1e1m32100	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture)	m3	2100	B.20	Run3-45b
s3a1e1m42020	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-45c
s3a1e1m42030	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.21	Run3-45c
s3a1e1m42040	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-45c
s3a1e1m42050	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-45c
s3a1e1m42060	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.21	Run3-45c
s3a1e1m42070	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-45c
s3a1e1m42080	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-45c
s3a1e1m42090	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-45c
s3a1e1m42100	GRID Raster	High	s3	Low	a1	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.21	Run3-45c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios										
		Sea Level Rise		Accretion		Erosion of New Inlet		Management		Planning Horizon	Figure	ESA Model Run
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s3a1e2m12020	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2020	--	Run3-49
s3a1e2m12030	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2030	B.22	Run3-49
s3a1e2m12040	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2040	--	Run3-49
s3a1e2m12050	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2050	--	Run3-49
s3a1e2m12060	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2060	B.22	Run3-49
s3a1e2m12070	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2070	--	Run3-49
s3a1e2m12080	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2080	--	Run3-49
s3a1e2m12090	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2090	--	Run3-49
s3a1e2m12100	GRID Raster	High	s3	Low	a1	Yes	e2	Allow marshes to transgress into dry land	m1	2100	B.22	Run3-49
s3a1e2m22020	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-49
s3a1e2m22030	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2030	B.23	Run3-49
s3a1e2m22040	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-49
s3a1e2m22050	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-49
s3a1e2m22060	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2060	B.23	Run3-49
s3a1e2m22070	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-49
s3a1e2m22080	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-49
s3a1e2m22090	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-49
s3a1e2m22100	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2100	B.23	Run3-49
s3a1e2m32020	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-49b
s3a1e2m32030	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2030	B.24	Run3-49b
s3a1e2m32040	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-49b
s3a1e2m32050	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-49b
s3a1e2m32060	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2060	B.24	Run3-49b
s3a1e2m32070	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-49b
s3a1e2m32080	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-49b
s3a1e2m32090	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-49b
s3a1e2m32100	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture)	m3	2100	B.24	Run3-49b
s3a1e2m42020	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-49c
s3a1e2m42030	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.25	Run3-49c
s3a1e2m42040	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-49c
s3a1e2m42050	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-49c
s3a1e2m42060	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.25	Run3-49c
s3a1e2m42070	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-49c
s3a1e2m42080	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-49c
s3a1e2m42090	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-49c
s3a1e2m42100	GRID Raster	High	s3	Low	a1	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.25	Run3-49c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios								Planning Horizon	Figure	ESA Model Run
		Sea Level Rise		Accretion		Erosion of New Inlet		Management				
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s3a2e1m12020	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2020	--	Run3-44
s3a2e1m12030	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2030	B.26	Run3-44
s3a2e1m12040	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2040	--	Run3-44
s3a2e1m12050	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2050	--	Run3-44
s3a2e1m12060	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2060	B.26	Run3-44
s3a2e1m12070	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2070	--	Run3-44
s3a2e1m12080	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2080	--	Run3-44
s3a2e1m12090	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2090	--	Run3-44
s3a2e1m12100	GRID Raster	High	s3	High	a2	No	e1	Allow marshes to transgress into dry land	m1	2100	B.26	Run3-44
s3a2e1m22020	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-44
s3a2e1m22030	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2030	B.27	Run3-44
s3a2e1m22040	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-44
s3a2e1m22050	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-44
s3a2e1m22060	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2060	B.27	Run3-44
s3a2e1m22070	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-44
s3a2e1m22080	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-44
s3a2e1m22090	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-44
s3a2e1m22100	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (excluding agriculture)	m2	2100	B.27	Run3-44
s3a2e1m32020	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-44b
s3a2e1m32030	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2030	B.28	Run3-44b
s3a2e1m32040	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-44b
s3a2e1m32050	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-44b
s3a2e1m32060	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2060	B.28	Run3-44b
s3a2e1m32070	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-44b
s3a2e1m32080	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-44b
s3a2e1m32090	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-44b
s3a2e1m32100	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture)	m3	2100	B.28	Run3-44b
s3a2e1m42020	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-44c
s3a2e1m42030	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.29	Run3-44c
s3a2e1m42040	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-44c
s3a2e1m42050	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-44c
s3a2e1m42060	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.29	Run3-44c
s3a2e1m42070	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-44c
s3a2e1m42080	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-44c
s3a2e1m42090	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-44c
s3a2e1m42100	GRID Raster	High	s3	High	a2	No	e1	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.29	Run3-44c

Appendix A. Table of SLAMM Deliverables

Note: The "allow erosion of new inlet" scenario is not recommended for display on the web map or for release to the public. The file names of these outputs are highlighted in ***red*** *. Please see section 6.3 of main report for explanation.*

		Scenarios								Planning Horizon	Figure	ESA Model Run
		Sea Level Rise		Accretion		Erosion of New Inlet		Management				
File Name	File Type	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Description*	*sym*	*Year*	*in Appendix B*	*#*
s3a2e2m12020	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2020	--	Run3-48
s3a2e2m12030	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2030	B.30	Run3-48
s3a2e2m12040	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2040	--	Run3-48
s3a2e2m12050	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2050	--	Run3-48
s3a2e2m12060	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2060	B.30	Run3-48
s3a2e2m12070	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2070	--	Run3-48
s3a2e2m12080	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2080	--	Run3-48
s3a2e2m12090	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2090	--	Run3-48
s3a2e2m12100	GRID Raster	High	s3	High	a2	Yes	e2	Allow marshes to transgress into dry land	m1	2100	B.30	Run3-48
s3a2e2m22020	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2020	--	Run3-48
s3a2e2m22030	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2030	B.31	Run3-48
s3a2e2m22040	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2040	--	Run3-48
s3a2e2m22050	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2050	--	Run3-48
s3a2e2m22060	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2060	B.31	Run3-48
s3a2e2m22070	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2070	--	Run3-48
s3a2e2m22080	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2080	--	Run3-48
s3a2e2m22090	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2090	--	Run3-48
s3a2e2m22100	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (excluding agriculture)	m2	2100	B.31	Run3-48
s3a2e2m32020	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2020	--	Run3-48b
s3a2e2m32030	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2030	B.32	Run3-48b
s3a2e2m32040	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2040	--	Run3-48b
s3a2e2m32050	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2050	--	Run3-48b
s3a2e2m32060	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2060	B.32	Run3-48b
s3a2e2m32070	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2070	--	Run3-48b
s3a2e2m32080	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2080	--	Run3-48b
s3a2e2m32090	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2090	--	Run3-48b
s3a2e2m32100	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture)	m3	2100	B.32	Run3-48b
s3a2e2m42020	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2020	--	Run3-48c
s3a2e2m42030	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2030	B.33	Run3-48c
s3a2e2m42040	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2040	--	Run3-48c
s3a2e2m42050	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2050	--	Run3-48c
s3a2e2m42060	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2060	B.33	Run3-48c
s3a2e2m42070	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2070	--	Run3-48c
s3a2e2m42080	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2080	--	Run3-48c
s3a2e2m42090	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2090	--	Run3-48c
s3a2e2m42100	GRID Raster	High	s3	High	a2	Yes	e2	Fortify developed dry land (including agriculture and managed ponds)	m4	2100	B.33	Run3-48c

Appendix B

SLAMM Results for all Scenarios

Habitat Type

- Blank (No Data)
- Developed Uplands
- Undeveloped Uplands
- Freshwater Wetland with Trees/Shrubs/Riparian Forest
- Freshwater Marsh
- Tidal Marsh
- Tidal Estuarine Wetland with Trees/Shrubs
- Emergent Salt Marsh
- Estuarine Beach
- Mud Flat
- Coastal Strand
- Rocky Intertidal
- Open Water
- Riverine Tidal
- Open Water Subtidal
- Tidal Channel
- Open Ocean
- Rarely Flooded Salt Marsh / Salt Pans
- Arroyo / Gravel / Shore
- Tidal Wetland with Trees/Shrubs
- Dunes
- Agriculture

12/15/2013

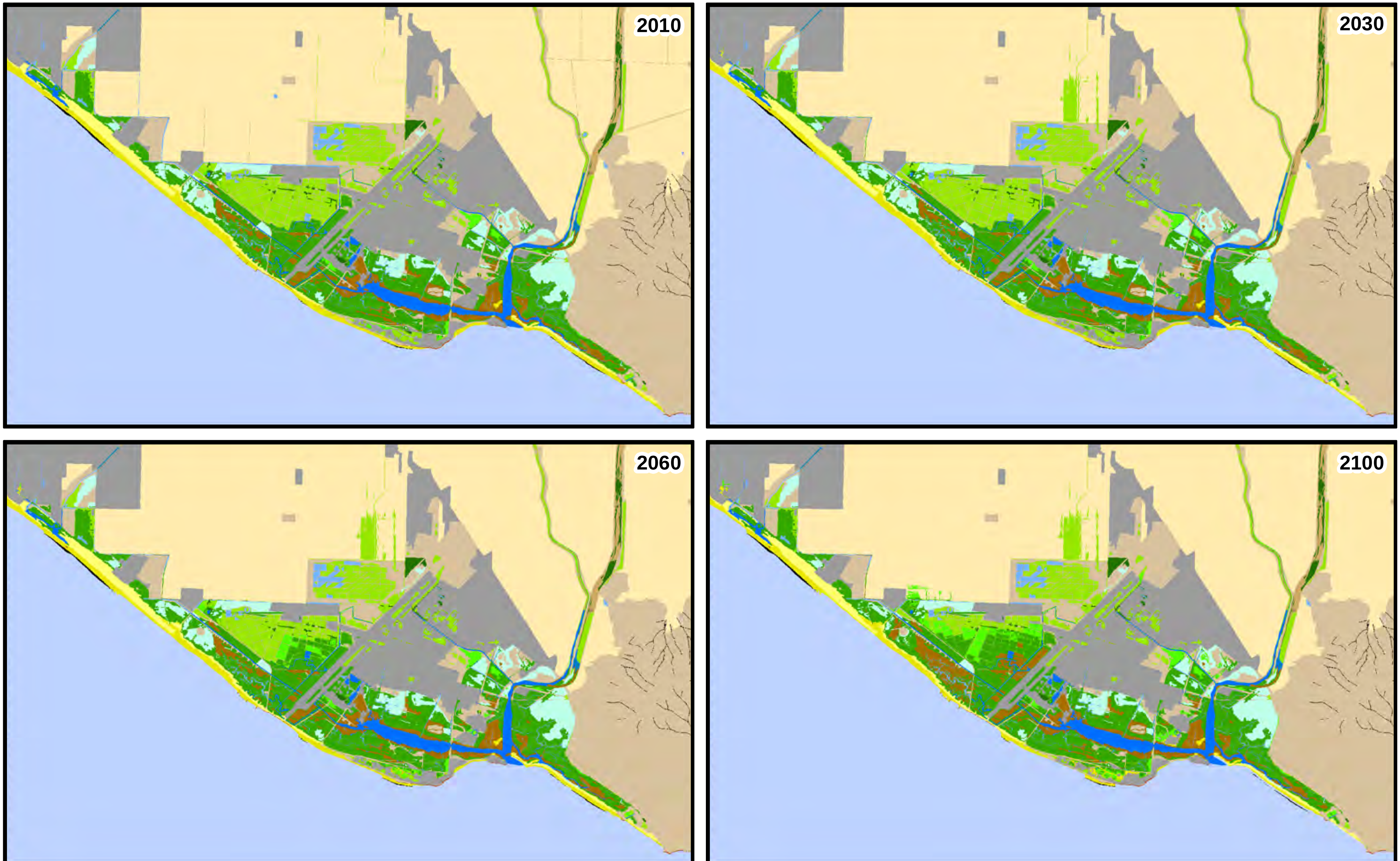
figure ***B.1***

Ventura County Climate Change Vulnerability Study

Legend for Appendix B - SLAMM Results

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e1m1 (Run 3-47)

12/15/2013

N

0 1 2 Miles

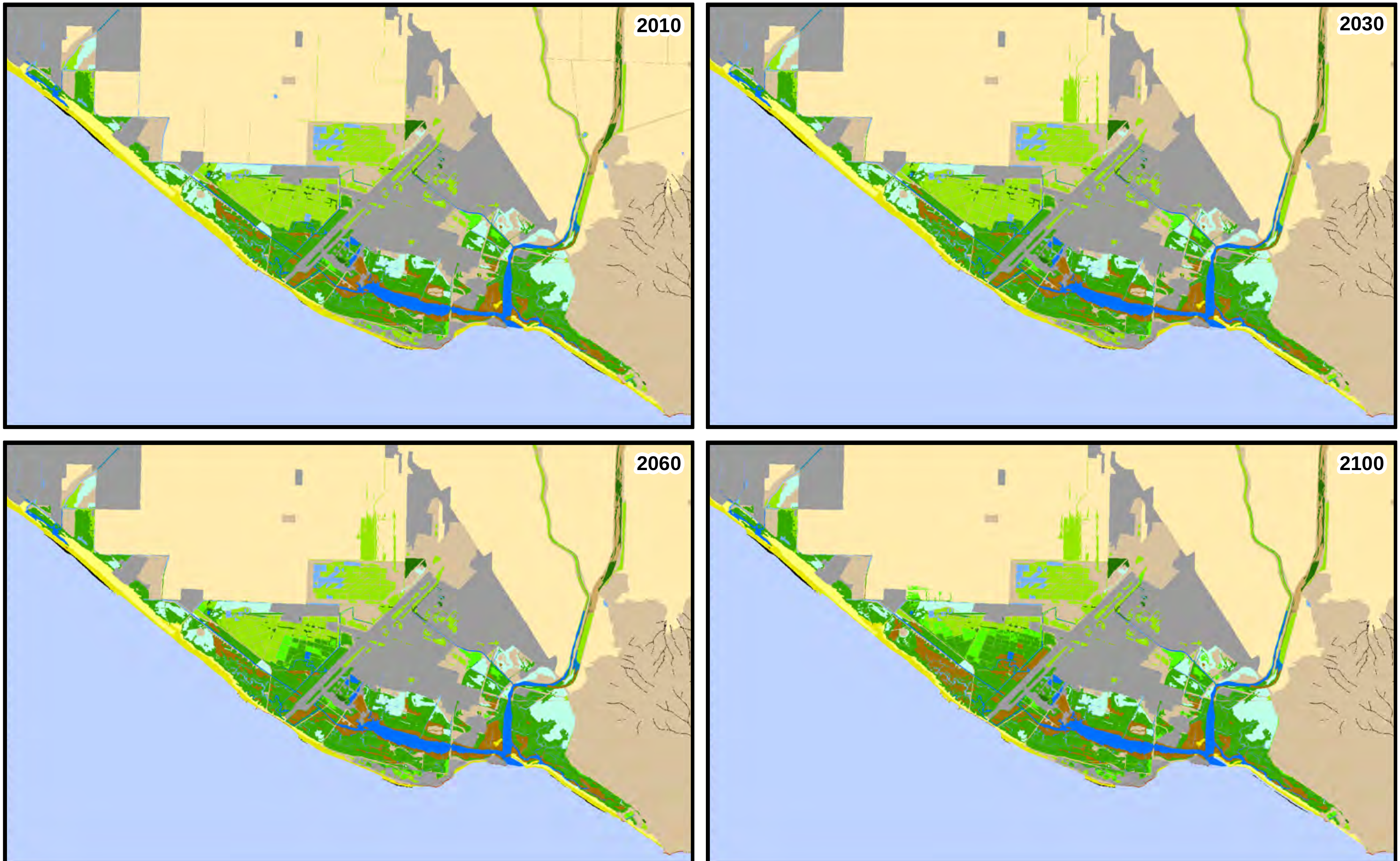
figure ***B.2***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, No Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e1m2 (Run 3-47)

12/15/2013

N

0 1 2 Miles

figure ***B.3***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a1e1m3 (Run 3-47b)

12/15/2013

N

0 1 2 Miles

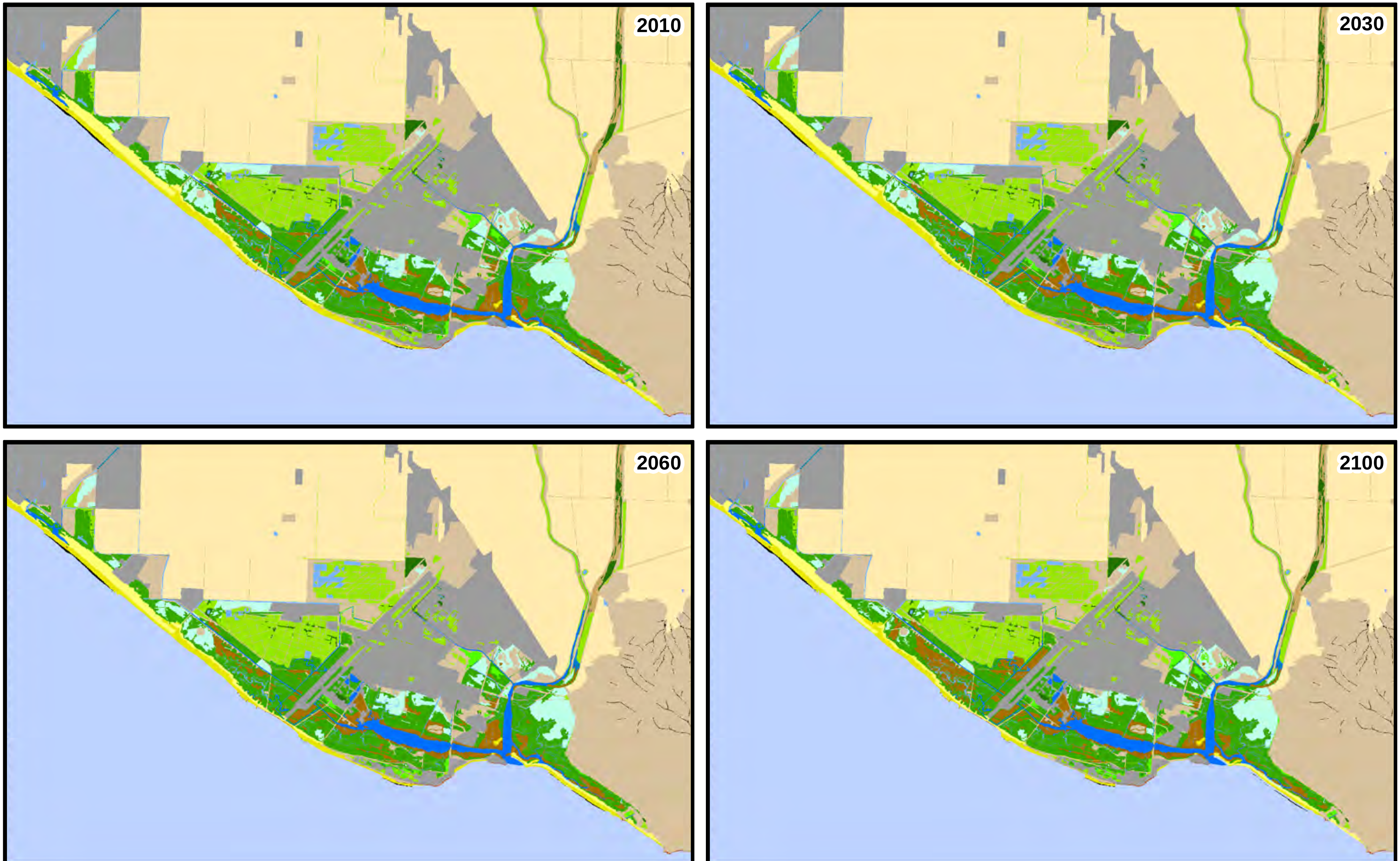
figure ***B.4***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e1m4 (Run 3-47c)

