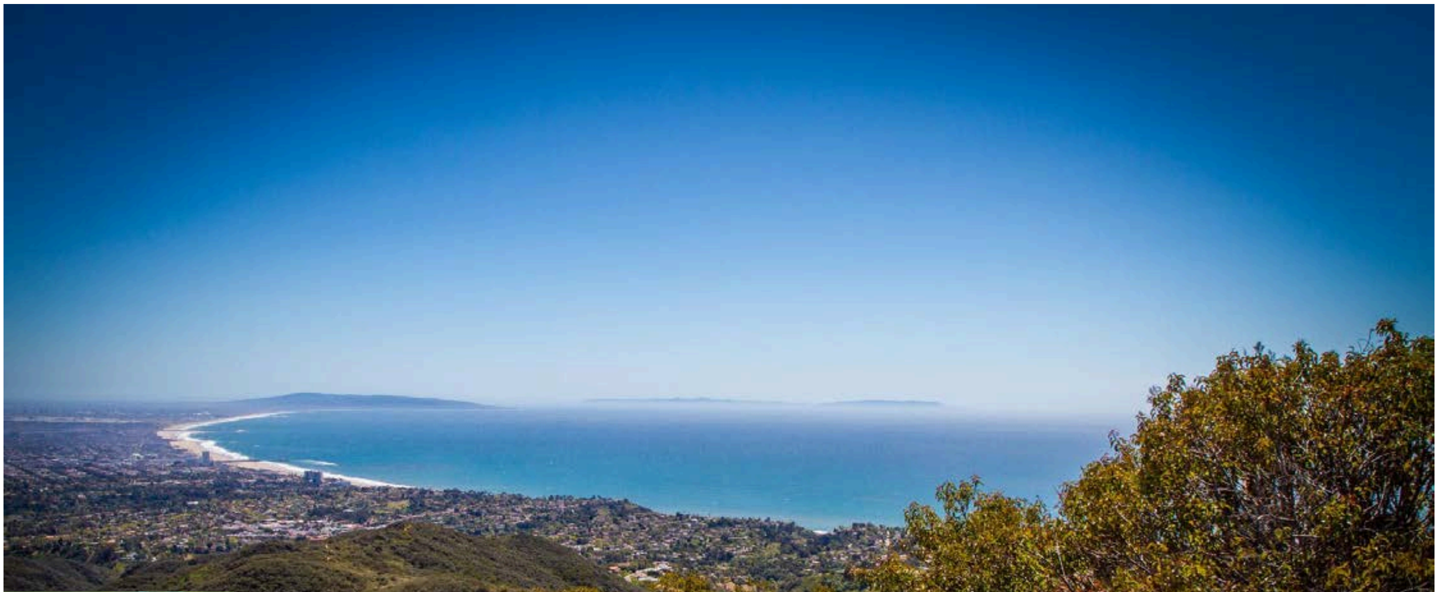

Climate Change Vulnerability Assessment of the SMBNEP Bay Restoration Plan

September 2016

Prepared by the Santa Monica Bay National Estuary Program for submittal to the US Environmental Protection Agency

SMBNEP
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September 2016

Prepared by: Santa Monica Bay National Estuary Program (SMBNEP)
Prepared for: United States Environmental Protection Agency (USEPA)

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Common Acronyms

ASBS	Areas of Special Biological Significance
AOGCM	Atmosphere-Ocean Global Circulation Model
BEP	Boater Education Program
BRP	Santa Monica Bay Restoration Plan
BWER	Ballona Wetlands Ecological Reserve
CA-BCM 2014	California Basic Characterization Model (2014)
C-CAN	California Current Acidification Network
CCSM	Community Climate System Model
CCVA	Climate Change Vulnerability Assessment
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CIMP	Coupled Model Intercomparison Project
CMP	Santa Monica Bay Comprehensive Bay Monitoring Program
CoSMoS	Coastal Storm Modelling System
CVA	Clean Vessel Act
CWD	Climatic Water Deficit
DBW	California State Parks Division of Boating and Waterways
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved Oxygen
ENSO	El Niño/Southern Oscillation
EWMP	Enhanced Watershed Management Plans
GB	Santa Monica Bay Restoration Commission Governing Board
GCM	Global Circulation Model
GFDL	Geophysical Fluid Dynamics Laboratory
GPRA	Government Performance and Results Act
HABs	Harmful Algal Blooms
HHW	Household hazardous waste
IPCC	Intergovernmental Panel on Climate Change
LACDPW	Los Angeles County Department of Public Works
LARC	Los Angeles Regional Collaborative for Climate Action
LARWQCB	Los Angeles Regional Water Quality Control Board
LCP	Local Coastal Plan
MPA	Marine Protected Area
MRCA	Mountains Recreation and Conservation Authority
NEP	National Estuary Program
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	Natural Resource Council
OA	Ocean acidification
OAH	Ocean acidification and hypoxia
OHC	Ocean heat content
OWDS	On-site Wastewater Disposal Systems
PCB	Polychlorinated biphenyls
POTW	Public owned treatment works
Prop.	Proposition Grant

RCDSMM	Resource Conservation District of the Santa Monica Mountains
SCC	California State Coastal Conservancy
SLR	Sea level rise
SMBNEP	Santa Monica Bay National Estuary Program
SMBRA	Santa Monica Bay Restoration Authority
SMBRC	Santa Monica Bay Restoration Commission
SotB Report	2015 State of the Bay Report
SST	Sea surface temperature
SWRCB	State Water Resources Control Board
TAC	Santa Monica Bay Restoration Commission Technical Advisory Committee
TBF	The Bay Foundation (also known as the Santa Monica Bay Restoration Foundation)
TMDL	Total Maximum Daily Load
UCLA	University of California, Los Angeles
USACE	United States Army Corps of Engineers
USC	University of Southern California
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WAC	Santa Monica Bay Restoration Commission Watershed Advisory Committee
WMP	Watershed Management Plans

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Executive Summary

In 2016, The Bay Foundation (TBF), with support from the Santa Monica Bay Restoration Commission (SMBRC), was awarded an EPA grant to conduct a broad, risk-based, Climate Change Vulnerability Assessment (CCVA) of the objectives in the Santa Monica Bay National Estuary Program (SMBNEP's) Bay Restoration Plan (BRP). The CCVA identifies risks associated with individual objectives and goals in the BRP. Additionally, the CCVA identifies strengths and weaknesses of existing objectives to manage and adapt to the impacts of climate change.