12/15/2013

N

0 1 2 Miles

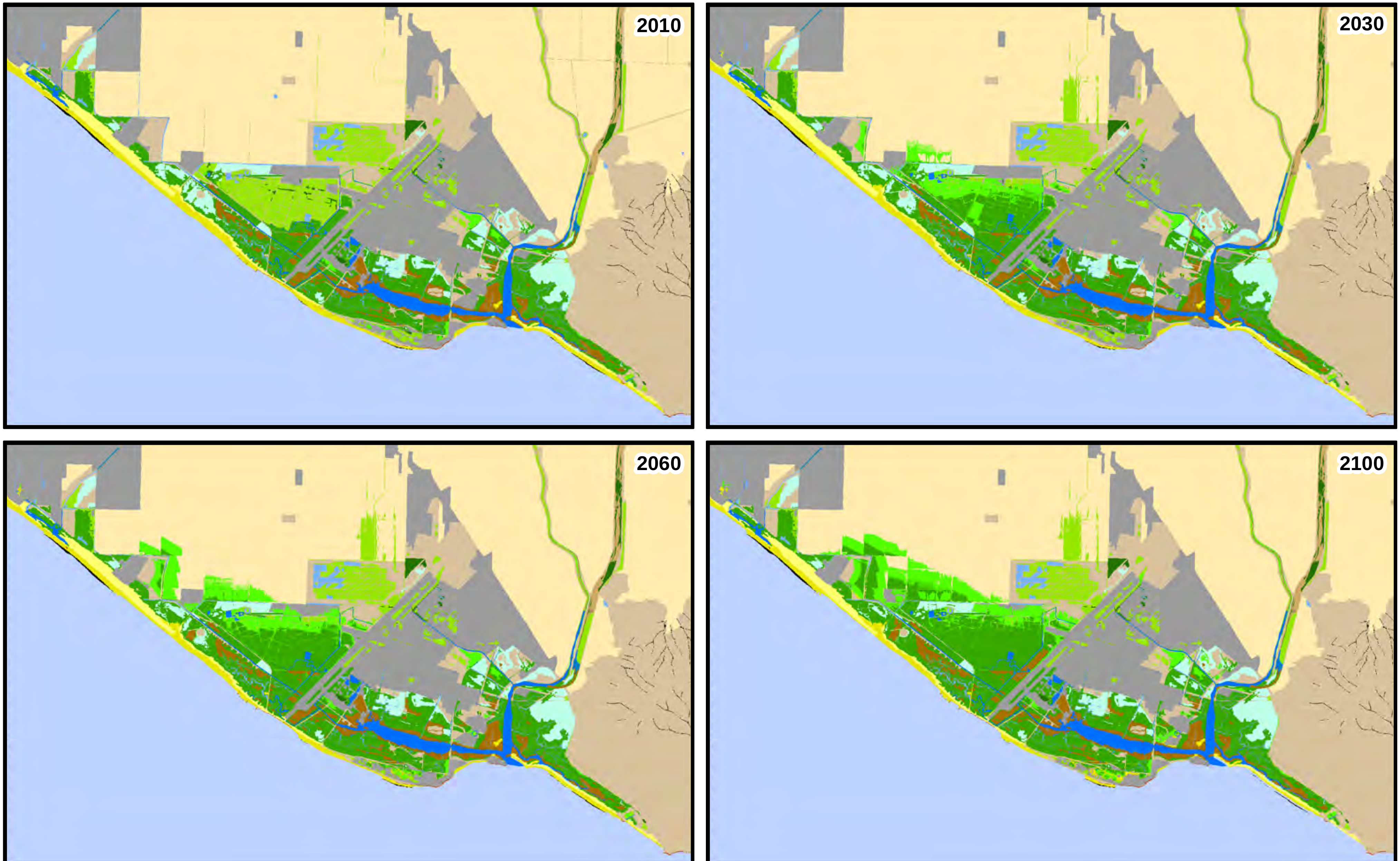
figure ***B.5***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e2m1 (Run 3-51)

12/15/2013

N
0 1 2 Miles

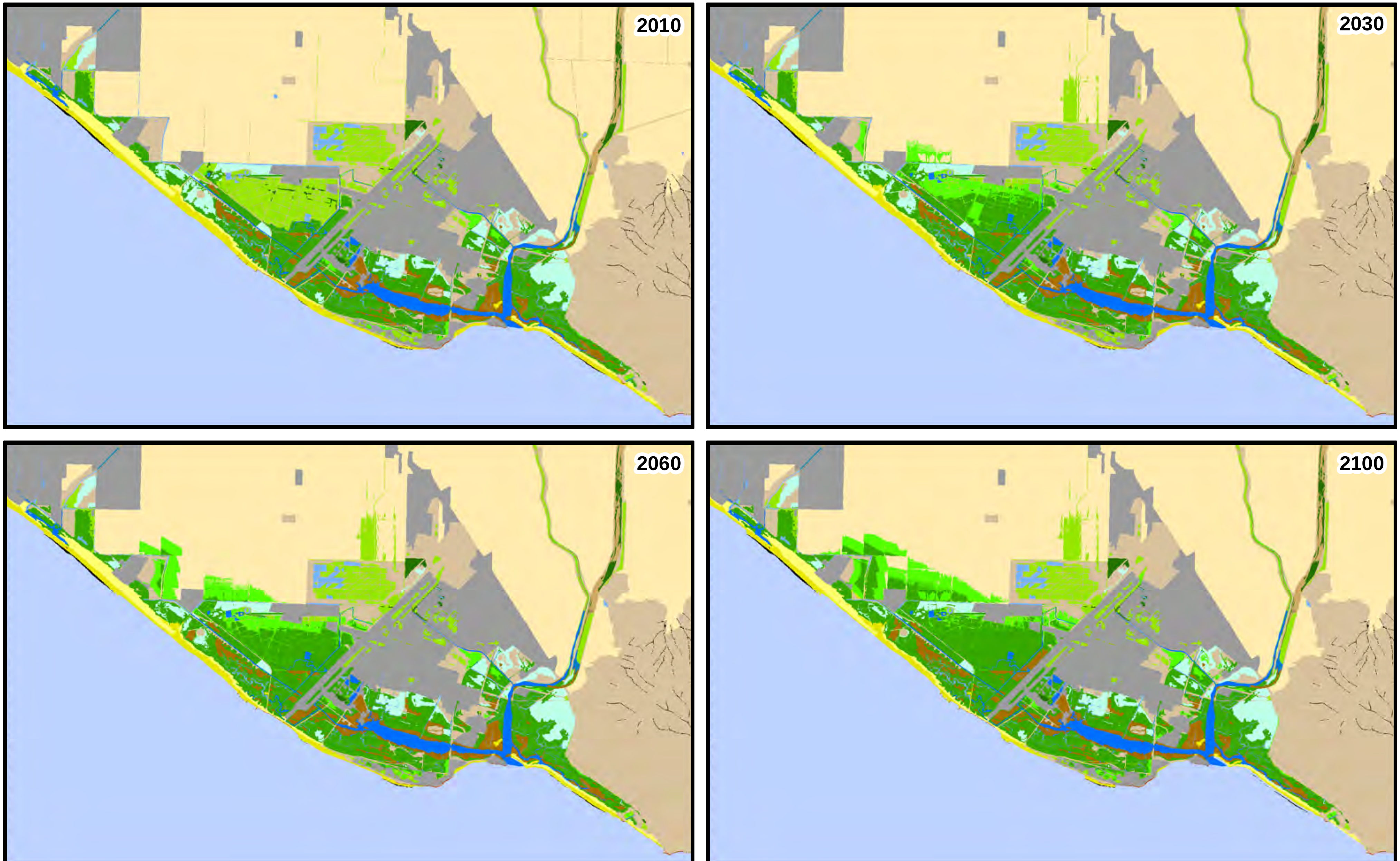
figure ***B.6***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e2m2 (Run 3-51)

12/15/2013

N

0 1 2 Miles

figure ***B.7***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a1e2m3 (Run 3-51b)

12/15/2013

N

0 1 2 Miles

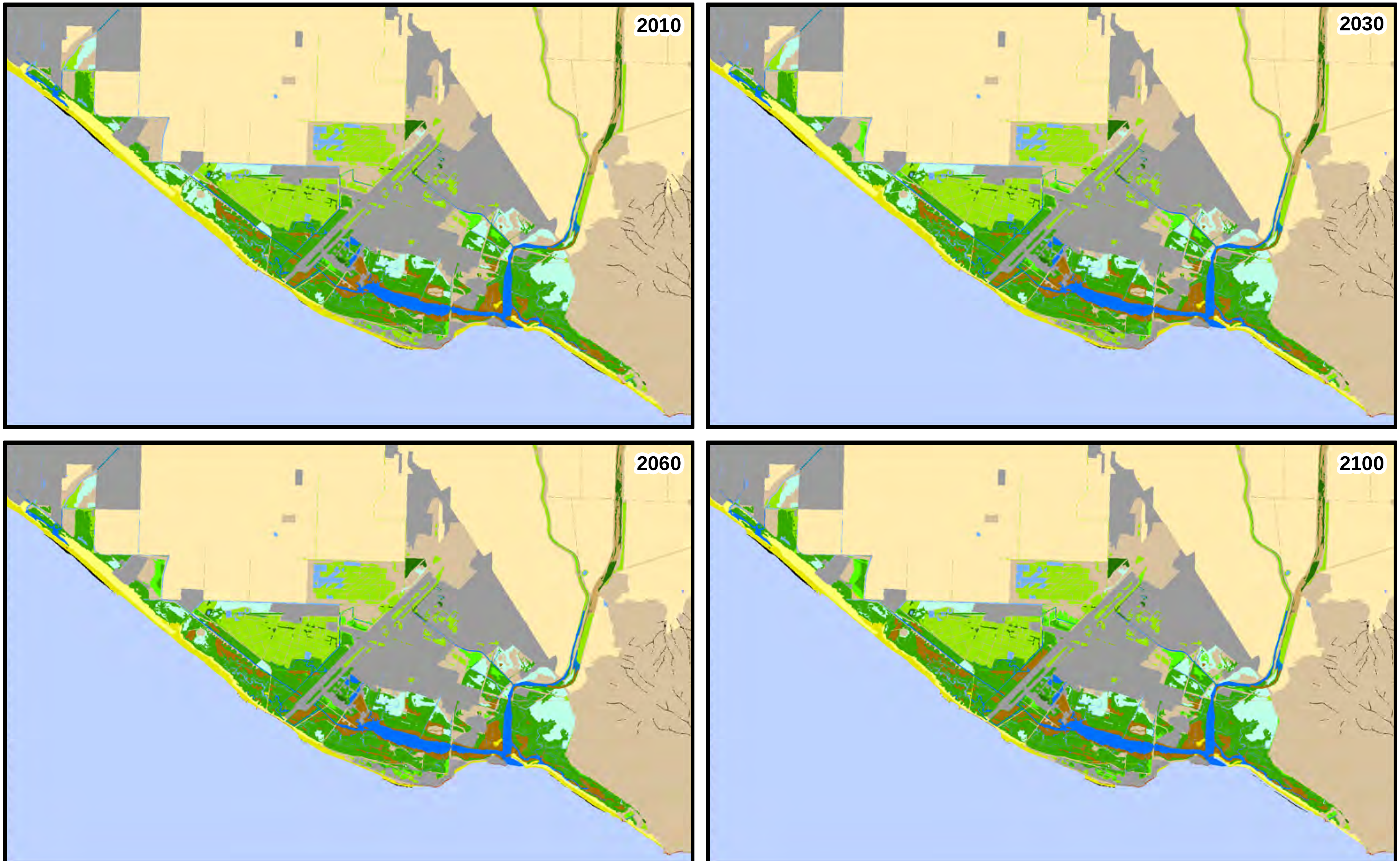
figure ***B.8***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a1e2m4 (Run 3-51c)

12/15/2013

N

0 1 2 Miles

figure ***B.9***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a2e1m1 (Run 3-46)

12/15/2013

N

0 1 2 Miles

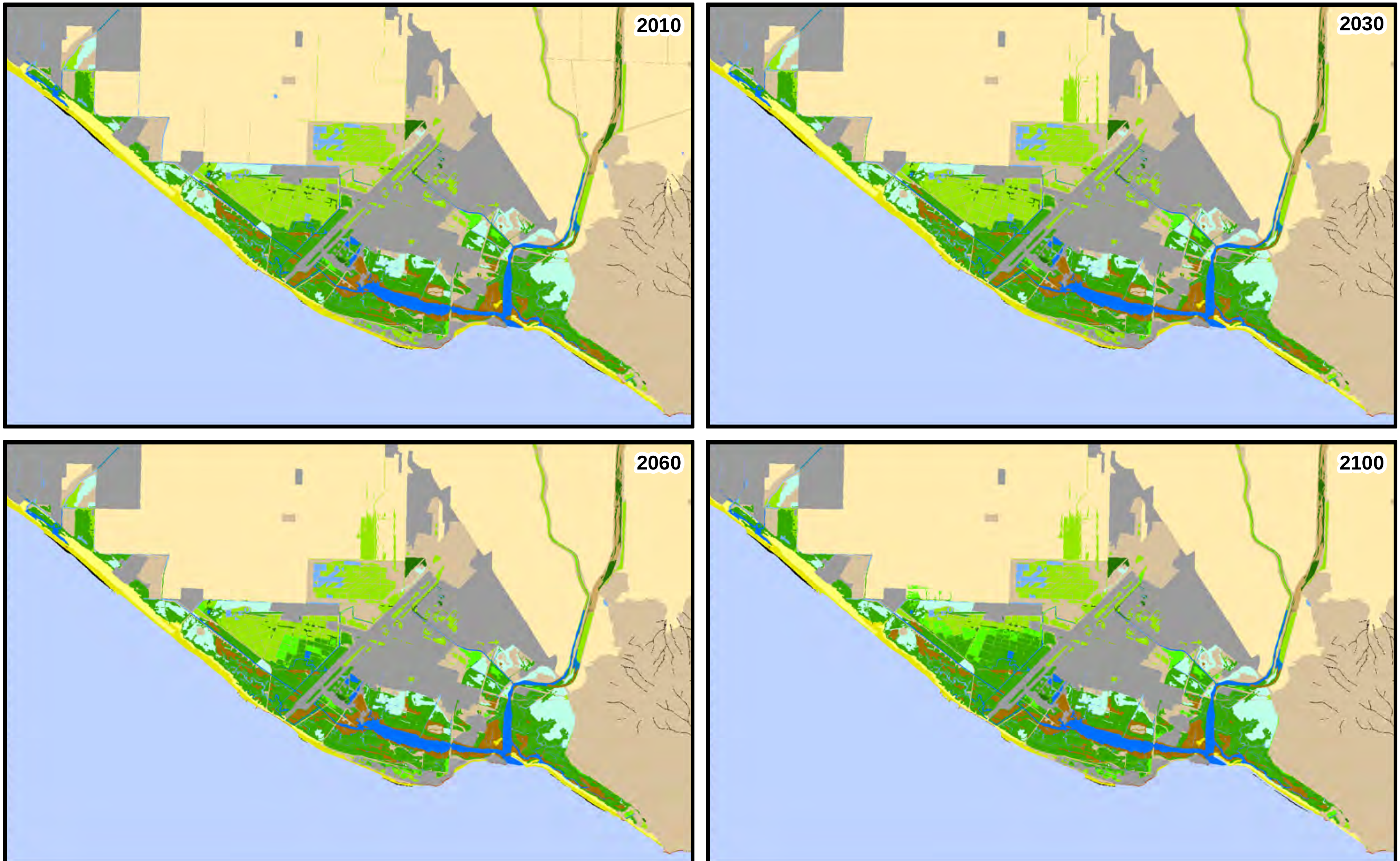
*figure **B.10***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, No Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a2e1m2 (Run 3-46)

12/15/2013

N

0 1 2 Miles

figure ***B.11***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a2e1m3 (Run 3-46b)

12/15/2013

N

0 1 2 Miles

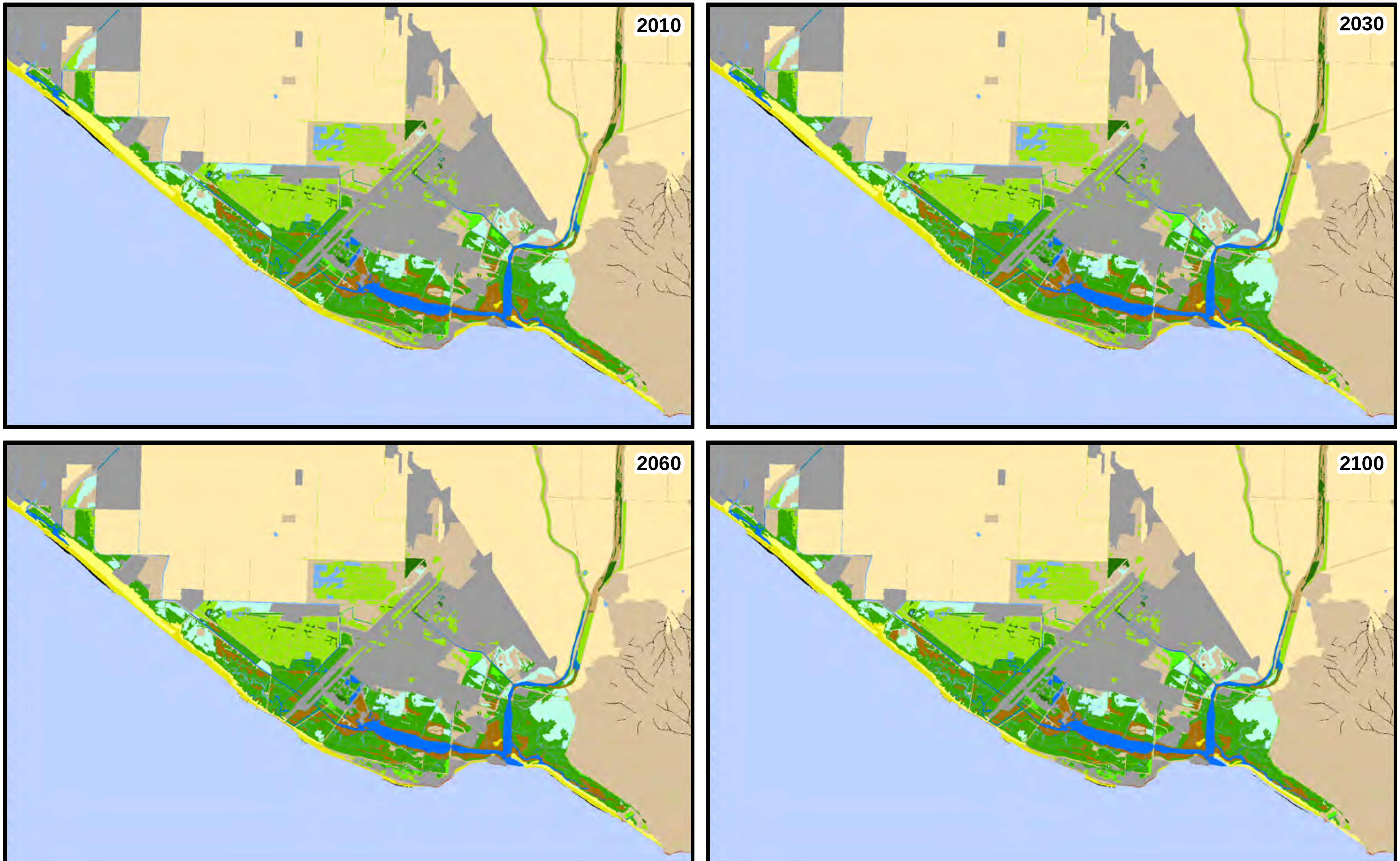
figure ***B.12***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a2e1m4 (Run 3-46c)

12/15/2013

N

0 1 2 Miles

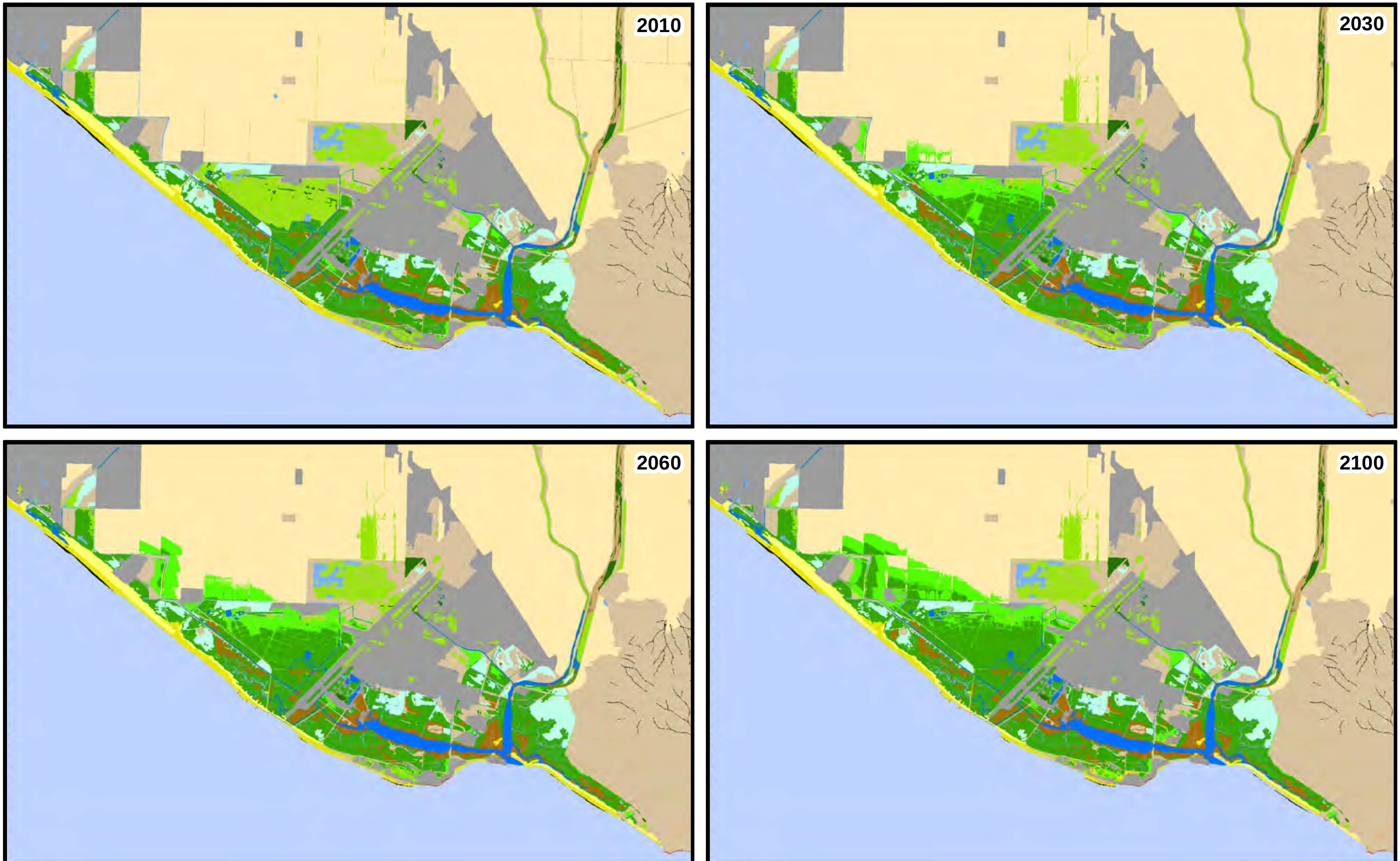
figure ***B.13***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a2e2m1 (Run 3-50)

12/15/2013

N

0 1 2 Miles

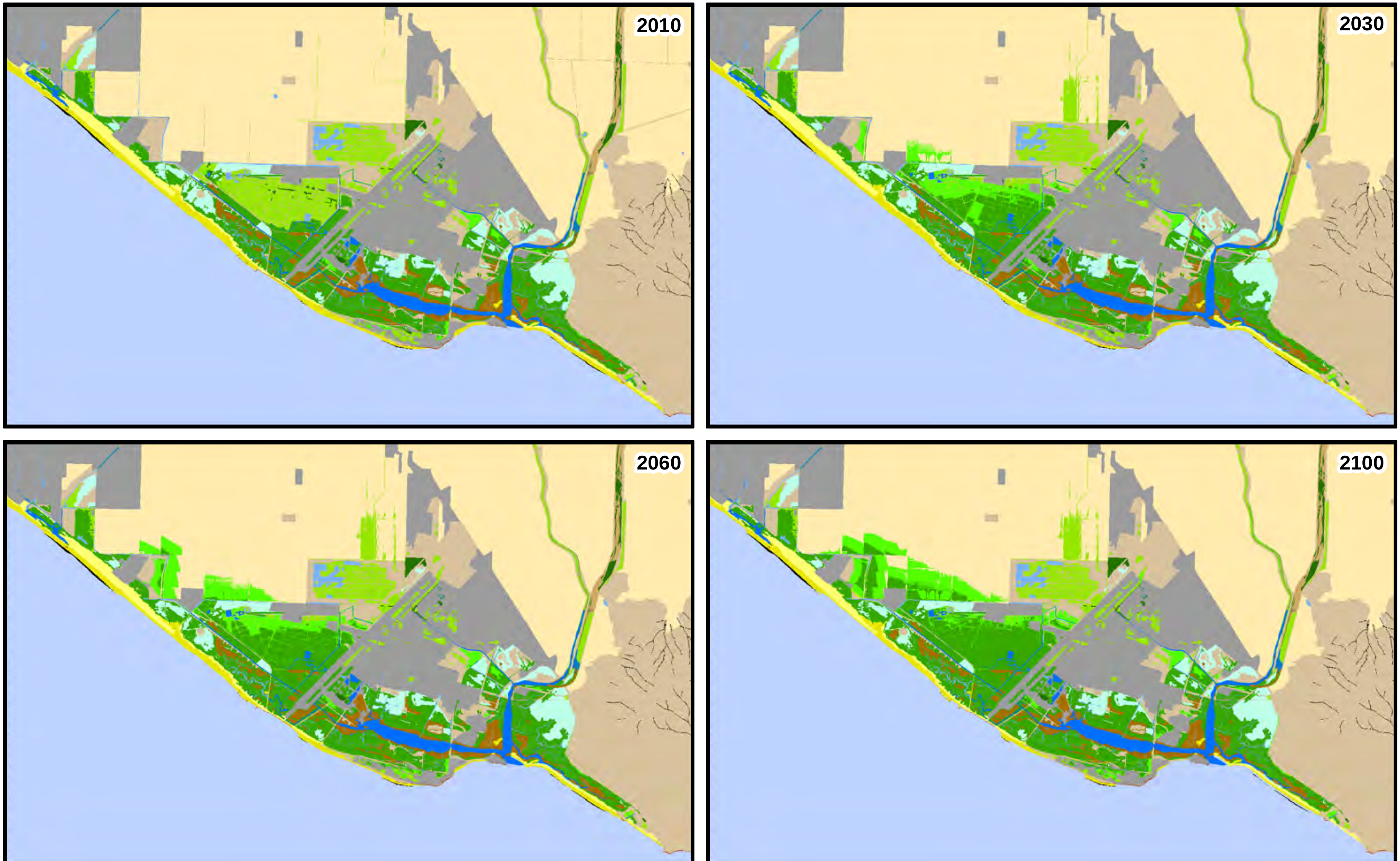
figure ***B.14***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s1a2e2m2 (Run 3-50)

12/15/2013

N

0 1 2 Miles

figure ***B.15***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a2e2m3 (Run 3-50b)

12/15/2013

N

0 1 2 Miles

*figure **B.16***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s1a2e2m4 (Run 3-50c)

12/15/2013

N

0 1 2 Miles

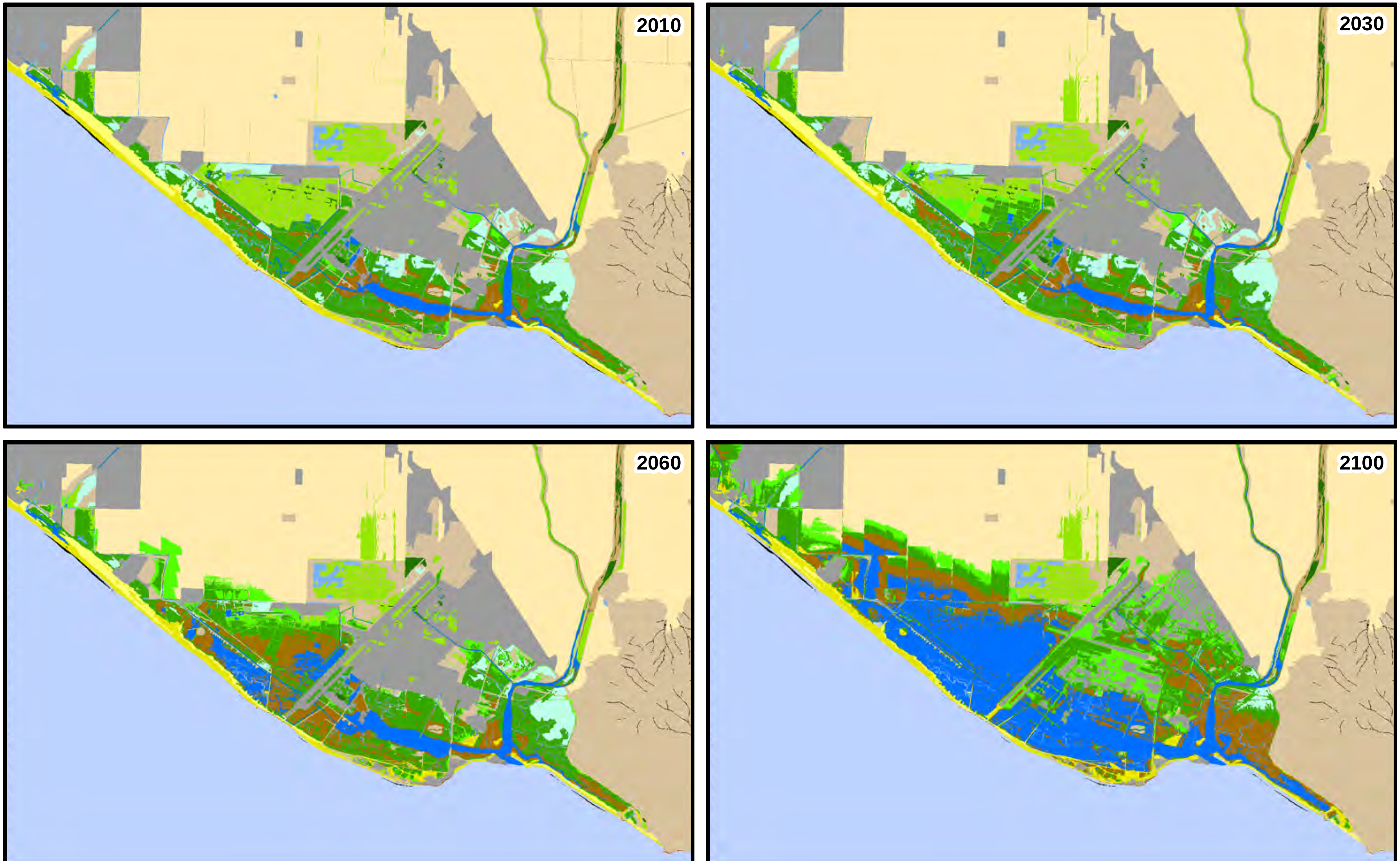
figure ***B.17***

Ventura County Climate Change Vulnerability Study

Results: Low SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a1e1m1 (Run 3-45)

12/15/2013

N

0 1 2 Miles

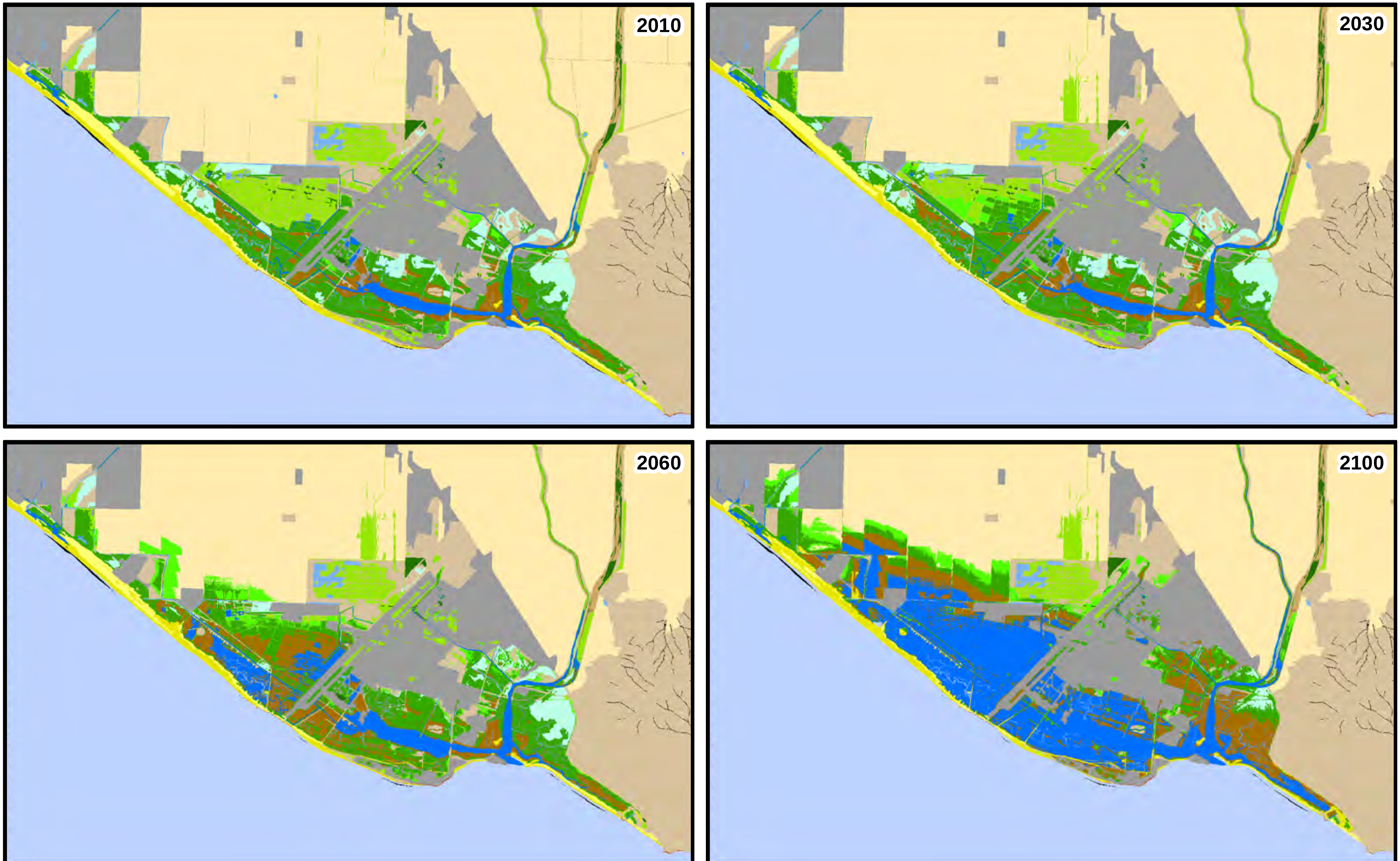
figure ***B.18***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, No Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a1e1m2 (Run 3-45)

12/15/2013

N

0 1 2 Miles

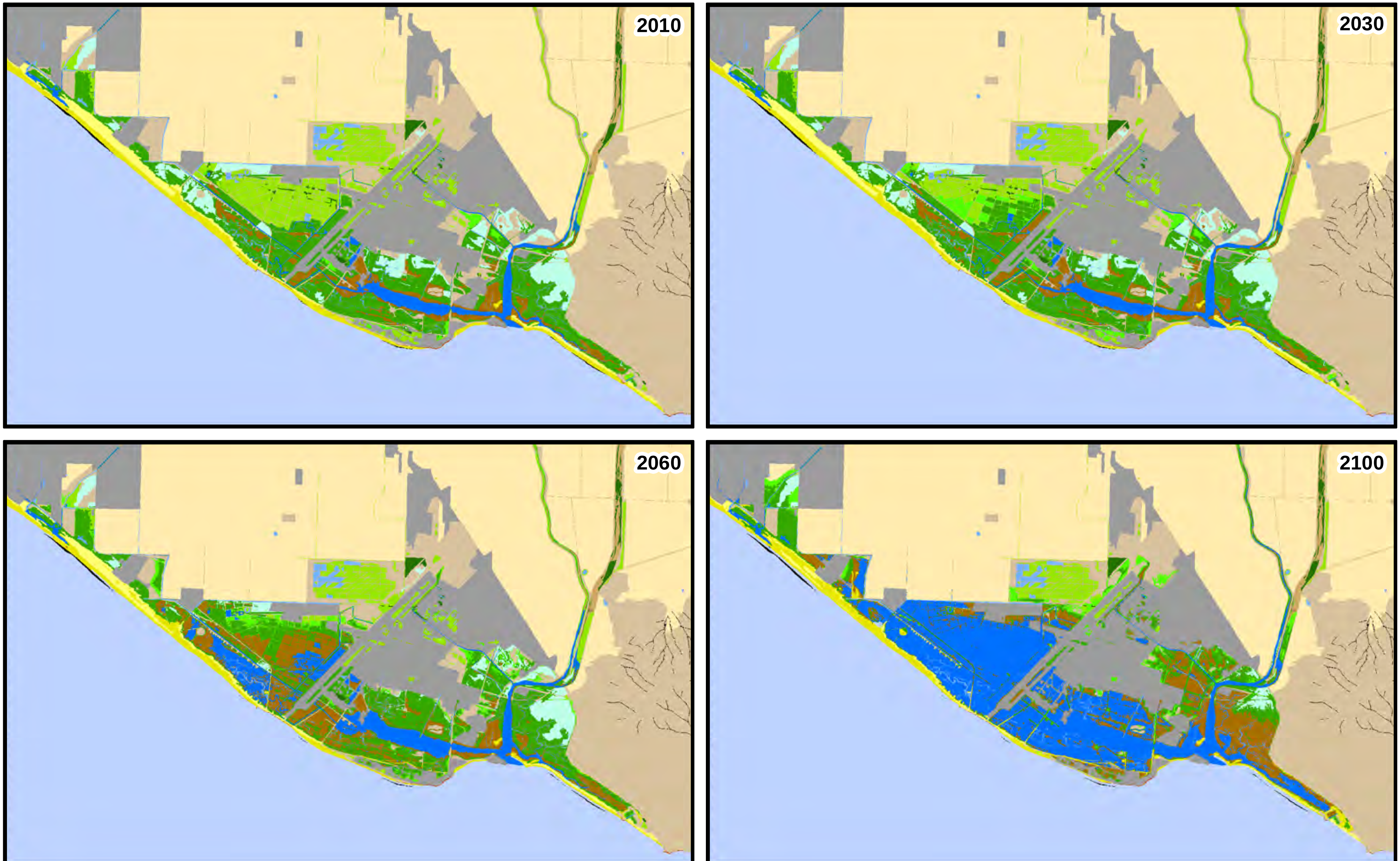
figure ***B.19***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a1e1m3 (Run 3-45b)

12/15/2013

N

0 1 2 Miles

*figure **B.20***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s3a1e1m4 (Run 3-45c)