Specific project tasks included first developing a literature review of existing applicable models for six different climate change stressors: warmer temperatures, warmer water, sea level rise, increased drought, increased storminess, and ocean acidification. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen (IPCC 2014). For purposes of the CCVA, a variety of climate change models associated with the six climate change stressors were investigated. Specific climate change models associated with the Santa Monica Bay Watershed region were chosen to inform staff and expert reviewers in the CCVA process. In general and when available, climate change models were analyzed for current, year 2050, and year 2100 scenarios. The model year is meant to be representative and not an exact timeframe.

The next step identified a broad set of risks and opportunities associated with each climate change stressor for individual BRP objectives and milestones. The goal of the risk identification step was to generate a broad list of reasonably foreseeable ways that climate change stressors may affect organizational goals. This was primarily a staff-driven brainstorm exercise conducted at the milestone level (lowest tier) and subsequently scaled up to the objective level (second tier). This step required an in depth understanding of the tasks covered by each milestone in the BRP and a high degree of staff expertise. In addition to risks, some potential outcomes were identified as "opportunities." These are circumstances arising from any of the six climate change stressors that may have beneficial effects instead of harmful impacts. It was subsequently reviewed by the expert climate scientist panel.

In summary, the total number of risks identified as part of the BRP evaluation was 474 across 59 objectives. Objectives relating to land acquisition or education and outreach tended to have more opportunities identified and fewer overall risks, while those relating to coastal habitats that are vulnerable to many climate change stressors had significantly more. However, it is important to understand that these risk counts should not be evaluated quantitatively, which is why the expert climate scientist panel decided not to include the number of risks in the CCVA framework. The number of risks identified is not necessarily correlated to its overall vulnerability, as some identified risks may contribute disproportionately more to an objective's vulnerability score. Some risks may eventually end up making some objectives infeasible or requiring immediate management action. The list of risks for each objective contained in Appendix B contributed to the overall vulnerability analysis, and some are discussed in more detail in the individual narratives found in the CCVA.

The next step included the development of a CCVA Framework by the panel of expert climate scientists. The CCVA Framework varied from the EPA's "Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans" (EPA Workbook), in that it did not compare the vulnerability of individual risks to one another; instead, it assessed the vulnerability of the BRP at the objective level using a framework based on the following factors: adaptive capacity, sensitivity, and exposure of each objective. Exposure was primarily categorized using the models identified in the literature review portion of this project and was identified in three time horizons: exposure (current), exposure (2050), and exposure (2100). The factors were averaged across each time horizon, projecting an approximate vulnerability score for each time horizon. The raw categorization scores are presented in Appendix C, but are not meant to be analyzed quantitatively. Instead, the results are presented in this report as qualitative visualizations that are broadly and generally interpreted to evaluate the vulnerability of the BRP at the objective level, to facilitate the future development of action planning to integrate the results into the next BRP update. The final CCVA visualizations were also reviewed by the expert climate scientist panel.

The overarching results from the vulnerability analysis and the interpretation of the visualizations was highly variable, and often individual and objective-dependent. Interpretations of the vulnerability of objectives that were broader often had more potential associated risks, and therefore a higher susceptibility to vulnerability from one or more climate change stressors. Objectives that were more specific may have had targeted associated risks identified as well as specific stressors. In general, outreach, education, and policy objectives were not very vulnerable and had a high associated adaptive capacity. Objectives or goals that were linked to a vulnerable habitat were often susceptible to multiple climate change stressors that increased the potential vulnerability of that habitat, e.g. objectives related to intertidal habitats and coastal wetlands. Additionally, objectives or goals that were related to a habitat with a low adaptive capacity to a particular stressor were often more vulnerable, e.g. kelp forests and their associated biological communities will have trouble adapting to OA and warmer waters, and the effects of both stressors may interact over time. OA was also identified in many cases as being a data gap, and more research is needed into this stressor to increase the confidence of the vulnerability evaluations for that stressor.

Completion of the CCVA is not an end point for SMBNEP. The inputs from this project will directly inform the revision of SMBNEP's BRP to be completed by 2019. In addition to this inherent value, the CCVA process drew on staff within different teams to inform the assessment. Resultantly, staff were able to work in teams differently configured than normal. This led to more inclusion, and considerable 'outside-the-box' thinking. The results of the vulnerability assessment presented in this report will be used to inform the next phase, risk-based action planning, which will be carried out prior to, and in conjunction with the BRP revision. The ultimate goal and final product of this process will be the newly revised BRP goals, objectives, and action items that either directly address climate change impacts, or are adaptive or sustainable under the stress of predicted climate change impacts.

Introduction

Located along the Southern Coast of California, the Santa Monica Bay is an integral part of the larger geographic region commonly known as the Southern California Bight. The Bay itself is the submerged portion of the Los Angeles Coastal Plain. It is bordered offshore by the Santa Monica Basin, on each end by the rocky headlands of Point Dume and the Palos Verdes Peninsula, and onshore by the Los Angeles Coastal Plain and the Santa Monica Mountains.

The 414 square mile area of land that drains naturally to the Bay, known as the Bay watershed, is bordered on the north by the Santa Monica Mountains from Ventura-Los Angeles County line to Griffith Park, extending south and west across the Los Angeles Coastal Plain to include the area east of Ballona Creek and north of Baldwin Hills. South of Ballona Creek, a narrow coastal strip between Playa del Rey and the Palos Verdes Peninsula forms the southern boundary of the watershed (Figure 1). There are 28 separate sub-watersheds within the larger Santa Monica Bay watershed. The three largest are Ballona Creek, Malibu Creek, and Topanga Creek watershed. The northern watershed is dominated by the Santa Monica Mountains, the central portion by the Los Angeles Coastal Plain, and southern portion by the Palos Verdes Peninsula.