12/15/2013

N

0 1 2 Miles

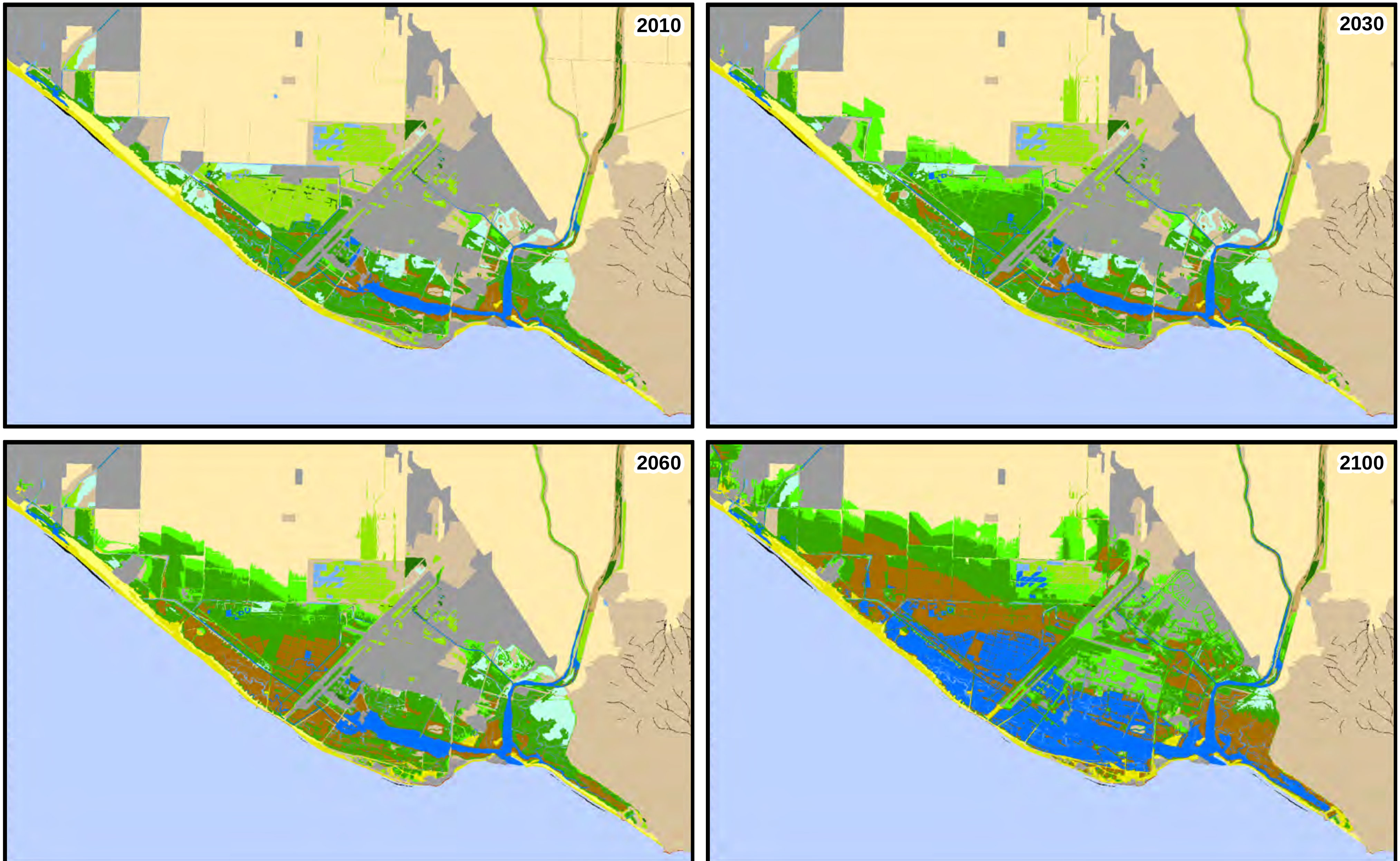
*figure **B.21***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a1e2m1 (Run 3-49)

12/15/2013

N

0 1 2 Miles

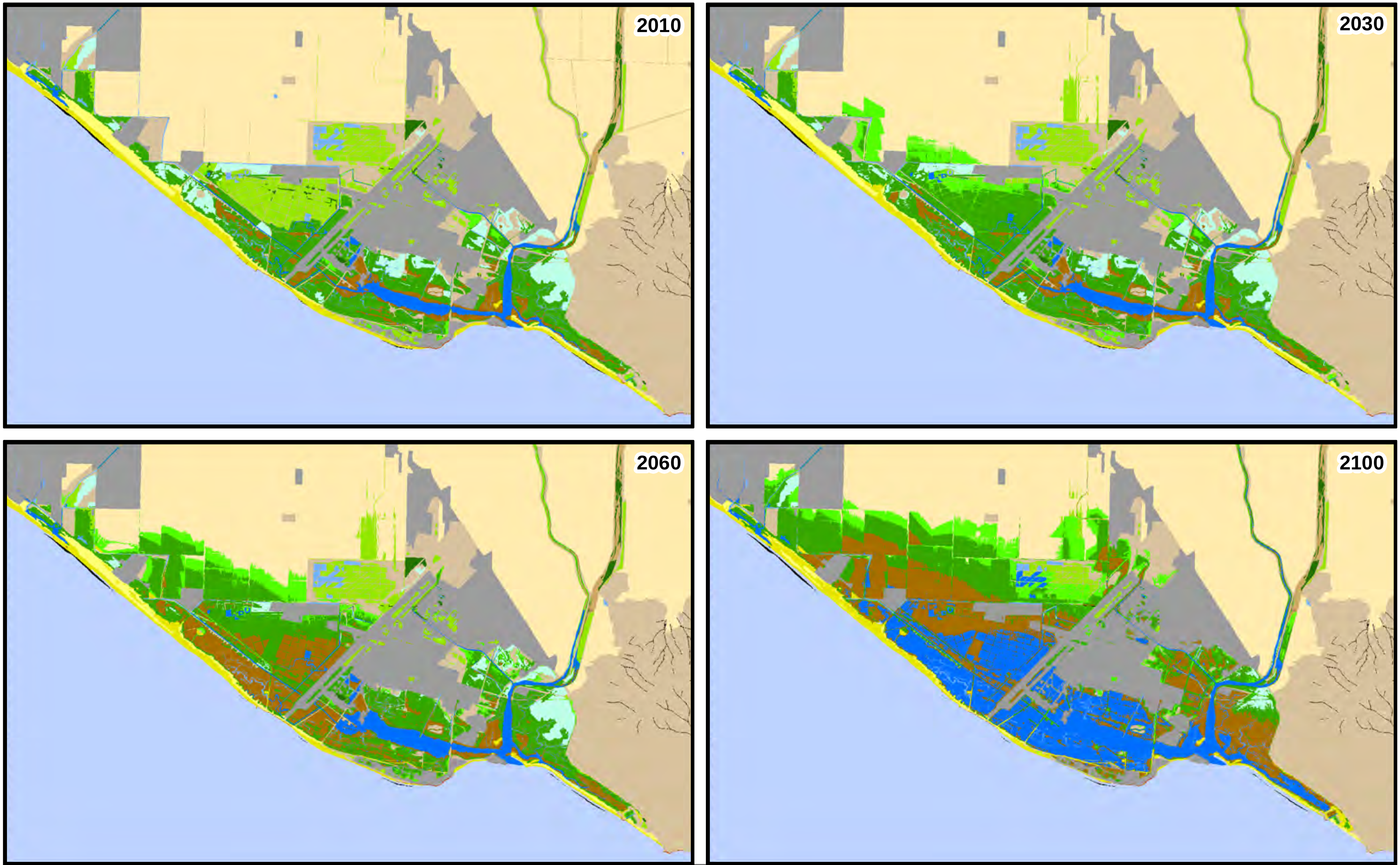
figure ***B.22***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a1e2m2 (Run 3-49)

12/15/2013

N

0 1 2 Miles

figure ***B.23***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s3a1e2m3 (Run 3-49b)

12/15/2013

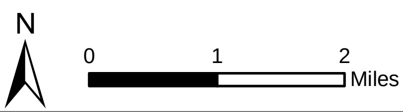


figure ***B.24***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s3a1e2m4 (Run 3-49c)

12/15/2013

N

0 1 2 Miles

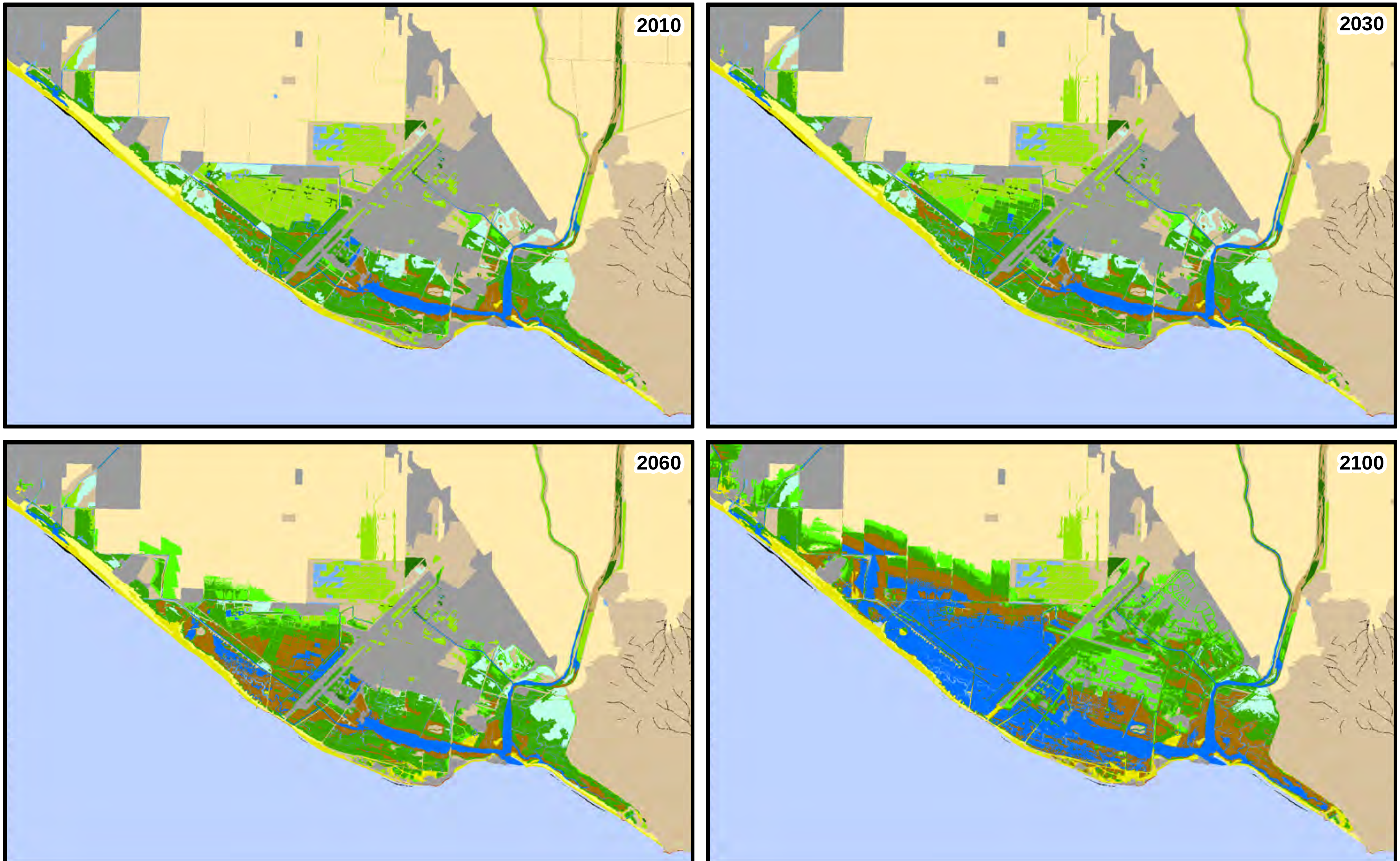
figure ***B.25***

Ventura County Climate Change Vulnerability Study

Results: High SLR, Low Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e1m1 (Run 3-44)

12/15/2013

N

0 1 2 Miles

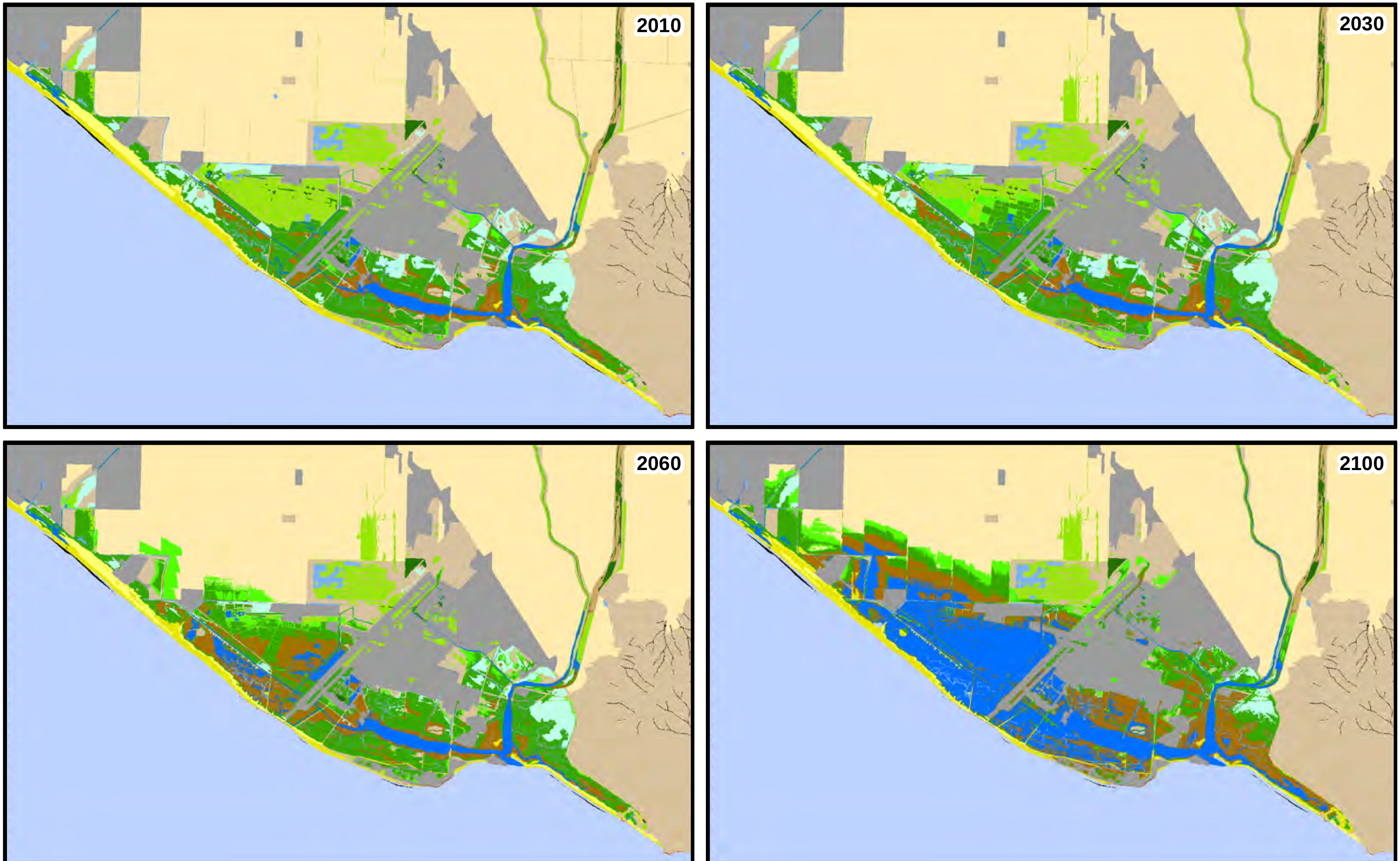
figure ***B.26***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, No Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e1m2 (Run 3-44)

12/15/2013

N

0 1 2 Miles

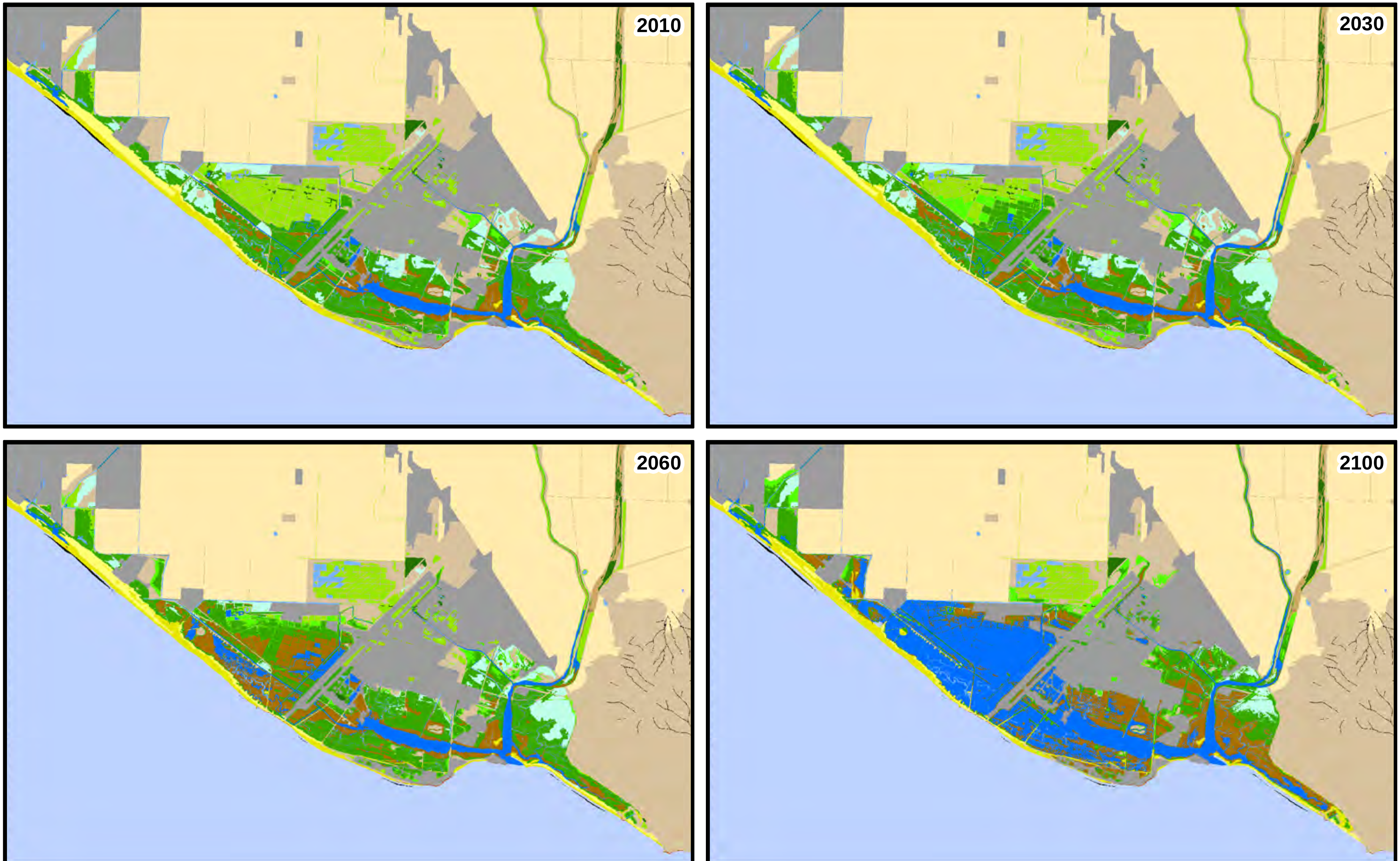
*figure **B.27***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e1m3 (Run 3-44b)