The diverse ecosystems within the Santa Monica Bay watershed provide habitats for more than five thousand species of plants, fish, birds, mammals, and other wildlife. The Bay's terrestrial habitats include riparian woodlands, coastal sage scrub, oak woodlands, coastal sand dunes, salt and brackish marshes, lagoons, and mudflats. Marine habitats include soft and hard bottom, sandy and rocky intertidal, and kelp and seagrass beds.

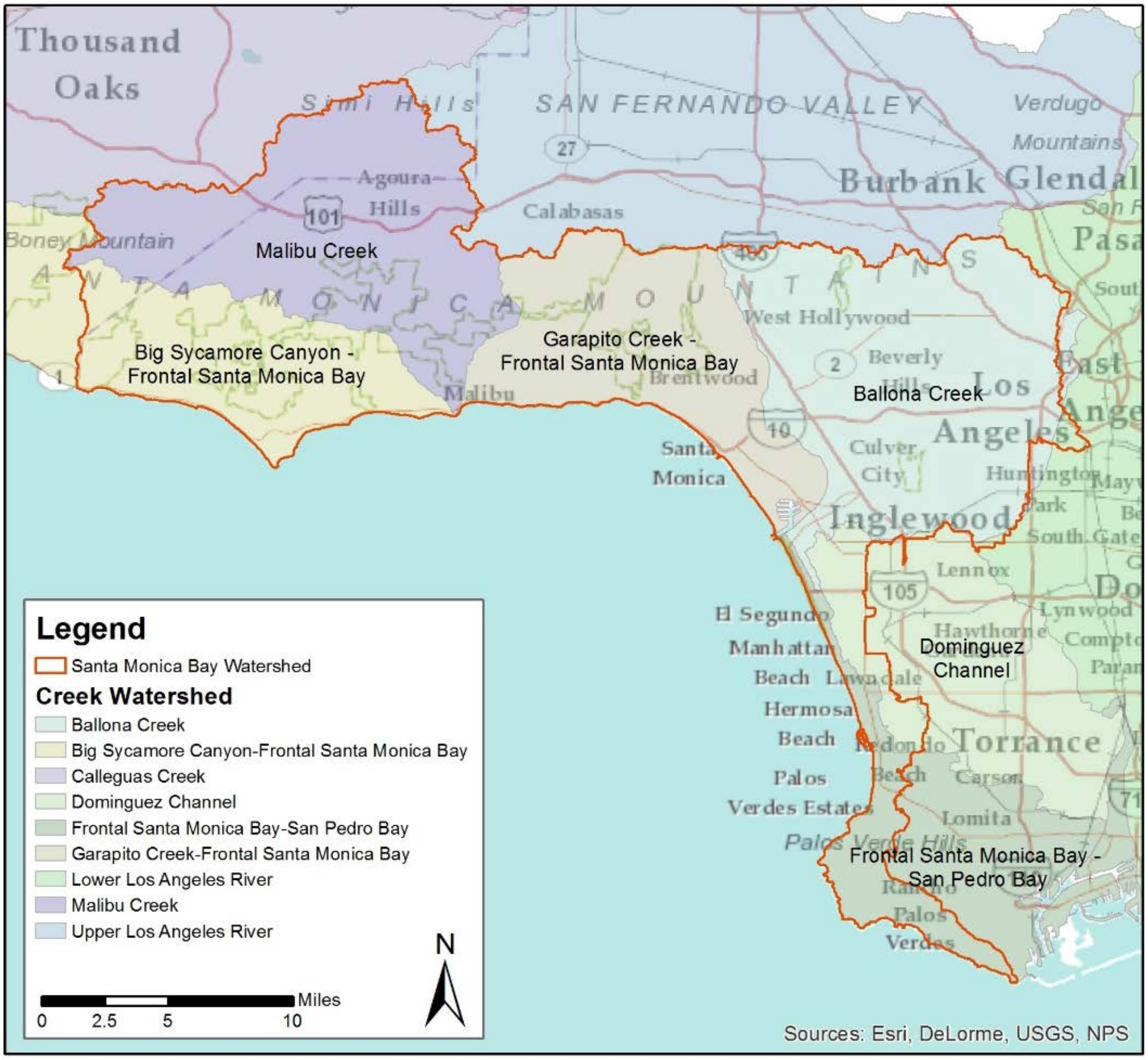


Figure 1. The Santa Monica Bay Watershed.

Santa Monica Bay National Estuary Program

Section 320 of the federal Clean Water Act establishes the National Estuary Program (NEP), which is administered by the United States Environmental Protection Agency (USEPA). To implement the NEP, USEPA identifies national estuaries, develops a Comprehensive Conservation and Management Plan to restore the estuaries, and provides grants to pay for activities necessary to implement the plan. USEPA identified the Santa Monica Bay as a national estuary and approved the Santa Monica Bay Restoration Plan (BRP), with the concurrence of the State that identifies actions and priorities to restore the Santa Monica Bay. The Santa Monica Bay National Estuary Program (SMBNEP) is implemented by three entities: the Santa Monica Bay Restoration Commission (SMBRC), the Santa Monica Bay Restoration Authority (SMBRA), and the Santa Monica Bay Restoration Foundation also known as The Bay Foundation (TBF) (Figure 2). Each entity is briefly described below, and more information can be found on the roles, membership, and relationship between entities on the following webpage: (http://www.smbrc.ca.gov/about_us/orientation/).

SMBRC is a non-regulatory, locally-based state entity established by an act of the California Legislature in 2002 [Pub. Res. Code §30988(d)]. SMBRC is charged with coordinating activities of federal, state, local, and other entities to restore and enhance the Santa Monica Bay, including identifying and leveraging funding to put solutions into action, building public-private partnerships, promoting cutting-edge research and technology, facilitating stakeholder-driven consensus processes, and raising public awareness (www.smbrc.ca.gov). SMBRC brings together local, state, and federal agencies, environmental groups, businesses, scientists, and members of the public on its 36-member Governing Board. SMBRC is also supported by a Technical Advisory Committee (TAC), and a broad stakeholder body, the Watershed Advisory Council (WAC).