12/15/2013

N

0 1 2 Miles

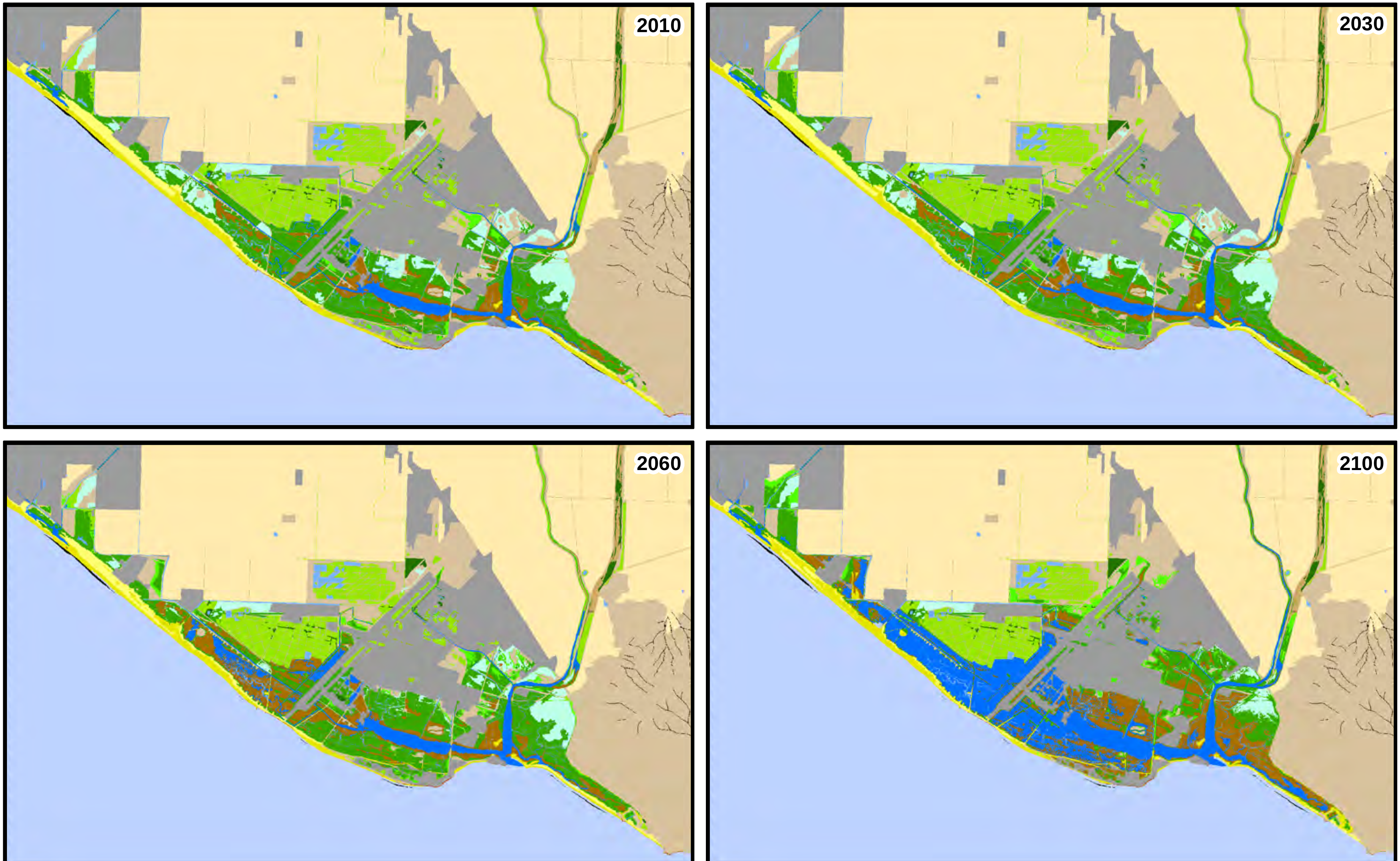
figure ***B.28***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e1m4 (Run 3-44c)

12/15/2013

N

0 1 2 Miles

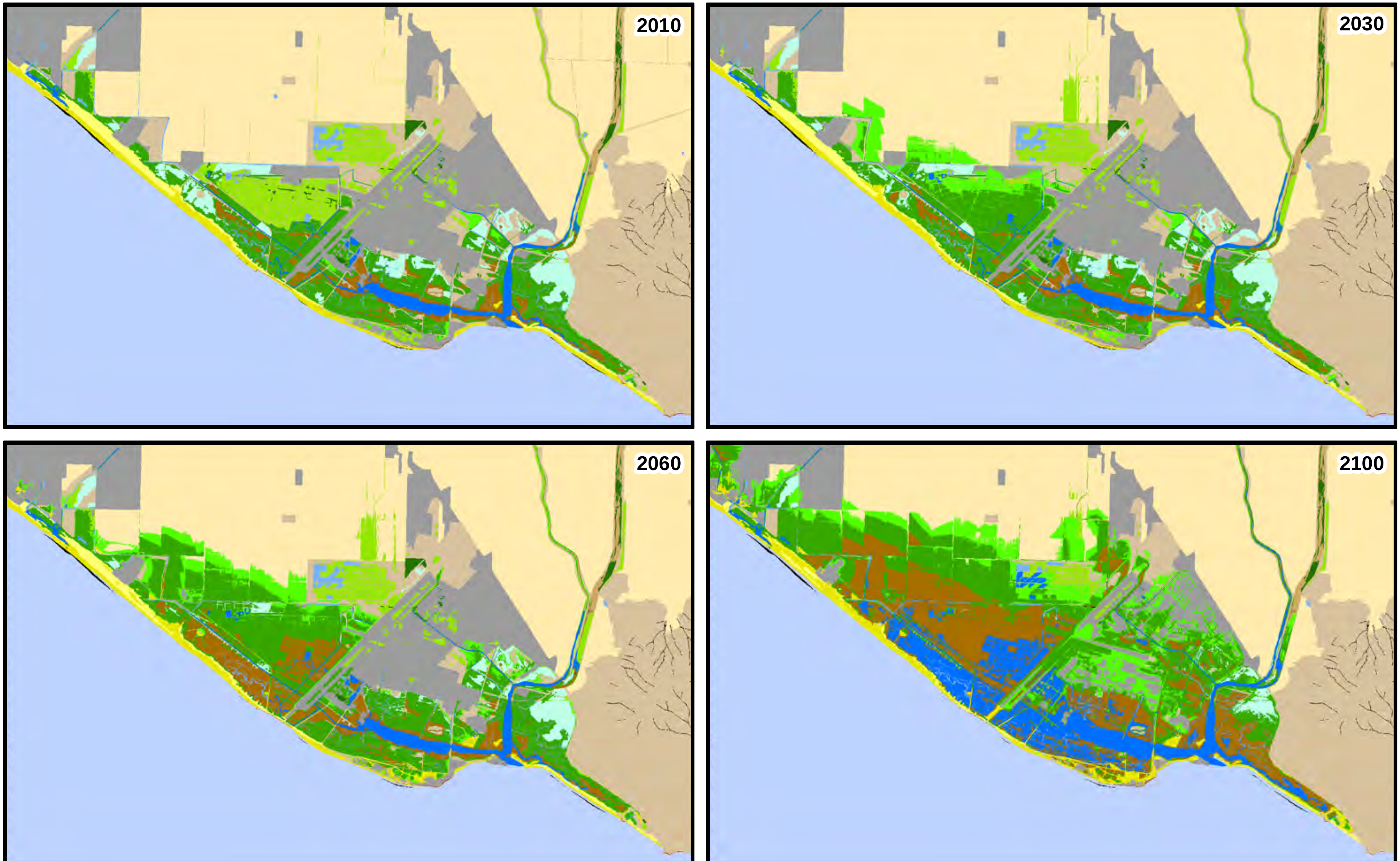
*figure **B.29***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, No Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e2m1 (Run 3-48)

12/15/2013

N

0 1 2 Miles

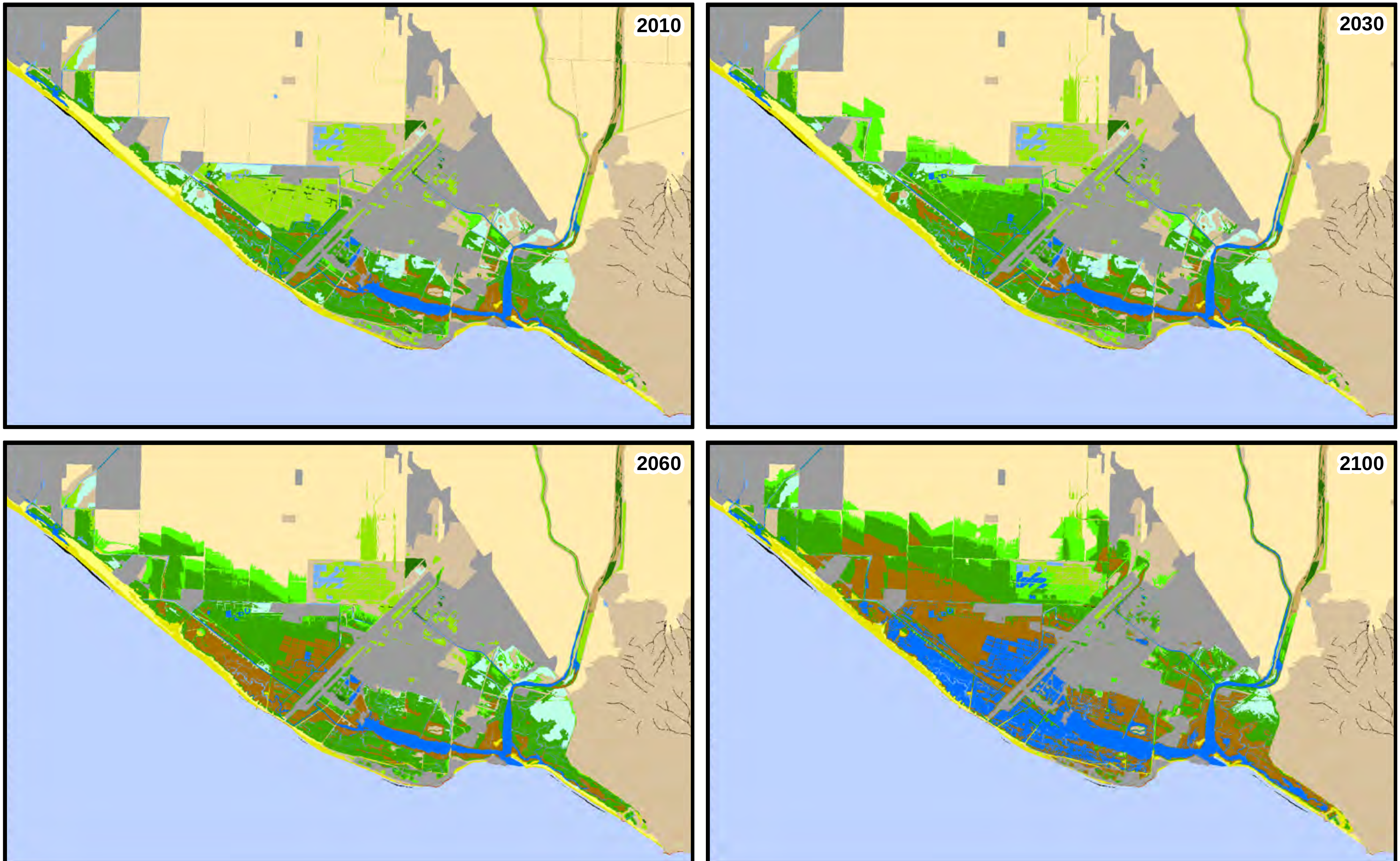
*figure **B.30***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, Erosion of New Inlet, Allow Marshes to Transgress

ESA PWA Ref# - D211452

ESA PWA



Please see Figure B.1 for legend.
Scenario: s3a2e2m2 (Run 3-48)

12/15/2013

N

0 1 2 Miles

figure ***B.31***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (excl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s3a2e2m3 (Run 3-48b)

12/15/2013

N

0 1 2 Miles

figure ***B.32***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag.)

ESA PWA Ref# - D211452

ESA PWA

Please see Figure B.1 for legend.
Scenario: s3a2e2m4 (Run 3-48c)

12/15/2013

N

0 1 2 Miles

figure ***B.33***

Ventura County Climate Change Vulnerability Study

Results: High SLR, High Accretion, Erosion of New Inlet, Fortify Dev. Dry Land (incl. Ag. + Ponds)

ESA PWA Ref# - D211452

ESA PWA

Appendix C

Sea Level Affecting Marshes Model (SLAMM)

ESA PWA

550 Kearny Street
Suite 900
San Francisco, CA 94108
415.896.5900 phone
415.896.0332 fax

www.esassoc.com

memorandum

date August 22, 2014

to Gretchen Greene, ENVIRON

from Elena Vandebroek and David Revell

subject Coastal Resilience Ventura: Beach Width Analysis

project D130257.00 – Nature Based Adaptation to Climate Change in Ventura County

Summary

This analysis builds on prior coastal hazards modeling for the Coastal Resilience Ventura project. Two landscape-scale adaptation approaches were developed in collaboration with stakeholders and the Coastal Resilience Ventura project team: Engineering Based Adaptation (EBA) "gray" and Nature Based Adaptation (NBA) "green" approaches. These approaches represent a plausible range of adaptation strategies that could occur. Actual adaptation will likely be a combination of these two strategies. The details of the strategies are described in an updated memo to The Nature Conservancy from ENVIRON and ESA PWA (ENVIRON and ESA PWA, 2014).

This memo presents methods used to assess changes to beach width, or the necessary adaptations to maintain a certain width of beach at three reaches in Ventura County.

Reach Selection

Three reaches were considered for the beach width analysis (Figure 1). The reaches were selected to represent a broad range of ecological and recreational values as well as various adaptation approaches.

1. ***Surfer's Point East*** – This reach is located just east of the Phase 1 Surfer's Point restoration (complete), where Phase 2 has been planned and permitted (Figure 2). The EBA and NBA approaches at this site are reinforcing the seawall/revetment and managed retreat/dune restoration, respectively. Dune restoration at this site would maintain a beach while reinforcing the existing seawall/revetment would maintain the existing condition, which is no beach at high tide.

2. ***Oxnard Shores*** – This reach fronts Mandalay Beach Road from W. 5th Street to Beach Way (Figure 3). This reach has relatively high recreational use. The EBA and NBA approaches at this site are constructing a seawall/revetment and dune restoration, respectively. Recreational use is similar to Pierpont and Hollywood by the Sea.

3. ***Ormond Beach Generating Station (OBGS)*** – This reach spans the along-shore width of the Ormond Beach Generating Station (Figure 4). The EBA and NBA approaches at this site are constructing a levee/revetment managed

retreat, respectively. This reach has lower levels of recreation and is backed by more rural areas than the other reaches, and has higher ecological value.

Beach Width Analysis

The beach width analysis was conducted on a representative profile for each reach. The locations of the representative profiles are shown on the three reach maps (Figure 2, Figure 3, and Figure 4). The profiles were developed using a combination of recent bare-earth LiDAR (NOAA 2012) collected in November 2009 and offshore bathymetry from a USGS seam-less high-resolution coastal DEM (Barnard and Hoover 2010). The bathymetry in this stitched dataset came from 2006 - 2007 PWC surveys by the USGS, a tsunami DEM from NOAA, and interpolation between the bathymetry and LiDAR datasets. The location of MHW was interpolated using the NOAA Rincon Island tidal datum. The starting "dry beach width" is assumed to be the distance between MHW and the backshore toe. Additional parameters developed during the prior coastal hazards mapping project were compiled for use in this beach width analysis and are presented in Table 1.

Table 1. Beach Width Modeling Inputs, by Reach

Parameter	**Surfer's Point**	**Oxnard Shores**	**OBGS**
Length of reach (m)	520	1830	390
Existing beach width (m)	9	100	180
Beach slope (m/m) [1]	0.07	0.11	0.07
Depth of closure (m NAVD)[1]	-8	-11	-10
100-yr Total Water Level[1,2] (m NAVD)	6.0	7.6	5.5
100-yr Storm Erosion Distance (m) [1]	30	35	29

[1]*From prior coastal hazard mapping project (ESA PWA 2013)*

[2]*Using Stockdon et al. 2006*

This beach width analysis uses projected future erosion rates from prior coastal hazards mapping (ESA PWA 2013). This analysis uses the "High" sea level rise curve of 1.47 m by 2100, relative to 2010. Table 2 reports the projected future long-term erosion rates based on the high sea level rise curve. These rates are the sum of the historic erosion trend and additional sea level rise-driven erosion. They do not include the impact of a 100-year storm (reported separately in Table 1).

Table 2. Projected Future Erosion Rates (m/year), by Reach

Year	**Surfer's Point**	**Oxnard Shores**	**OBGS**
2010	0.18	-0.13	0.12
2020	0.63	0.33	0.61
2030	0.70	0.41	0.69
2040	0.80	0.52	0.81
2050	0.89	0.61	0.90
2060	0.95	0.67	0.96
2070	1.05	0.77	1.07
2080	1.13	0.86	1.16
2090	1.21	0.94	1.26
2100	1.31	1.05	1.37

Baseline: No Action

This scenario applies to all three reaches and assumes that the existing shoreline erodes until the beach width reaches 30 meters + the 100-yr storm erosion distance, at which point the backshore and shoreline erode together at the projected future erosion rate (and the beach width stays constant through time). This minimum beach width (at which backshore erosion is induced) is wider for the no action case than for the dune restoration case (see below) because dunes provide additional protection during storms by releasing sand. In the case of Surfer's Point, the beach is already very narrow, so the beach and backshore erode together. At Oxnard Shores, the backshore begins to erode when the beach reaches the minimum beach width. At OBGS, the existing beach is very wide, so no backshore erosion is expected to occur over the planning horizon.

EBA: Build or Reinforce Seawall/Revetment/Levee

This scenario applies to all three reaches. In this EBA scenario, upland erosion is not allowed, but the shoreline erodes at the projected future erosion rates, leading to a narrower beach over time. In some cases the beach may disappear completely. Construction of the revetment/seawall is assumed to occur in 2011 and occupy space on the existing beach, reducing the initial beach width by 40 ft (12 m).

NBA: Beach and Dune Restoration

This scenario applies to the Surfer's Point and Oxnard Shores reaches[1]. The Beach and Dune Restoration scenario was applied differently to the two reaches, so they are discussed separately below. The resulting dune restoration schemes and beach widths are very high level/conceptual estimates for the purpose of comparing relative costs of EBA and NBA scenarios. Actual sand/cobble volumes, beach widths, and costs will differ from those described below.

Surfer's Point East

The existing beach, which is pinched between an eroding shoreline and a deteriorating sidewalk/parking lot, is very narrow at the Surfer's Point East reach. The NBA scenario would include approximately 33 meters of managed retreat in which the existing parking lot and walkway would be moved landward. This would make space for dune restoration and cobble augmentation, similar to the first phase of restoration at Surfer's Point, immediately west of this study reach. This scenario was modeled by modifying the existing profile to include a 30 meter wide dune, starting at the inland limit of managed retreat. Sand volumes were estimated assuming the dune has a trapezoidal cross-section, with a top width of 30 meters and a 32 degree angle of repose on the front and back of the dune. The top of dune elevation was set to the 100-year total water level (Table 1). This scenario also includes cobble beach nourishments in tandem with each dune reconstruction to reduce the rate of projected erosion. Cobble nourishments would be constructed to double the existing beach width (9 m), which would involve placing cobble between MLLW and MHHW (elevation difference of 1.7 m (5.5 ft)). This would require approximately 15 m^3/m (6 cy/ft) for a total of 12,000 m^3 (15,000 cy) of cobble with each dune nourishment (including 50% overfill).

The beach profile, including the dune face and cobble berm, is assumed to erode over time at the projected future erosion rates, reduced by 25% to reflect the cobble berm (Table 2), while the beach profile also rises with projected sea level rise. Each time the dune top width falls below a threshold (15 meters), the dune is rebuilt to be 30 meters wide again. With each reconstruction, the dune is built higher in accordance with projected sea level rise. The 15 meter threshold is based on the 100-year erosion distance at Surfer's Point (Table 1), which was estimated using an equilibrium profile approach that does not account for the finite duration of storms. Therefore, rather than maintaining a 30 m-wide dune at all times (the 100-year projected erosion distance for a storm of infinite duration), we maintain a minimum dune width of 15 m (50 ft).

[1] The NBA option for the OBGS was managed retreat, which is assumed to respond similar to the "No Action" scenario.

Based on the assumptions above, we obtain a conceptual schedule of 3 dune reconstructions and cobble nourishments (in 2011, 2060, and 2090). The first dune construction would require 56 m^3/m for a total of 30,000 m^3 or ~40,000 cy. The subsequent two re-constructions (which only re-build half the dune) would require 48 m^3/m and 70 m^3/m, respectively. Each dune reconstruction would require incrementally more sand to reflect the higher dune crest elevation and more rapidly eroding beach profile. This maintenance of the dune and repeating cobble nourishments would result in an average beach width of approximately 12 meters (60 feet) in front of the dune.

Oxnard Shores

The existing beach at Oxnard Shores is very wide and flat as a result of beach grooming activities. This scenario was modeled by modifying the existing profile to include a dune at the back of the beach. Sand volumes were estimated assuming the dune has a trapezoidal cross-section, with a top width of 35 meters and a 32 degree angle of repose on the front and back of the dune. The top of dune elevation was set to the 100-year total water level (Table 1) and the bottom elevation is based on the existing elevations at the back of the beach. The dune is not assumed to erode until the beach in front of it has narrowed to 30 meters (100 ft). This minimum beach width is based on repeat survey profiles that suggest that dune erosion occurs when the beach narrows to this width (interpreted from figures in Barnard et al 2009). Once the beach narrows to the minimum beach width, the dune and shoreline begin to erode at the same projected future erosion rate. Each time the dune top width falls below a threshold (17 m), the dune is rebuilt to be 35 meters wide again.