SMBRA was created in 2004 by a joint exercise of powers agreement between SMBRC and the Los Angeles County Flood Control District and operates as a local public agency within the Santa Monica Bay watershed and the jurisdictional boundaries of SMBRC and the District. The purpose of SMBRA is to broaden funding opportunities for projects within the Santa Monica Bay Watershed, and it provides an efficient method by which state agencies can fund important programs of SMBNEP.

TBF is an independent, non-profit 501(c)(3) organization founded in 1990. The mission of TBF is to contribute to the restoration and enhancement of the Santa Monica Bay and other coastal waters (www.santamonicabay.org). TBF receives an annual grant from USEPA pursuant to section 320 of the Clean Water Act (33 U.S.C. §1330) to implement the BRP. TBF also receives important grants and donations from other entities to support TBF and its activities.

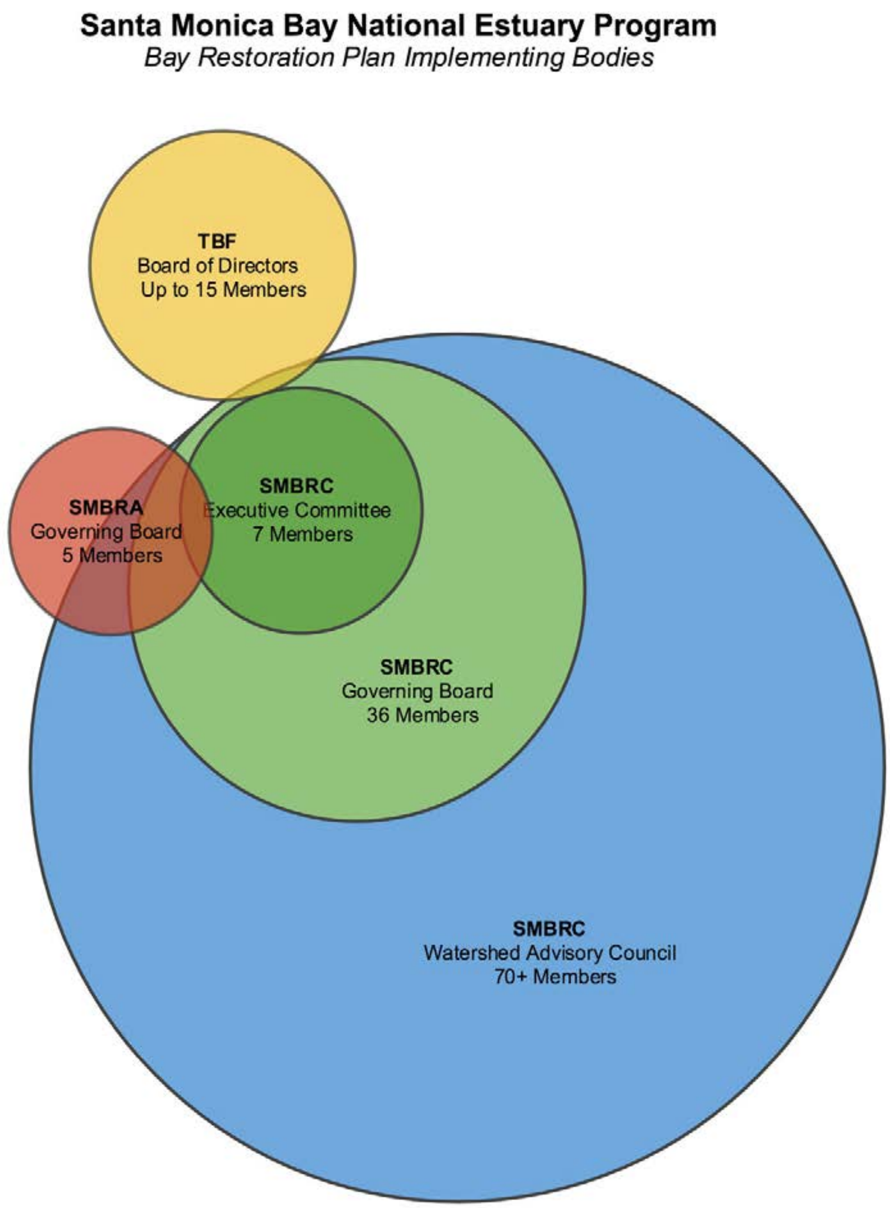


Figure 2. SMBNEP Bay Restoration Plan Implementing Bodies.

About this Project

There has been broad consensus that climate change will have significant impacts on local communities, and that preparation must be made to adapt to these impacts. Recent studies, especially downscaled modeling work conducted by researchers at UCLA, show that local impacts of climate change in the Santa Monica Bay region will include extreme weather patterns in the form of both increased storm intensity, severe drought, and increased extreme heat waves and Santa Ana wind events. Additionally, preliminary results from USGS coastal profiling modeling work indicates that the predominant climate change impacts to the regional shoreline will be SLR and an increased frequency and intensity of storm surge.

As part of a larger effort to help NEPs and environmental managers address climate change in watersheds and coastal areas, the USEPA developed the Climate Ready Estuaries Program (CRE) in 2008. The Climate Ready Estuaries Program (https://www.epa.gov/cre) brings together EPA's Oceans and Coastal Protection Programs and Climate Change Programs to build additional capacity in the NEPs and coastal communities as they prepare to adapt to the effects of climate change. Tasked by the USEPA to incorporate climate change evaluations into all of SMBNEP's goals, projects, and planning efforts, TBF applied for and received a small CRE grant from the USEPA to conduct a Climate Change Vulnerability Assessment (CCVA) of the SMBNEP's guiding document, the Bay Restoration Plan (BRP).

The overarching goal of this project is to develop a broad, risk-based CCVA for all goals and objectives in the BRP. The CCVA is phase one of a two phase process. Phase two will use the CCVA for future BRP planning efforts, to develop and implement adaptation strategies, and create a "climate ready" BRP. Additionally, because the BRP goals span a wide range of water quality, natural resources, and human use values and benefits, the results of this assessment may help inform many of the SMBNEP partner agencies in their CCVA and adaptation planning efforts. The process of conducting a CCVA offers useful lessons to other NEPs and urban coastal cities.

This project and report will use the EPA Workbook, "Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans," as a guide to identify strengths and weaknesses of existing objectives to manage and adapt to the impacts of climate change. The specific tasks completed as part of the CCVA are:

1. Review, compile, and communicate the results of the latest research in climate change impacts with focus on specific regional risk identification and characterization;
2. Identify and evaluate risks for BRP objectives and goals;
3. Build from the risk identification step to apply a vulnerability framework to each BRP objective and conduct a vulnerability analysis using visualizations for each climate change stressor;
4. Draw conclusions and begin the process of identifying the next steps (after the completion of this project) related to action planning and a "climate ready" BRP.

Bay Restoration Plan

The BRP is the SMBNEP's comprehensive plan of action for protecting and restoring the Santa Monica Bay. The BRP was initially approved by the USEPA and State of California in 1995 and updated in 2008 and again in 2013. The BRP includes goals, objectives, and milestones that guide SMBNEP's programs and projects in three priority areas: water quality, natural resources, and benefits and values to humans. The BRP also identifies the responsible lead and partner entities, and the roles of the SMBNEP in supporting, promoting, and implementing Bay restoration work.

Figure 3. Malibu Lagoon restoration project, kelp restoration project, and boater education program.

Goals

Fourteen goals are identified in the 2013 BRP, in three major "Priority Issue" categories: Water Quality, Natural Resources, and Benefits and Values to Humans. Overarching goals can be broken down into objectives and further down into detailed milestones (Figure 4). The goals, objectives, and milestones collectively describe the necessary steps needed to restore and protect the ecosystem of the Santa Monica Bay and the Bay watershed. The 14 goals are described in further detail below.

Figure 4. SMBNEP's BRP grouping of goals, objectives, and milestones.

Priority Issue – Water Quality

Goal 1: *Improve water quality through enhancement of current regulatory framework and collaborative, integrated watershed-wide planning and implementation*
Goal 2: *Improve water quality through pollution prevention and source control*
Goal 3: *Address potential impacts of emerging contaminants*

The first section of the BRP lays out goals, objectives, and milestones for addressing major water quality issues existing in the Bay and the Bay watershed. One primary goal of this section is to improve water quality through enhancement of current regulatory framework and collaborative, integrated watershed-wide planning and implementation (Goal 1). To achieve this goal, SMBNEP has worked, and will continue to work with, parties responsible for meeting allocations of total maximum daily loads (TMDLs) and dischargers responsible for complying with National Pollutant Discharge Elimination System (NPDES) permits. Goal 2 is aimed at implementing projects to reduce and prevent the generation of pollutants at their sources before entering the region's waterways. To achieve this goal, SMBNEP has spearheaded and carried out several successful pollution source control programs including the residential rain garden program, Southern California Boater Education Program, and the Clean Bay Restoration Certification program. Goal 3 involves developing and implementing a comprehensive strategy to address the issues of emerging contaminants. SMBNEP is focusing on conducting and supporting further monitoring and studies that involve estimating the scale of contamination and determining the environmental risk associated with emerging contaminants. Additionally, outreach and education to reduce the loading of emerging contaminants for which risks are better known is recommended in this goal.

Priority Issue – Natural Resources

Goal 4: *Create and support policies and programs to protect natural resources*
Goal 5: *Acquire land for preservation of habitat and ecological services*
Goal 6: *Manage invasive species*
Goal 7: *Restore wetlands, streams, and riparian zones*
Goal 8: *Restore coastal bluffs, dunes, and sandy beaches*
Goal 9: *Restore intertidal and subtidal habitats*
Goal 10: *Protect and restore open ocean and deep water habitats*

The BRP addresses the natural resources-related issues first by supporting better information gathering and implementation of more effective protection policies, regulations, and management programs (Goal 4), and by laying out specific steps and projects needed for protection and restoration for each of the major habitats in the Bay (Goals 5–10). Land acquisition, through ownership or conservation easement, is an integral part of habitat conservation planning and often the most critical and important component of a comprehensive strategy for habitat preservation and restoration (Goal 5).

Invasive plants and animals have also become a major threat to the integrity of many wetland and stream habitats in the Bay watershed as addressed by Goal 6 of the BRP, and specific objectives and milestones were established to investigate, control, and eradicate invasive species that affect wetland and riparian habitats, such as New Zealand mudsnail, crayfish, ice plant, and others. Wetlands, streams, and riparian zones are lifelines of the Bay watershed ecosystem and their preservation and restoration is a high priority. Goal 7 of the BRP calls for restoration of wetlands, streams, and riparian zones and outlines specific objectives and milestones for restoration of the Ballona Wetlands Ecological Reserve (Reserve), Malibu Lagoon, Topanga Lagoon, and other coastal wetlands. Specific objectives and milestones are also established to restore streams through removal of fish barriers, restore or daylight culverted streams in urban areas, and construct greenways along urban streams.

Goal 8 of the BRP calls for restoration of coastal bluffs, dunes, and sandy beaches and outlines specific objectives and milestones for restoration of specific dune habitats including dune habitats at LAX, and comprehensive measures to protect, manage, and restore sandy beaches.

Relatively sparse and restricted in distribution compared to sandy beach and soft bottom habitats, rocky intertidal and subtidal habitats are highly diverse and productive, and home to hundreds of species.

These habitats are also highly vulnerable to, and have been greatly impacted by human activities, as well as natural processes. Goal 9 of the BRP calls for restoration of rocky intertidal and subtidal habitats and outlines specific objectives and milestones for kelp restoration through sea urchin removal, education and other management measures to address impacts of visitors to rocky reef habitats, and reintroduction and restoration of abalone populations in the Bay. Goal 10 focuses on protecting and restoring open ocean habitats in the Santa Monica Bay. The pelagic, soft-bottom, and hard-bottom ocean habitats support a wide range of organisms of all trophic levels including planktonic (e.g. bacteria, phytoplankton, zooplankton) to nektonic (e.g. whales, porpoises, and dolphins) and face major threats including overfishing, pollutant loading, climate change, and harmful algal blooms.