Based on the assumptions above, we obtain a conceptual schedule of 3 dune reconstruction nourishments (in 2011, 2075, and 2095). The first dune construction would require 135 m^3/m for a total of 70,000 m^3 or ~90,000 cy. The subsequent two re-constructions (which only re-build half the dune) would require 100 m^3/m and 120 m^3/m, respectively. Each dune reconstruction would require incrementally more sand to reflect the higher dune crest elevation and more rapidly eroding beach profile. We assume that this maintenance of the dune would result in an average beach width of approximately 35 meters (~110 feet) in front of the dune.

List of Figures

References

Barnard, P.L., and D. Hoover, (2010), A seamless, high-resolution coastal digital elevation model (DEM) for southern California. U.S. Geological Survey Data Series 487, 8 p. and database.

Barnard, P.L., Revell, D.L., Hoover, D., Warrick, J., Brocatus, J., Draut, A.E., Dartnell, P., Elias, E., Mustain, N., Hart, P.E., and Ryan, H.F., 2009, Coastal processes study of Santa Barbara and Ventura Counties, California: U.S. Geological Survey Open-File Report 2009-1029, 904 p. [http://pubs.usgs.gov/of/2009/1029/].

ENVIRON and ESA PWA (2014). Management Scenarios for Nature Based Adaptation in Ventura, California. Memo to Sarah Newkirk at The Nature Conservancy. Revised April 17, 2014. Revised by ESA PWA (June 9, 2014)

ESA PWA (2013). Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping. Prepared by ESA PWA, San Francisco, for The Nature Conservancy. July 2013.

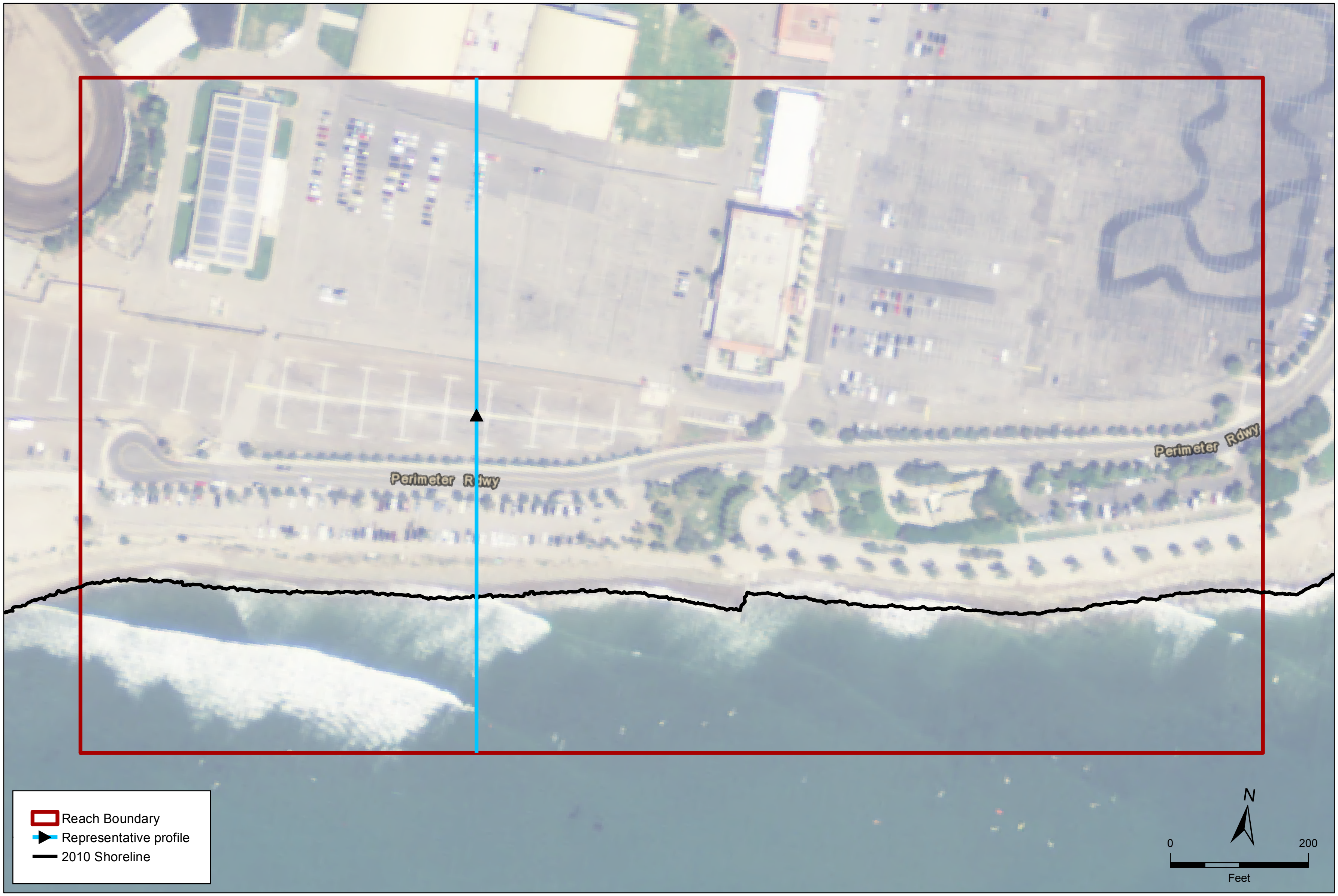
NOAA (2012). “2009 – 2011 CA Coastal Conservancy Coastal LiDAR Project: Hydro-flattened Bare Earth DEM.” NOAA Coastal Services Center. Charleston, South Carolina. Available online: http://www.csc.noaa.gov/dataviewer/#.

Stockdon, H.F., Holman, R.A., Howd, P.A., and Sallenger, Jr., A.H., 2006, Empirical parameterization of setup, swash, and runup, Coastal Engineering, 53, pp. 573-588.

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure X

Beach Width Analysis Locations

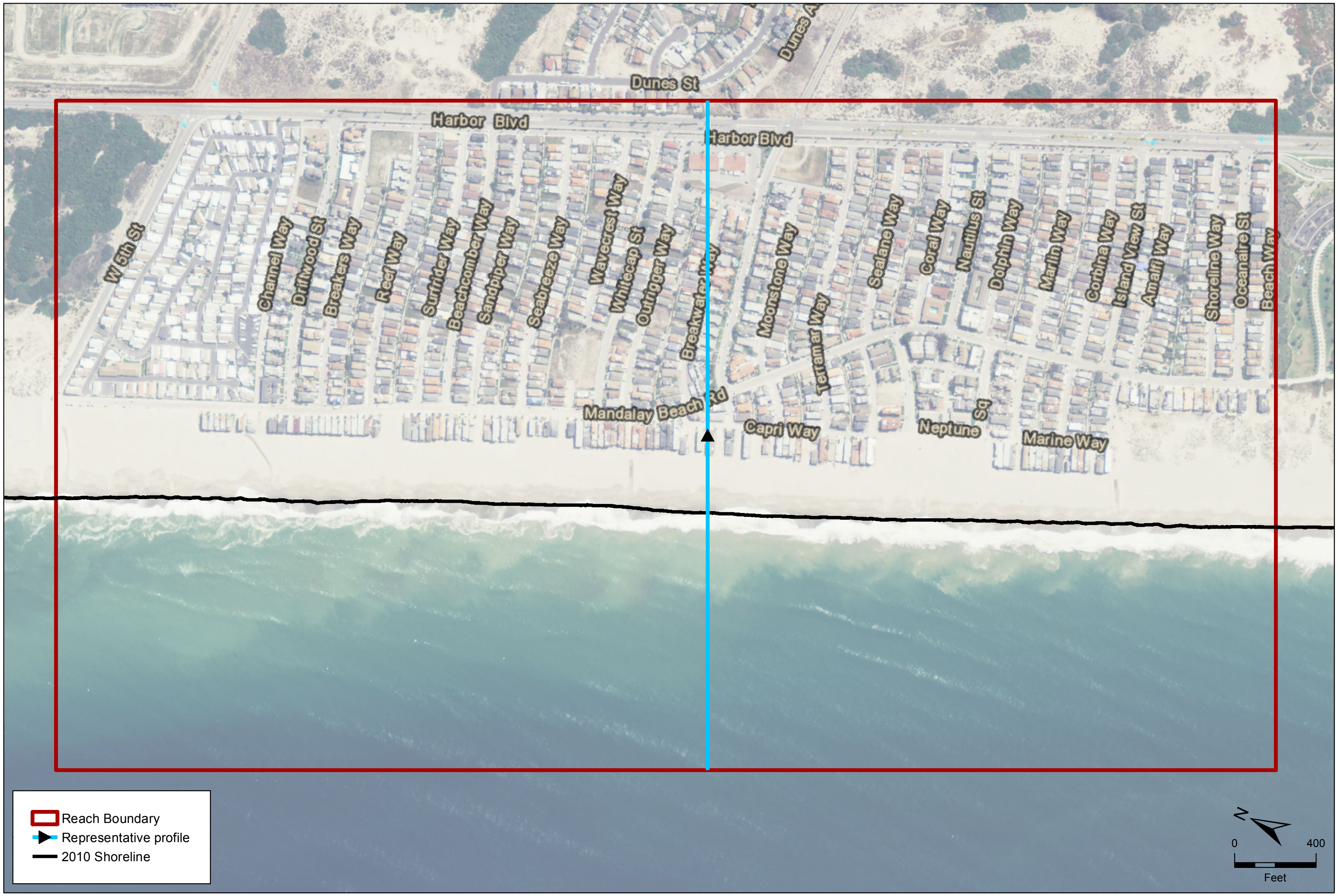


SOURCE: Air Photo from NAIP (May 2012)

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 2

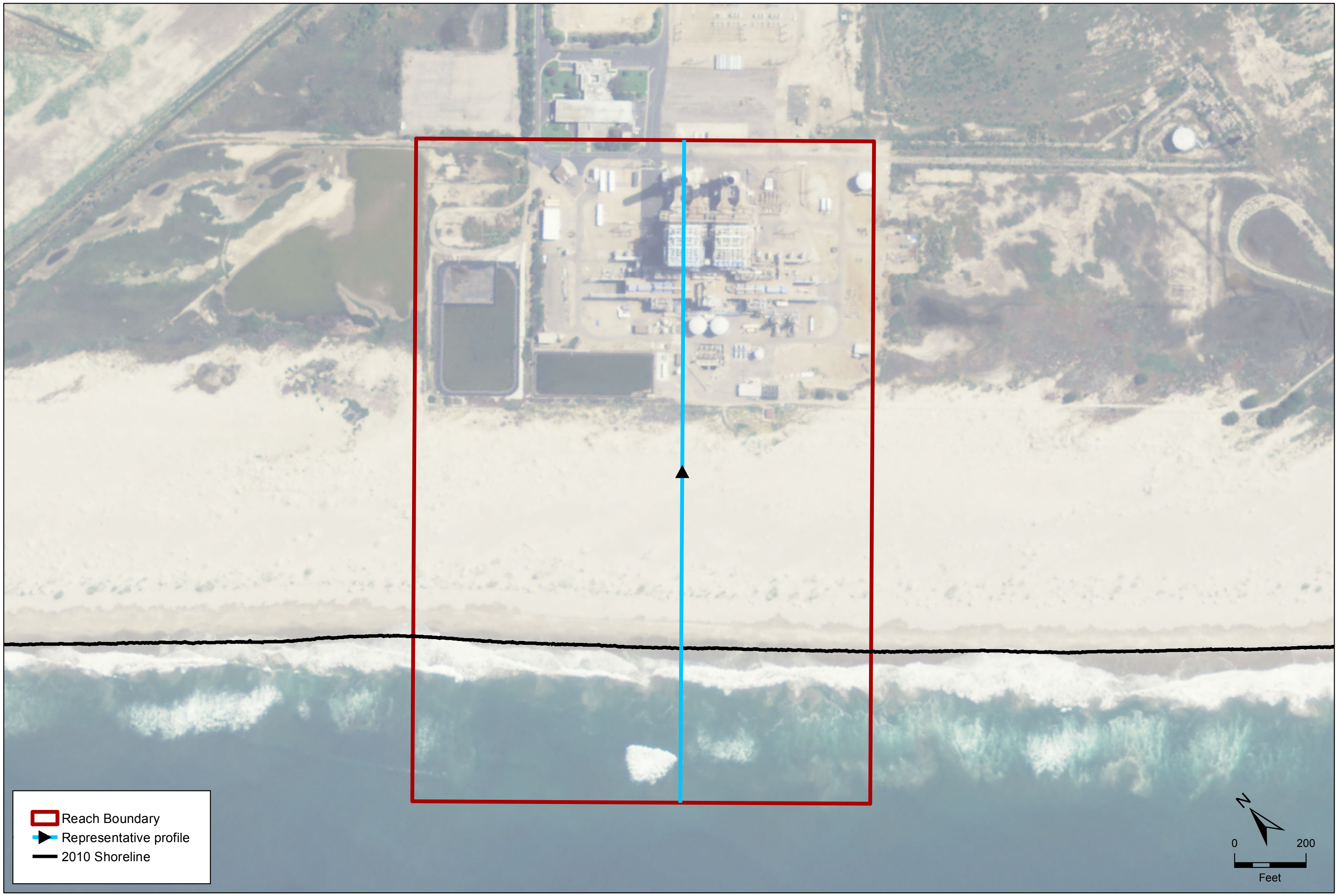
Reach Boundary: Surfer's Point



SOURCE: Air Photo from NAIP (May 2012)

Nature Based Adaptation to Climate Change in Ventura County . 130257.00

Figure 3
Reach Boundary: Oxnard Shores



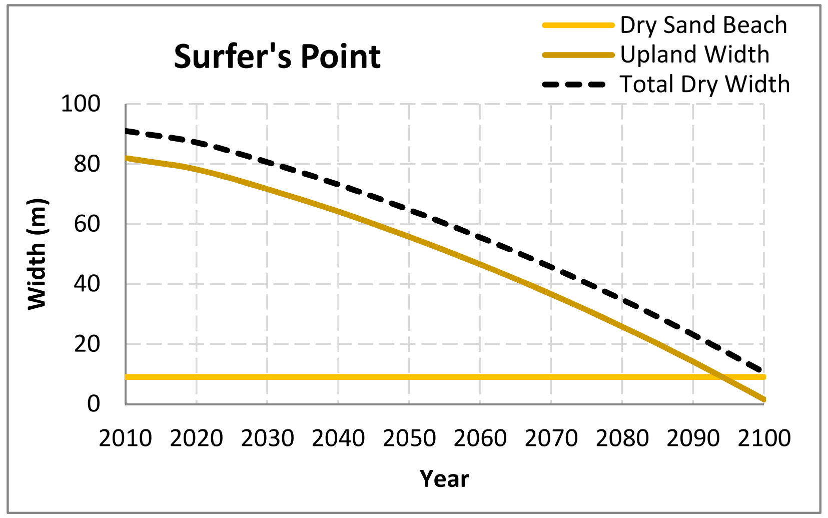
SOURCE: Air Photo from NAIP (May 2012)

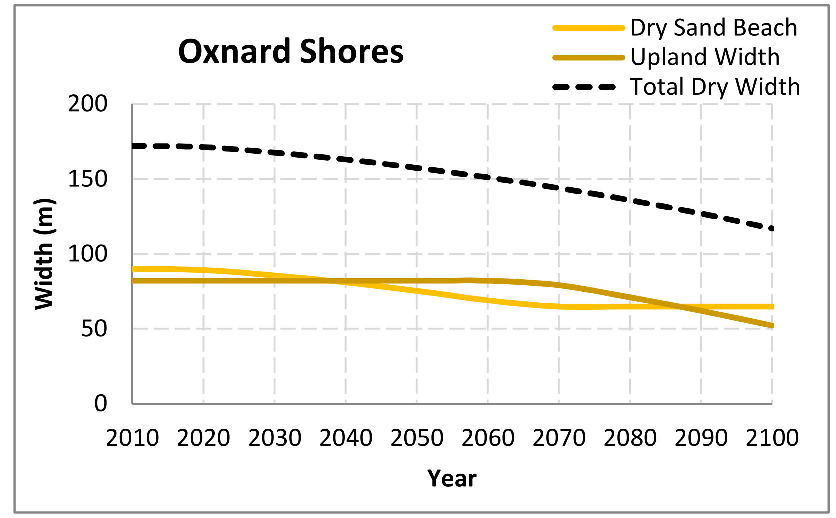
Nature Based Adaptation to Climate Change in Ventura County . 130257.00

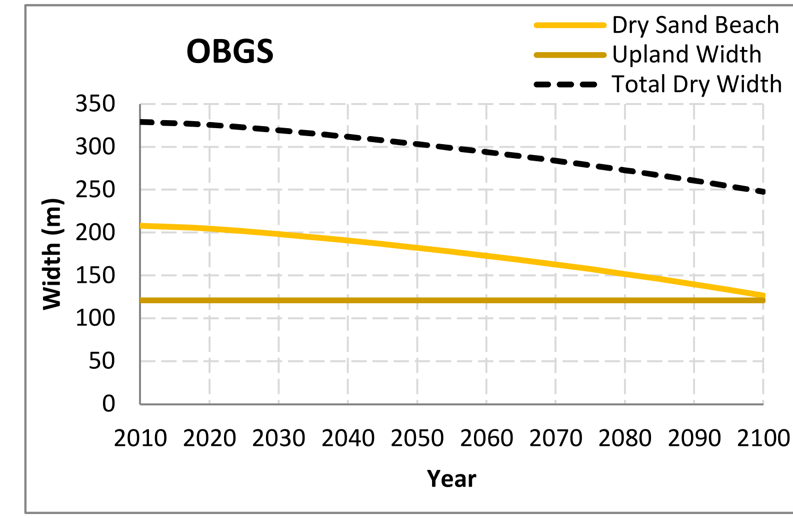
Figure 4

Reach Boundary: Ormond Beach Generating Station

Figure 5. Results Summary: Baseline Scenario (Allow Erosion)