Priority Issue – Benefits and Values to Humans

Goal 11: *Protect public health*
Goal 12: *Maintain/increase natural flood protection through ecologically functioning floodplains and wetlands*
Goal 13: *Increase public access to beaches and open space*
Goal 14: *Conserve water and increase local water supply*

Goal 11 aims to address public health risks associated increased pathogens and pollutants to beaches and the surfzone and seafood contamination issues through increased monitoring and indicator development as well as updated advisories and risk communication messages.

In a highly urbanized region, Goal 12 addresses the importance of maintaining and increasing natural flood protection through acquiring and restoring priority parcels that include floodplains and wetlands. This goal also addresses the need to develop and implement a comprehensive regional sediment management plan for restoring natural hydrological functions of riverine systems. Increasing public access to beaches and open space is detailed in Goal 13. Parks, public beaches, and preserves can provide the opportunity for escape and relaxation for residents and others, as well as promote the conservation of open space and protection of important habitats.

The importance of adequate water supply to local residents in the arid Southern California locale cannot be overstated, and has gained more urgency recently amid one of the worst drought periods in the state’s recent history. The drought condition, potential threat of climate change, and the need and requirement for environmental damage mitigation mean that the region can and should no longer rely on imported water as its major source of water supply. Instead, local public agencies should rethink, devise, and implement new strategies to secure a locally sustainable water supply through a combination of water conservation, water recycling, runoff capture and underground storage (Goal 14).

Current SMBNEP Climate Change Actions

SMBNEP's climate change program was initiated around the same time as the implementation of the Climate Change Implications for the Ballona Wetlands Restoration, which was a climate change modeling and adaptation project completed in 2012 with funding support from the USEPA Climate Ready Estuaries (CRE) Program. Since then, SMBNEP's efforts in addressing the impacts of climate change has been growing and has become broader and integrated with ongoing regional efforts in Southern California.

In 2013, SMBRC teamed up with the Los Angeles Regional Collaborative for Climate Action (LARC), USC Sea Grant, City of Santa Monica, and Heal the Bay, to support a successful grant application by the City of Santa Monica for the State Coastal Commission/Conservancy LCP climate change adaptation grant. With the grant award, the collaborative team in the summer of 2014 formally launched AdaptLA, a regional multi-year project that will gather data and assess the Los Angeles coastal region's exposure to sea level rise (SLR) and coastal storms, model regional shoreline change, identify vulnerable communities, assets, and ecosystems, and help communities begin an adaptation planning process. SMBRC and TBF have continued to partner with LARC, USC Sea Grant and other local agencies to disseminate information related to climate change impacts and facilitate climate change adaptation by municipalities in the watershed.

In FY16, TBF secured funding for two much-needed research projects on the potential scale and impacts of climate change: Kelp Forest Hydrodynamics Study, and ocean acidification (OA) monitoring and assessment. The Kelp Forest Hydrodynamics Study is an integral part of TBF's on-going kelp restoration program that is specially designed to demonstrate the benefit of kelp restoration in remediating the impacts of climate change through alteration of currents and related sediment transport, OA, and attenuation of wave energy. The second FY16 grant supported installation of a high precision instrument package for pH, dissolved oxygen, and pCO2 to provide valuable time-series information on acidification and hypoxia in Santa Monica Bay and advance research on status and trends as well as response to acidification by biological communities in the Bay. In collaboration with the Los Angeles County Sanitation District, the City of Los Angeles Environmental Monitoring Division, the Southern California Coastal Water Research Project, and the Los Angeles Regional Water Quality Control Board, installation of the sensors are targeted for completion by September 2016.

In FY17, SMBNEP will also continue to promote comprehensive sediment management and other "soft" and "living" measures to address the impact of sea level rise in the beach and adjacent ecosystems of the Bay. As an example, the Santa Monica Beach Restoration Pilot Project, which will restore several acres of sandy coastal habitats on the beaches of Santa Monica to establish a native fore-dune plant community, will showcase and provide valuation information to evaluate the effectiveness of restored natural ecological functions of sandy beaches in protection of coastal infrastructure from SLR and erosion, while providing a vital refuge for wildlife.

Background

EPA Climate Change Workbook

The following information was pulled directly from EPA's "Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans" (EPA Workbook). The EPA Workbook presents a guide to climate change adaptation planning based on EPA's experience with watershed management, the National Estuary Program, and the Climate Ready Estuaries program. The EPA Workbook will assist organizations that manage environmental resources to prepare a broad, risk-based adaptation plan.

The audience for the EPA Workbook are professionals at organizations who manage environmental resources, especially organizations with a coastal or watershed focus. They are knowledgeable about their systems but not necessarily sophisticated about climate science or risk management. They may be addressing a myriad of issues that require immediate attention and have limited time to focus on adaptation planning for the future. Furthermore, they may need to adapt to climate change impacts within their organization's existing resources. Despite these challenges, managers who realize that climate change will affect their ability to meet their goals will see the need to incorporate climate change risk into their planning. Identifying risks associated with climate change and managing them to reduce their impacts is essential.

Although risk management and risk-based CCVA's have been highlighted or recommended by experts in the field of climate change adaptation, to-date only a handful of risk-based plans have been published. Interviews with coastal managers conducted by Climate Ready Estuaries staff in 2011 revealed that managers are not sure what is meant by a "risk-based vulnerability assessment," and would like tools to help them proceed.

The EPA Workbook is part of a growing and dynamic body of literature on how to evaluate vulnerability and respond to climate change. Although risk management itself has been successfully used for decades, adaptation to climate change is a rapidly developing field. New material is constantly being published. Many excellent governmental and non-governmental tools and publications are available that explain how to conduct community outreach, identify and comment on the severity of expected climate impacts, or provide instruction on how to assess the vulnerability of a specific species, site or sector to a particular climate change risk.

SMBNEP used the EPA Workbook as a guiding document, or a roadmap to apply a risk-based methodological analysis to our goals and objectives identified in our guiding strategic document, the BRP. The EPA Workbook Steps 1-5 outline the general steps SMBNEP used to conduct the CCVA; however, SMBNEP modified Step 5 in the CCVA process (Figure 5). Subsequent steps (Steps 6-10) will allow for the application of this vulnerability analysis towards future action planning.