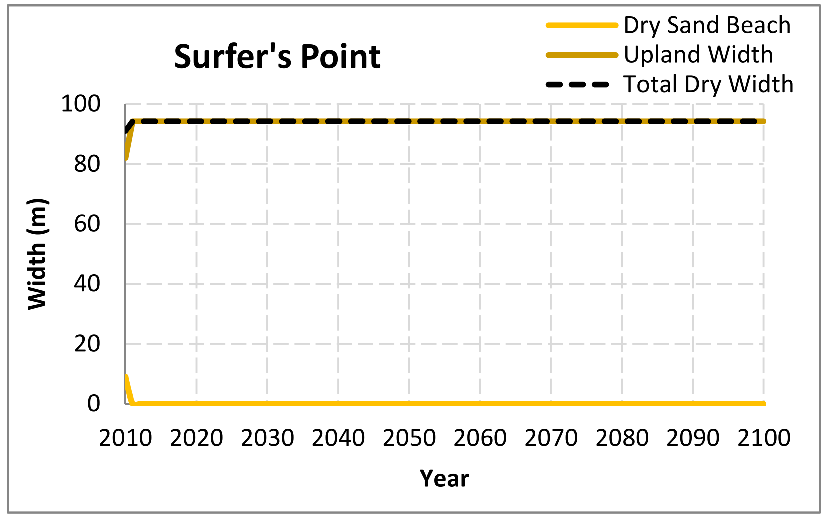


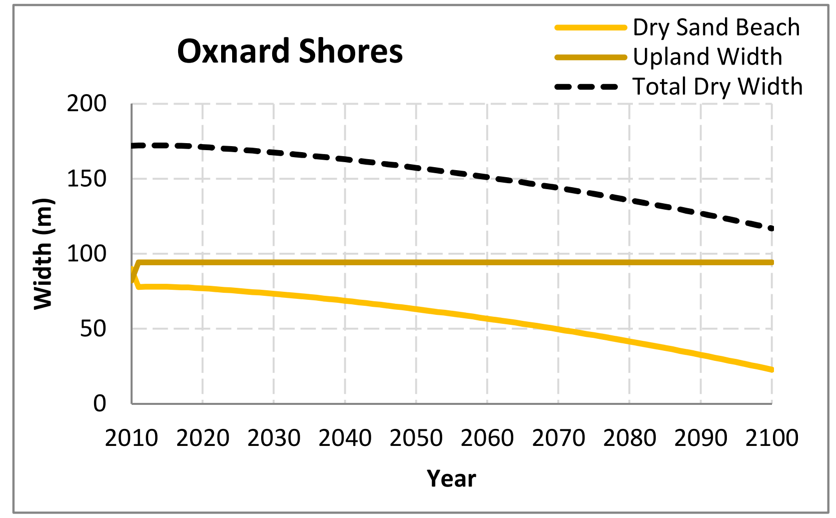


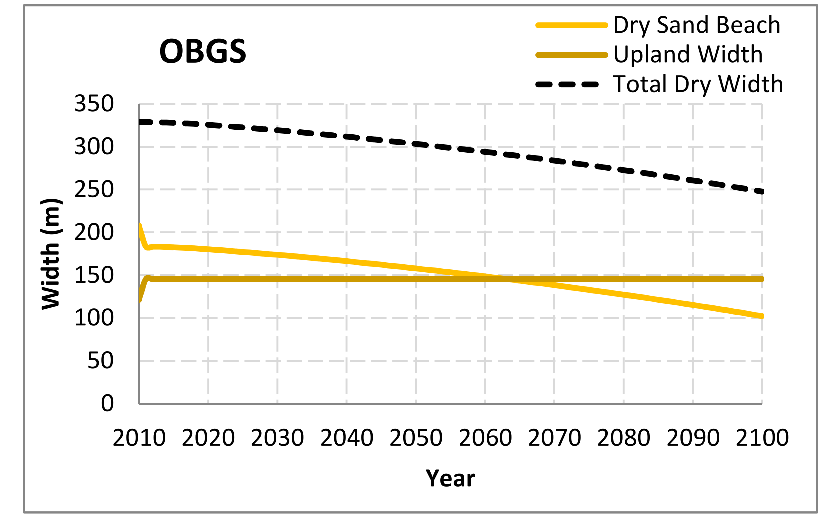
	Surfer's Point			Oxnard Shores			OBGS		
Year	Dry Sand Beach	Upland Width	Total Dry Width	Dry Sand Beach	Upland Width	Total Dry Width	Dry Sand Beach	Upland Width	Total Dry Width
	m	m	m	m	m	m	m	m	m
2010	9	82	91	90	82	172	208	121	329
2020	9	78	87	89	82	171	205	121	326
2030	9	72	81	86	82	168	198	121	319
2040	9	64	73	81	82	163	191	121	312
2050	9	56	65	75	82	157	182	121	303
2060	9	47	56	69	82	151	173	121	294
2070	9	37	46	65	79	144	163	121	284
2080	9	26	35	65	71	136	152	121	273
2090	9	14	23	65	62	127	140	121	261
2100	9	2	11	65	52	117	127	121	248

Notes: "Upland" width is estimated from an arbitary upland location.
For Ormond Beach Generating Station, these results are the same for the "Managed Retreat" scenario, in which erosion is allowed.
The plots display the data in a 1-year interval; the summary table provides values at 10-year timesteps

Figure 6. Results Summary: Engineering Based Adaptation (Hold the Line)



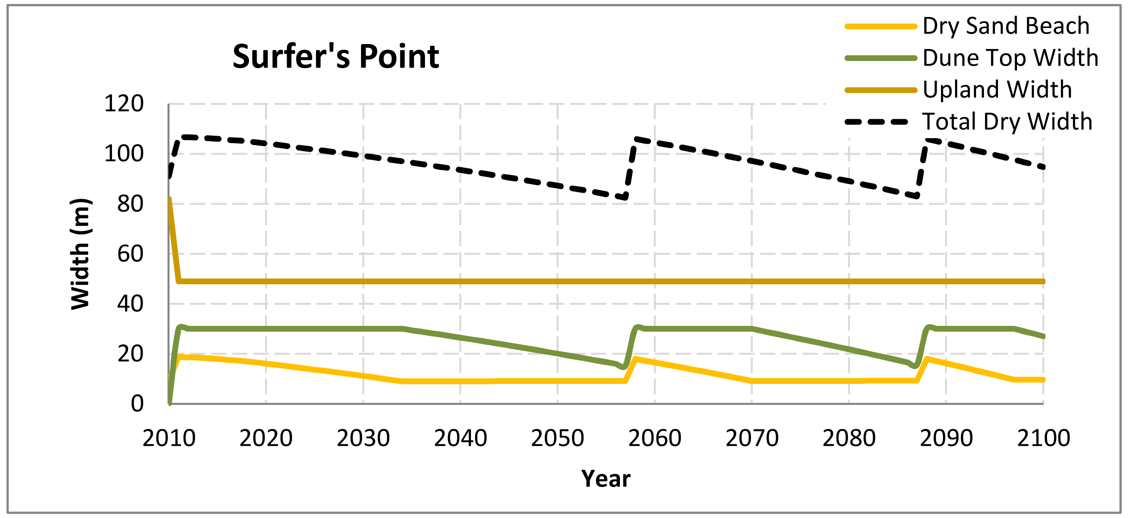


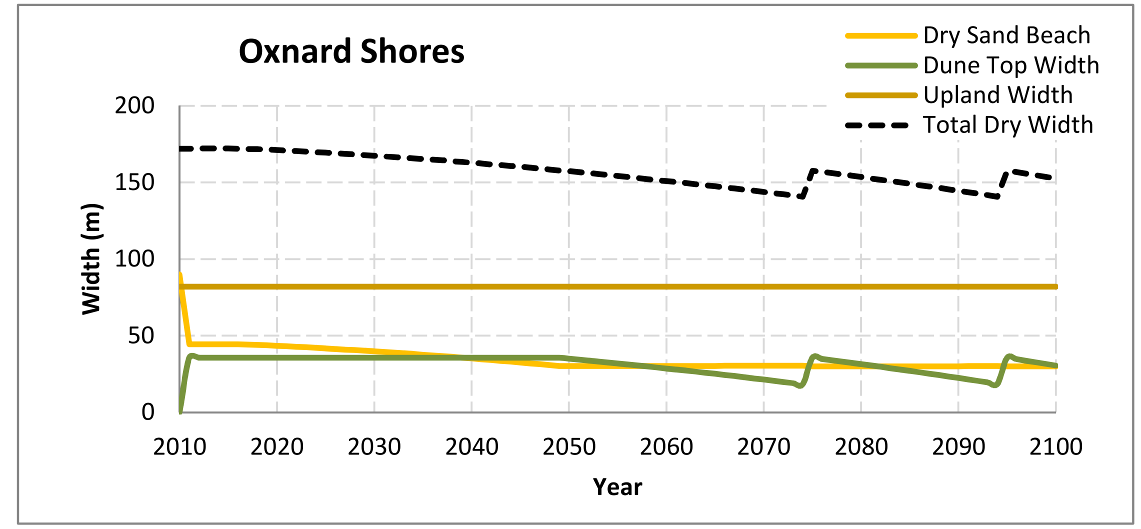


	Surfer's Point			Oxnard Shores			OBGS		
Year	Dry Sand Beach	Upland Width	Total Dry Width	Dry Sand Beach	Upland Width	Total Dry Width	Dry Sand Beach	Upland Width	Total Dry Width
	m	m	m	m	m	m	m	m	m
2010	9	82	91	90	82	172	208	121	329
2020	0	94	94	77	94	171	205	121	326
2030	0	94	94	73	94	168	198	121	319
2040	0	94	94	69	94	163	191	121	312
2050	0	94	94	63	94	157	182	121	303
2060	0	94	94	57	94	151	173	121	294
2070	0	94	94	50	94	144	163	121	284
2080	0	94	94	42	94	136	152	121	273
2090	0	94	94	33	94	127	140	121	261
2100	0	94	94	23	94	117	127	121	248

Note: "Upland" width is estimated from an arbitary upland location.
The plots display the data in a 1-year interval; the summary table provides values at 10-year timesteps

Figure 7. Results Summary: Nature Based Adaptation (Dune Restoration)





	Surfer's Point				Oxnard Shores			
Year	Dry Sand Beach	Dune Top Width	Upland Width	Total Dry Width	Dry Sand Beach	Dune Top Width	Upland Width	Total Dry Width
	m	m	m	m	m	m	m	m
2010	9	0	82	91	90	0	82	172
2020	16	30	49	104	43	36	82	171
2030	11	30	49	99	40	36	82	167
2040	9	27	49	94	35	36	82	163
2050	9	20	49	87	30	35	82	157
2060	17	30	49	105	30	29	82	151
2070	9	30	49	97	30	21	82	144
2080	9	22	49	89	30	31	82	154
2090	16	30	49	104	30	22	82	145
2100	10	27	49	95	30	31	82	153

Note: "Upland" width is estimated from an arbitary upland location.
The plots display the data in a 1-year interval; the summary table provides values at 10-year timesteps

Appendix E

Brief Annotated Bibliography of Literature Related to Costs and Benefits of Climate Change Adaptation

Brief Annotated Bibliography of Literature Related to the Costs and Benefits of Adaptation

This section summarizes some of the research and guidance that has been developed describing how benefits and costs of climate change, and climate change adaptation have been evaluated. This review covers the impacts of SLR, potential adaptation costs, and models that are already in place to facilitate quantification of economic impacts.

Nicholls et al. (2007) Coastal Systems and Low-lying Areas. Climate Change 2007: Impacts, Adaptation and Vulnerability

This is one chapter (Chapter 6) of a larger global study by the Intergovernmental Panel on Climate Change (IPCC); "IPCC Fourth Assessment Report (AR4), Climate Change 2007: Impacts, Adaptation and Vulnerability." In addition to presenting tools for assessing types of adaptation, it presents the costs of adaptation, covering the range from specific interventions to global aggregations, based on available literature on the topic. Selected comparative costs of coastal adaptation measures are presented in Table 6.11 of the report. The authors observe that financial cost is not the only criterion on which adaptation should be judged – local conditions and circumstances might result in a more expensive option being favored, especially where multiple benefits result.

UNFCC (2009) United Nations Framework Convention on Climate Change: Potential Costa and Benefits of Adaption Options: A Review of Existing Literature

This study provides an assessment of literature on costs and benefits of adaptation. Three aggregation levels were assessed: global studies, national studies, and a brief selection of local studies. It assesses the approaches and methods used, their applications and outputs, and their strengths and weaknesses. Where possible, it also compares the studies. The paper investigates the costs of adaptation, defined as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs." It also investigates the benefits of adaptation, defined as "the avoided damage costs or the accrued benefits following the implementation of adaptation measures." For both of these aspects, this paper considers the economic costs and benefits of adaptation, considering the wider costs and benefits to society as a whole, rather than financial ones alone. The document provides a synthesis of global-, national-, and local-level studies in tabular forms (for example, Table 11). The authors observe that there is a continued lack of detailed analyses of the costs and benefits of adaptation, including in a form that is relevant to decisions on public funding.

Nicholls (2003) Case Study on Sea Level Rise Impacts

This work examines the potential impacts of human-induced sea-level rise in the context of the evolving coastal system, rather than simply imposing sea-level rise on today's coastal zone and its activities. The observed and likely changes in sea level are considered over the 20th and 21st Century and beyond to illustrate the long time scales associated with this issue. The paper includes a consideration of the effects of mitigation on sea-level rise. The paper also presents and discusses an appropriate conceptual framework for considering the impacts of sea-level rise. Further, the paper reviews the impacts of sea-level rise, including the potential for adaptation. The potential costs of adaptation/protection based on country studies (including the

US) and costs associated with sea-level rise in the US based on various studies are presented in Tables 2 and 3, respectively, in Chapter 4. Further discussion on adaptation is provided in Chapter 5.

Watkiss et al (2010) The Costs and Benefits of Adaptation in Europe: Review Summary and Synthesis

This policy brief summarizes the review and synthesis work on the costs and benefits of adaptation to climate change in Europe. The review covers about 50 European, sectorial, regional, and national studies, as well as global studies that report information for Europe. Among other findings, the authors observe that the coverage of the adaptation cost estimates is limited, though the evidence base in now growing (though it is primarily in the gray literature). The briefing reports the estimates for adaptation costs from the various studies, and also provides examples of different decision support tools in adaptation in Europe.

Cooley et al. (2012) Social Vulnerability to Climate Change in California

This work presents the development of a new climate vulnerability index to indicate the social vulnerability of a region's population to climate-related harm. The index combines 19 indicators into one overall climate vulnerability score and includes factors specifically related to climate impacts, such as air conditioner ownership, childhood obesity, and percentage of tree cover, pre-term births, workers in outdoor occupations, and others.

Cayan et al. (2012) Climate Change Scenarios and SLR Estimates for California 2008 Climate Change Scenarios Assessment

This analysis provides an evaluation of physical elements of climate change and SLR that are contained in the California Climate Change Vulnerability and Adaptation Assessment. Section 6 in particular discusses sea-level rise.

Garzon et al. (2012) Community Based Climate Action Planning: A Case Study of Oakland California.

The authors provides a detailed analysis of climate impacts, vulnerabilities, and adaptation options in Oakland, California. The goal of this study was to inform the development of a comprehensive and equitable climate adaptation plan effort. This research project engaged active members of the Oakland Climate Action Coalition, including community-based organizations and resident leaders, in analyzing both the impacts of, and social vulnerabilities to, climate change. Further, adaptation strategies that can be implemented at the local level, and their advantages and disadvantages are discussed. It also identifies social equity concerns. Finally, it identifies trends and best practices in climate adaptation planning processes.

Grannis (2011) Threat of Seal Level Rise Costs and Benefits of Adaptation in European Coastal Countries.

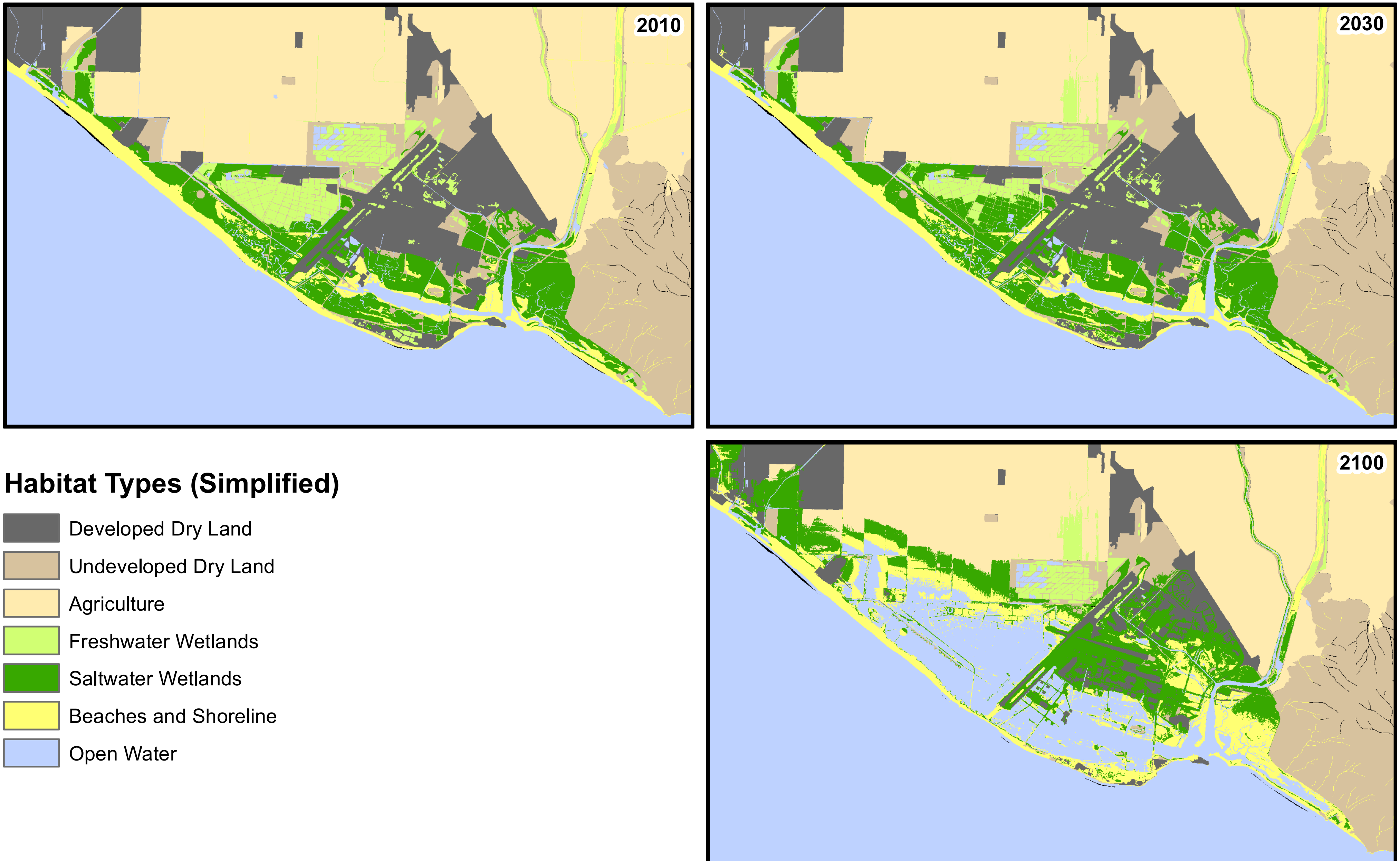
This work is geared towards local and state governments and their citizens and provides them with practical knowledge to help adapt to sea-level rise. The Tool Kit offers a menu of generally used legal devices that can reduce future effects.

Perez (2009) Potential Impacts of Climate Change on California's Energy Infrastructures and Identification of Adaptation Measures

This work presents a brief discussion about potential impacts to California's energy infrastructure and concludes with the identification of adaptation or coping strategies that the State could implement in the near future.