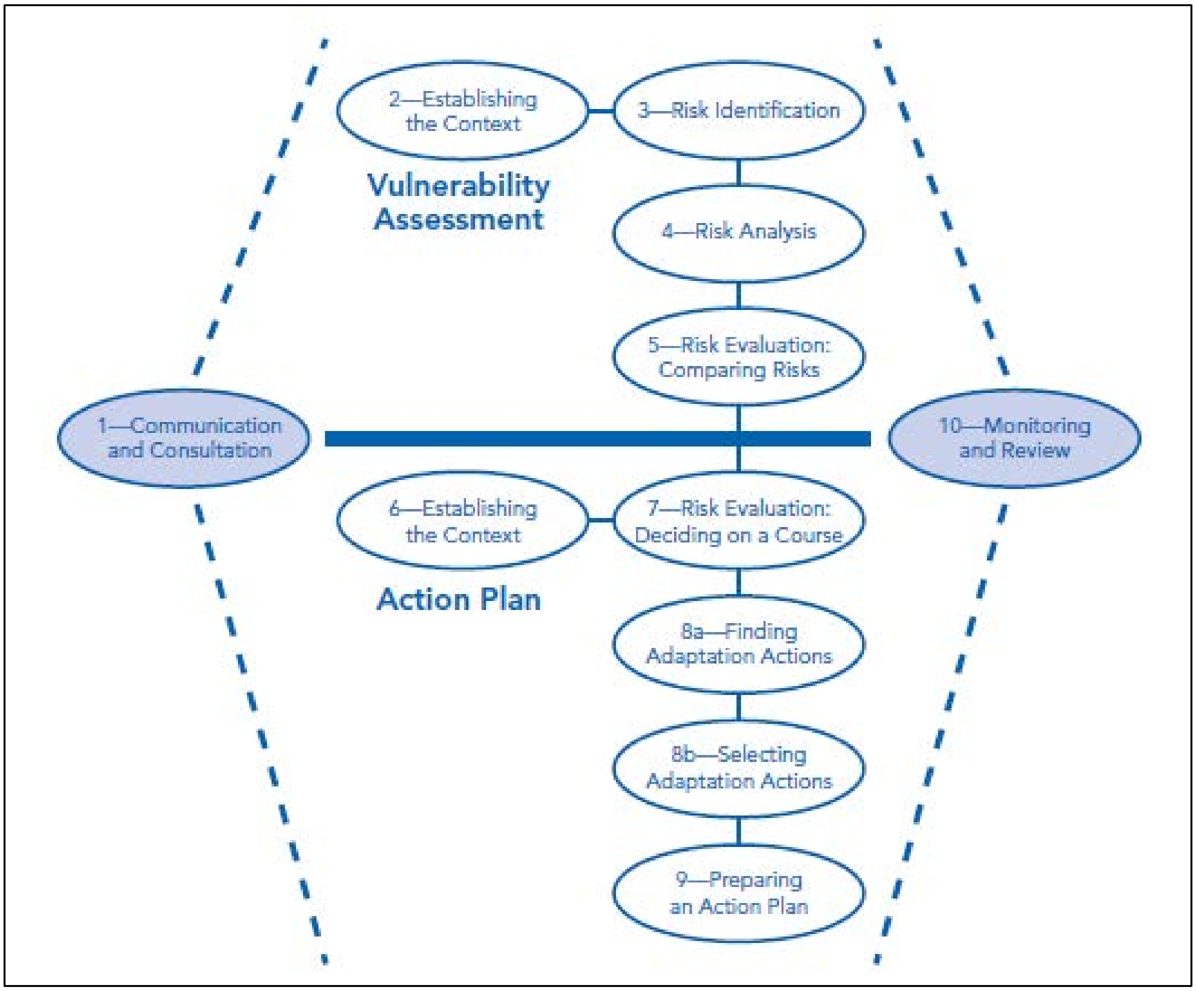


Figure 5. EPA Workbook Steps (EPA 2014).

Climate Change Stressors

Identifying risks and conducting the CCVA on the BRP required defining the climate change stressors being considered. Climate change stressors were adopted from the EPA Workbook, which recommended seven stressors: warmer summers, warmer winters, warmer water, increasing drought, increasing storminess, sea level rise (SLR), and ocean acidification (OA). As the EPA Workbook was written to apply broadly to the entire nation and encompass all 28 National Estuary Programs, SMBNEP adopted it to the Southern California region by combining both warmer summers and warmer winters into one category, “Warmer Temperatures”, which applies to generalized overall air temperature warming over time. The remaining five stressors apply to the Southern California region and were retained.

Abbreviated descriptions of the final six climate change stressors evaluated as part of the SMBNEP CCVA are summarized below, with in-depth discussions of the priority models identified as part of the analysis for each climate change stressor in the subsequent section of this report:

Warmer Temperatures

This stressor is generally about the warm season being warmer and the cold season not being as cold as it was formerly and is related to the overall climate of a region. Air, surface, soil, and groundwater temperatures will be warmer during the summer. During the winter, air, surface, soil, and groundwater temperature may become warmer earlier in the year and stay warmer for longer periods of time. This stressor is the combination of 'warmer summers' and 'warmer winters' in the EPA Workbook, as the analyses were the same for both stressors in southern California.

Warmer Water

This stressor, regardless of season, comes from a higher temperature of water bodies, including the ocean, and affects the chemical, physical, or biological characteristics of the water body itself. This stressor was applied both to oceanic temperatures rising and other waters within a watershed such as within streams, rivers, and wetlands.

Increasing Drought

Drought is a deficiency in precipitation over an extended period of time. The magnitude of the deficiency, the duration, or the number of droughts could be greater due to climate change. Southern California has already been experiencing drought for several years, and it is likely to continue and change in intensity over time.

Increasing Storminess

This stressor encompasses all aspects of intensifying precipitation in any form: more seasonal precipitation, more total precipitation during events, or higher rates of precipitation during events. Stronger or more frequent instances of extratropical and tropical cyclones, El Niño driven storms, or other weather conditions are included in this definition. If acting as stressors, then floods, wind-driven waves, wind, and coastal storm surge are also included in the definition and the analyses.