Appendix F

Extrapolation of SLAMM Results



Scenario: s3a1e1m1 (High SLR, Low Accretion, No Erosion of New Inlet, Allow Marshes to Transgress)

11/17/2014

N

0 1 2 Miles

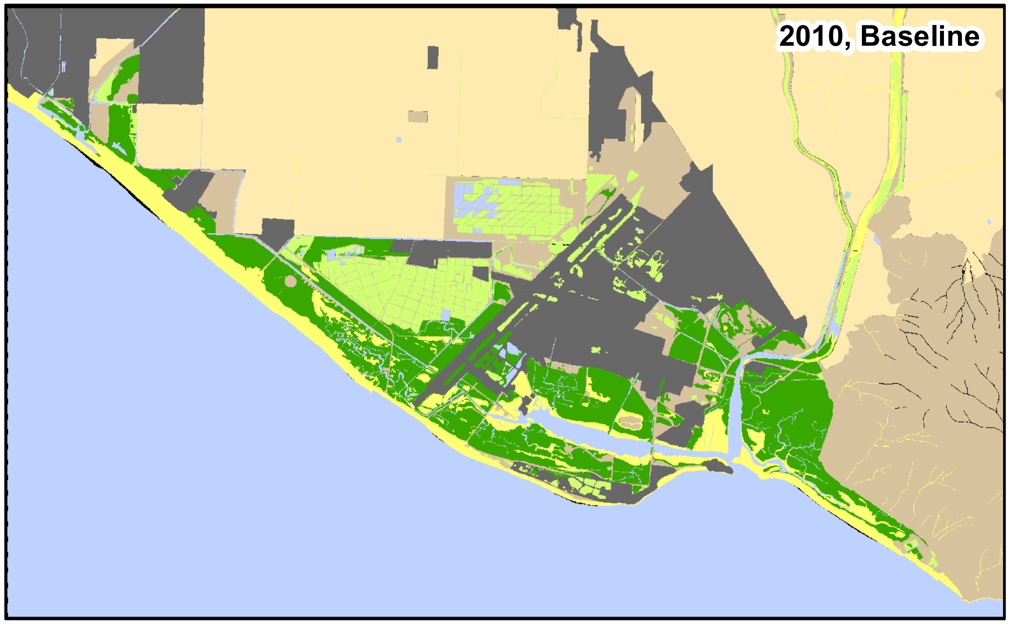
figure 1

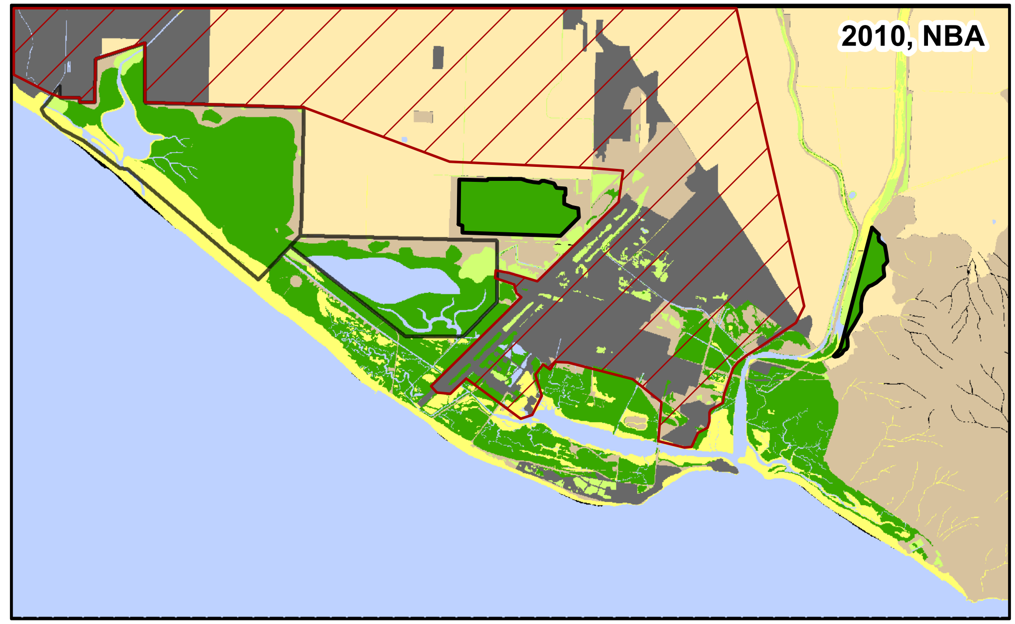
Ventura County Climate Change Vulnerability Study

Baseline Results (Simplified Habitats)

ESA PWA Ref# - D211452

ESA PWA





Habitat Types

- Developed Dry Land
- Undeveloped Dry Land
- Agriculture
- Freshwater Wetlands
- Saltwater Wetlands
- Beaches and Shoreline
- Open Water
- Wetland Restoration Measure
- Area protected by adaptation (not transgression permitted)

Scenario: s3a1e1m1 (High SLR, Low Accretion, No Erosion of New Inlet, Allow Marshes to Transgress)

11/17/2014

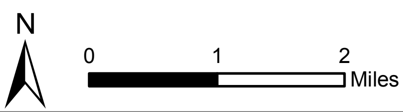


*figure **2***

Ventura County Climate Change Vulnerability Study

Existing Conditions for all Scenarios

ESA PWA Ref# - D211452

ESA PWA

Quantifying Ecosystem Services: Post-Processing SLAMM results to align with NBA/EBA scenarios
Nature Based Adaptation for Ventura County
December 5, 2014
ESA Project D130257.00

Results delivered in separate excel file (NBA_EBA_SLAMM_Results_5Dec2014.xlsx)

Background

The economics assessment in Ventura County shows similar results for NBA and EBA scenarios, but does not yet consider ecosystem services from habitats like wetlands and beaches. ESA modelled future wetland acreage using SLAMM in the vicinity of Mugu Lagoon/Ormond Beach. During this study, four management scenarios were modelled to compare impacts on wetland area. During the economics assessment of the Coastal Resilience Ventura project, three revised scenarios were identified based on discussions with stakeholders and science advisors: Baseline (no action), Nature Based Adaptation (NBA) and Engineering Based Adaptation (EBA). This document describes how the original SLAMM results were post-processed to better align with the NBA and EBA scenarios. The original SLAMM baseline scenario (m1 – allow wetlands to transgress) aligns well with the economics Baseline scenario, so the baseline scenario required no post-processing.

Methods

The EBA and NBA scenarios are described in a memo from ENVIRON and ESA PWA to TNC dated June 9, 2014. The measures within each scenario were described briefly and assigned unique codes. The first two columns of Table 1 and Table 2 list the measures relevant to the Mugu Lagoon/Ormond Beach study area for the NBA and EBA scenarios, respectively.

The NBA and EBA future habitat acreages were estimated by post-processing the Baseline scenario. The Baseline scenario corresponds to the “s3a1e1m1” (s3 - high sea level rise of 1.47 m between 2010 and 2100, a1 - low accretion, e1 - no erosion of new inlet, and m1 - allow marshes to transgress) in the SLAMM study (ESA PWA 2014a). The m1 (allow marshes to transgress) scenario resulted in the most expansive wetland transgression with sea level rise. Both the NBA and EBA scenarios prevent some of this transgression from occurring. For example, we assume that wetlands are not able to transgress past a newly constructed levee or seawall/revetment. Two GIS polygon masks were created to represent areas where no wetland transgression was allowed to occur for the NBA and EBA scenarios. In these areas, the Baseline scenario was post-processed by replacing these “fortified” areas with the existing conditions habitats (i.e. no change of habitats is allowed to occur in these areas). For example, in both the NBA and EBA scenarios, a ring levee is constructed around Navy Base Ventura County (NBVC). The 2030 and 2100 Baseline habitats inside this levee were replaced with the existing (2010) land cover types, reverting any new wetlands that had transgressed to previous land cover. This approach allows wetlands in the non-fortified areas to evolve as modelled. This approach aligns closely with how SLAMM would have modelled the scenarios had the entire model been re-run for EBA/NBA.

The third column of Table 1 and Table 2 explains how each management measure was addressed in this post-processing exercise.

Table 1. NBA Measures within Mugu Lagoon/Ormond Beach Study Area

Code	Brief Description	Modification of Baseline SLAMM
NBA-BD2b	Beach and dune restoration between Port Hueneme and Ormond Beach Lagoon	No modification
NBA-LV1	Construct ring levee surrounding airfield at NBVC	Replace areas inside levee with 2010 habitats
NBA-LV2	Construct levee along north side of Ormond Beach wetland restoration	Replace areas behind levee with 2010 habitats
NBA-MR6	Removal of Halaco Superfund site	No change – wetlands allowed to transgress
NBA-MR7	Removal of Ormond Beach Generating Station	No change – wetlands allowed to transgress
NBA-MR8	Decommission of some roads and NBVC infrastructure	No change – wetlands allowed to transgress
NBA-MR9	Remove revetment fronting the NBVC runway	No change – wetlands allowed to transgress
NBA-MR10	Removal of revetment and infrastructure on open coast at Mugu Lagoon	No change – wetlands allowed to transgress
NBA-MR11	Lower levee along Calleguas Creek	No change (see NBA-WL5)
NBA-WL1	Ormond Beach Wetland Restoration, Alt 2U	Replace habitats with Ormond Beach Wetland Restoration habitats, and assume no change within this area from SLR (likely over-estimating future salt marsh area).
NBA-WL2a	Restore southern duck ponds to tidal wetlands/Ormond Beach Wetland Restoration (Alt 2U)	Replace habitats with Ormond Beach Wetland Restoration habitats, and assume no change within this area from SLR (likely over-estimating future salt marsh area).
NBA-WL2b	Restore northern duck ponds to tidal wetlands	Replace northern duck ponds with salt marsh and assume stays salt marsh through time (likely over-estimating future salt marsh area)
NBA-WL3a	Allow wetland transgression into ag lands	No change – wetlands allowed to transgress [Note: this measure is slightly inconsistent with the Ormond Beach Restoration Plan in that it allows some transgression into ag fields (~400 acres). The Ormond Beach Restoration Plan included a levee along the back of the entire wetland restoration area, but our NBA does not include this levee.]
NBA-WL3b	Allow wetland transgression into ag lands	No change – wetlands allowed to transgress
NBA-WL5	Wetland restoration adjacent to Revelon Slough and Calleguas Creek	Assume this region is salt marsh and stays salt marsh through time. (likely over-estimating future salt marsh area)

Table 2. EBA Measures within Mugu Lagoon/Ormond Beach Study Area

Code	Brief Description	SLAMM Modification
EBA-AN1f	New seawall/revetment from South Ventura Road to Ormond Beach Wetland Restoration	Prevent wetland transgression. Replace areas behind wall with 2010 habitats
EBA-AN1g	New seawall/revetment from Ormond Beach Wetland Restoration to NBVC runway	No direct change to baseline results.
EBA-AN1h	New seawall/revetment from NBVC runway to I Avenue	No direct change to baseline results.
EBA-AN1i	New seawall/revetment inside mouth of Mugu Lagoon	No direct change to baseline results.
EBA-AN1j	New seawall/revetment along east arm of Mugu	No direct change to baseline results.
EBA-AR1f	Reinforce seawall/revetment along NBVC runway	No direct change to baseline results.
EBA-AR1g	Reinforce seawall/revetment between I Avenue to mouth of Mugu Lagoon	No direct change to baseline results.
EBA-EL1a	Raise road to Ormond Beach Generating Station	No change to baseline results (area change negligible)
EBA-LV1b	Construct ring levee around Ormond Beach Generating Station	Prevent wetland transgression. Replace areas inside levee with 2010 habitats
EBA-LV2a	Construct ring levee surrounding airfield at NBVC	Prevent wetland transgression. Replace areas inside levee with 2010 habitats
EBA-LV2b	Construct levee along back of Ormond Beach Wetland restoration	Prevent wetland transgression. Replace areas behind levee with 2010 habitats
EBA-LV3	Raise levee along Revelon Slough	No change to baseline results
EBA-TB2	Tidal barrier/lock across bridge at Laguna Road	Assume wetlands can't transgress above the 2010 EMHW elevation contour (replace areas above this contour with existing habitats)
EBA-WL1	Ormond Beach Wetland Restoration (Alt 3C)	Replace habitats with Ormond Beach Wetland Restoration habitats, and assume no change within this area from SLR (likely over-estimating future salt marsh area).

The revised NBA/EBA SLAMM habitat maps were re-classified into simpler categories, according to Table 3. Two habitat categories were not tabulated from the SLAMM results: Coastal Strand and Open Ocean. The beach (Coastal Strand) was analysed separately outside of SLAMM (ESA PWA 2014b, ESA PWA 2014c), as SLAMM is not capable of modelling the adaptation scenarios proposed under EBA and NBA. The Open Ocean category has much lower ecological value than other open water habitats. Total acreages for each simplified habitat category, planning horizon (2010, 2030, 2100), and adaptation scenario (Baseline, NBA, EBA) are provided in the Excel file (NBA_EBA_SLAMM_Results_5Dec2014.xlsx) accompanying this document.

Table 3. Habitat Reclassification for Economic Assessment

SLAMM ID	Original SLAMM Habitat Category	Simplified Category for Economic Assessment
1	Developed Uplands	Developed Uplands
2	Undeveloped Uplands	Undeveloped Uplands
3	Freshwater Wetland with Trees/Shrubs/Riparian Forest	Freshwater Wetlands
5	Freshwater Marsh	Freshwater Wetlands
6	Tidal Marsh	Freshwater Wetlands
7	Tidal Estuarine Wetland with Trees/Shrubs	Saltwater Wetlands
8	Emergent Salt Marsh	Saltwater Wetlands
10	Estuarine Beach	Mudflats and other Inlands Shores
11	Mud Flat	Mudflats and other Inland Shores
12	Coastal Strand	N/A – this category is tracked separately using a more sophisticated beach width analysis.
14	Rocky Intertidal	Mudflats and other Inland Shores
15	Open Water	Inland Open Water
16	Riverine Tidal	Inland Open Water
17	Open Water Subtidal	Inland Open Water
18	Tidal Channel	Inland Open Water
19	Open Ocean	N/A – This category is not considered in the economic assessment.
20	Rarely Flooded Salt Marsh / Salt Pans	Saltwater Wetlands
22	Arroyo / Gravel / Shore	Mudflats and other Inland Shores
23	Tidal Wetland with Trees/Shrubs	Freshwater Wetlands
26	Dunes	N/A – this category is tracked separately using a more sophisticated beach width analysis.
100	Agriculture	N/A – this category is tracked separately using a more sophisticated beach width analysis.

Key assumptions

- Adaptation strategies only affect where wetlands can transgress. They do not change tide range, topography, adjacent habitat types, accretion and erosion rates, sediment supply, water levels, connectivity, any other factors important in wetland evolution. In other words, none of the added complexities introduced by the EBA and NBA scenarios were modelled. In general, we simply remove areas where we don't expect wetlands to transgress and add in areas of new wetland restoration (assuming they are static through time).
- At Ormond Beach, use habitats mapped in the Ormond Beach Wetland Restoration plan for all planning horizons because SLAMM was not run for this restoration plan. In other words, assume marsh is able to keep up with sea level rise, which is a big assumption since SLAMM shows marshes in Mugu can't keep up. This would depend on the restoration design.

References

ESA PWA (2014a). Coastal Resilience Ventura: Final Technical Report for Sea Level Affecting Marshes Model (SLAMM). Prepared for the Nature Conservancy. March 18, 2014.

ESA PWA (2014b). Coastal Resilience Ventura: Beach Width Analysis. Memo from ESA PWA (E. Vandebroek and D. Revell) to ENVIRON (G. Greene). August 22, 2014.

ESA PWA (2014c). Quantifying Ecosystem Services: Extrapolating Beach Width Analysis to all of Ventura County. Prepared by ESA PWA for ENVIRON. December 4, 2014.

Appendix G

Elements of Adaptation Costs

Note	NBA	Cost per unit ($)	unit cost	Quantity
Part 1	NBA-BD1- Beach and Dune Restoration - Norish with cobbles and backbeach dunes	$200,000	per acre	17
Part 1	NBA-BD2a - Beach and Dune restoration - Dune Enhancement	$75,000	per acre	84
Part 2	NBA-BD2b- Beach and Dune restoration - Dune Restoration/Maintenance	$85,000	per acre	45
	NBA-BD2c- Beach and Dune restoration - Dune Restoration/Maintenance	$85,000	per acre	170
	NBA-BD2d- Beach and Dune restoration - Dune Restoration/Maintenance	$85,000	per acre	42
Part 2	NBA-WL1 - Restoration of Ormond Beach Wetlands (wetland conversion)	$10,000	per acre	1,120
Part 3	NBA-WL2a - Conversion of duck ponds to tidal wetlands	$10,000	per acre	568
Part 3	NBA-WL2b - Conversion of duck ponds to tidal wetlands	$10,000	per acre	229
Part 3	NBA-WL3a &WL3b - Conversion of agricultural lands to wetlands, purchase of lands	$45,000	per acre	1,893
Part 2	NBA-WL5 - Retreat of shoreline and transgression of wetlands	$20,000	per acre	60
Part 1	NBA-WL6 - Restore wetland and lagoon connectivity	$50,000	per acre	20
Part 2	NBA-LV1 - Construction of ring levee surrounding Mugu airfield	$50	per cubic yard	829,241
	NBA-LV2 - Construction of ring levee along north side of OB wetland restoration	$50	per cubic yard	164,500
Part 1	NBA-AR1a - Elevate bulkheads around Ventura Harbor	$2,000	per foot	30,834
Part 2	NBA-AR1b - Elevate bulkheads at Channel Islands Harbor	$2,000	per foot	54,548
Part 2	NBA-AR1c - Elevate bulkheads at Port Hueneme Harbor	$2,000	per foot	15,549
	NBA-AR2A - Reinforce seawall and Revetment	$2,000	per foot	1,754
	NBA-AR2B - Reinforce seawall and Revetment	$2,000	per foot	3,606
Part 2	**Re do all in 2050 and 2070**			
	NBA-MR1: Managed retreat between surfer's point and Promenade Park			
	NBA-MR2: Removal of parking lot and Hwy 101 on-ramps east			
	NBA-MR3 - Relocation of Ventura Water Reclamation Facility			
	NBA - MR4 - Relocate McGrath State Beach Park and Campground	$100,000	per acre	107
	NBA-MR5: Decommission Mandalay Power Plant			
	NBA-MR6: Removal of Halaco Superfund Site	$100,000	per acre	25
	NBA-MR7: Decommission of Ormond Beach Generating Station			
	NBA-MR8: Decommission of roads and NBVC infrastructure	$10,000	per linear mile	9
	NBA-MR9: Removing the revetment fronting the NBVC runway	$50,000	per linear mile	16
	NBA-MR10: Removal of revetment and all infrastructure	$50,000	per linear mile	0
	NBA-MR11 - lower the levee	$6	per cubic yard	106,880
	NBA-MR-12 - abandon existing residential structure and purchase res. structure elsewhere	$500,000	per acre	15
	NBA-EL1 - raise the roads - East Harbor Blvd			
Parts 1 and 2	NBA-EL2 - raise residential houses	$150,000	per house	2,680

Note	CAA	Cost per unit ($)	unit cost	Quantity
	Existing Revetment			
	EBA-AR1a: Reinforcement of the existing revetment - West end of Ventura Promenade to Ventura Pier	$2,000	per foot	3,233
	EBA-AR1b:Reinforcement of the existing revetment: Greenlock Lane to Ventura Marina	$2,000	per foot	1,682
	EBA-AR1c: Reinforcement of the existing revetment: Ventura Marina to Santa Clara River	$2,000	per foot	3,979
	EBA-AR1d: Reinforcement of the existing revetment: Channel Islands Harbor to Port Hueneme	$2,000	per foot	6,920
	EBA-AR1e: Reinforcement of the existing revetment: Port Hueneme to South Ventura Road	$2,000	per foot	5,022
	EBA-AR1f: Reinforcement of the existing revetment: NBVC runway	$2,000	per foot	2,227
	EBA-AR1g: Reinforcement of the existing revetment: I Avenue to mouth of Mugu Lagoon	$2,000	per foot	8,841
	New Revetment			
	Rubble - Mound new revetment			
	EBA-AN1a: Surfer's Point: Ventura River Levee to roundabout	$5,000	per foot	2,150
	EBA-AN1b: Ventua Pier to San Pedro Street	$5,000	per foot	5,126
	EBA-AN1c: San Pedro Street to Greenock Lane in Ventura	$5,000	per foot	5,255
	EBA-AN1d: Santa Clara River Mouth to Mandalay Generating Station	$5,000	per foot	11,768
	EBA-AN1e: Mandalay Generating Station to Channel Islands Harbor	$5,000	per foot	18,782
	EBA-AN1f: South Ventura Road to Ormond Beach Wetland Restoration	$5,000	per foot	6,292
	EBA-AN1g: Ormond Beach Wetland Restoration to NBC runway (waterproof)	$5,000	per foot	8,272
	EBA-AN1h: NBCV runway to I Avenue	$5,000	per foot	6,860
	EBA-AN1i: Inside mouth of Mugu Lagoon	$5,000	per foot	2,746
	EBA-AN1j: East Arm of Mugu Lagoon	$5,000	per foot	9,987
	Total: EBA-AN	$5,000	per foot	77,238
	Revetment - H-soldier piles with reinforced concrete	$5,000	per foot	77,238
	Revetment - Steel sheet pile bulkhead	$8,000	per foot	77,238
	EBA-TB1a- Tidal Barrier/Lock at mouth of harbor - Mouth of Ventura Harbor			570
	EBA-TB1b- Tidal Barrier/Lock at mouth of harbor - Mouth of Channel Islands Harbor			506
	EBA-TB1c- Tidal Barrier/Lock at mouth of harbor - Mouth of Port HuenemeHarbor			668
	EBA-TB2- Tide gate only - Mugu Lagoon			413
	EBA-LV1a: Construct levee with revetment - Ring levee around Mandalay Power Plant	$50	per cubic yard	78,278
	EBA-LV1b: Construct Levee around Ormond Beach Generating station	$50	per cubic yard	131,704
	EBA-LV2a: Ring Levee surrounding airfield at NBVC	$50	per cubic yard	829,241
	EBA-LV2b: Construct Levee backing Ormond Beach Wetland Restoration	$50	per cubic yard	436,352
	EBA-LV3: Raise levee along Revelon Slough	$50	per cubic yard	136,722
	EBA-EL1a: Raise the access road to Ormond Beach Generating Station:			
	EVA-WL1: Small scale restoration of Ormond Beach along TNC and Coastal Conservancy properties	$30,000	per acre	695