Sea Level Rise

This stressor implies that ocean water levels will rise over time. This definition includes effects of higher water levels adjacent to the shore, as well as how elevated coastal water levels may affect inland systems. Associated impacts from sea level rise (SLR) may include wave-driven erosion, coastal flooding, sea water intrusion, and other related effects.

Ocean Acidification

This stressor involves a decrease in the pH of the oceans caused by atmospheric inputs of carbon dioxide. Organisms or habitats that are sensitive to a more acidic ocean environment will be affected by this stressor. Ocean acidification (OA) was identified as a data gap for our region and is the stressor with the least amount of confidence associated with the vulnerability analysis.

Climate Change Models

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen (Intergovernmental Panel on Climate Change (IPCC) 2014).

As part of the first step in the project, including communications, a UCLA student group from an honors collegium project led by Dr. Alison Lipman, took part in a quarter-long project developing an inventory of local and regional climate change resources (tools) that could potentially aid the SMBNEP in their CCVA. The purpose of developing a climate change tool inventory was to compile the wealth of resources (including reports, online or geospatial tools, databases, or studies) available to guide policy, projects, and implementation of climate change assessments in the LA Region into a concise database for ease of reference. The UCLA student group project resulted in a climate change tool inventory with over 60 resources relevant to the Santa Monica Bay Watershed (Appendix A – Climate Change Tool Inventory). Tools were documented in terms of name, type (e.g. online, journal, database, etc.), geographic scale (e.g. global, national, regional, etc.), major agencies responsible for creating the tool, aspects of climate change addressed (detailed and general topics of interest), website address where the tool can be accessed, and associated time scale. Topics of interest included designations of "Climate Change I" defined as tools that record data or trends directly related to climate change stressors, such as temperature and precipitation, and "Climate Change II" defined as tools that record the subsequent effects of changes caused by climate change stressors, such as SLR and OA. The UCLA student group also recommended SMBNEP BRP goals, if any, that could be directly linked to individual tools' topics of interest.

For purposes of the CCVA, a variety of climate change models associated with the six climate change stressors were investigated. Specific climate change models associated with the Santa Monica Bay Watershed region were chosen to inform staff and expert reviewers in the CCVA process. In general and when available, climate change models were analyzed for current, year 2050, and year 2100 scenarios. The model year is meant to be representative and not an exact timeframe. It is more important to acknowledge the thresholds identified by the models rather than the approximate year of reaching those thresholds. However, for ease of interpretation and adaptability of the framework across the entire BRP, a very diverse set of goals and objectives, the "time horizons" were bracketed into 2050 and 2100. These should not be interpreted rigorously, and the vulnerability evaluations are usually more broadly described in terms of the "near future" (i.e. 2050) and "future" (i.e. 2100).

Uncertainty Disclaimers

The data presented in climate change models are projections of future climate. Although climate models are powerful and effective tools for simulating the climate system, there is some uncertainty inherent in any projection of the future, and climate model projections are no exception. Most climate model projections used to inform this climate change vulnerability study illustrate how the climate system is expected to behave under specific scenarios of greenhouse gas emissions. The emissions of greenhouse gases is dependent on a variety of different social, political, and economic factors, therefore projected climate models may alter if actual emissions differ from the scenarios used to run the models. Different climate models, tools used to simulate the climate system and produce future climate data, may produce different outcomes and one way to account for model differences is to average projections from many different models to get a range of possible outcomes.

Summary of Models

Temperature, drought, and storminess variables were modelled using datasets from the 2014 California Basin Characterization Model (CA-BCM 2014). The CA-BCM 2014 dataset provides historical and high resolution projected climate and hydrologic data for regions in California. Created by United States Geological Survey (USGS), the CA-BCM 2014 provides the ability to evaluate climate change models at a watershed scale by downscaling the 800-m^2 cells produced by Global Circulation Model (GCM) scenarios into smaller 270-m^2 cells. The development of the CA-BCM 2014 model considers the interactions of climate (rainfall and temperature) with empirically measured landscape attributes including topography, soils, and underlying geology (Figure 6) (Flint et al. 2014). This model, which includes a monthly dataset of historical (1896-2010) and 18 projected future climate scenarios (2011-2099) for the California hydrologic region, has been used as a base for multiple research projects and vulnerability assessments (Heller et al. 2015, Kershner 2014, MBNEP 2016, Micheli et al. 2012). Of the 18 projected future climate scenario models, 4 scenarios were selected to be used in SMBNEP's CCVA, which provided a fairly well represented range of variation in projected climatic conditions, from warm and wet to hot and dry (Table 1). All four model scenarios have been used to conduct a suite of climate change simulations for the 4th and 5th Intergovernmental Panel on Climate Change (IPCC) assessment reports. In order to compare different models and improve understanding of the climate system the Coupled Model Intercomparison Project (CMIP) was developed, the CMIP5 effort incorporates 62 different models from 29 different modeling groups. The CMIP5 provides additional information on the 4 models chosen for this CCVA (Flato et al. 2013).

The GFDL-A2 scenario originates from the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL). The A2 scenario is associated with medium-high, essentially "business as usual" greenhouse gas emissions (Delworth 2006). The GFDL-A2 scenario generally forecasts a warmer and drier climate. The MIROC RCP 8.5 scenario originates from the Japan's Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC). Of the four scenarios chosen for use in this CCVA, the MIROC RCP 8.5 produces the hottest and driest climate scenario and provides the ability to quantify what future drought conditions may look like. The Community Climate System Model (CCSM) 4 RCP 8.5 scenario created by The National Center for Atmospheric Research (USA) provides a mid-range scenario closest to the ensemble mean, while the CNRM RCP 8.5 scenario developed by Météo-France/Centre National de Recherches Météorologiques (France) forecasts a warm and very wet future. Figure 7 below, summarizes model variation in precipitation and temperature changes from future (year 2090-2099) relative to current conditions (year 2000-2010) from each of the four models for the Santa Monica Bay Watershed.

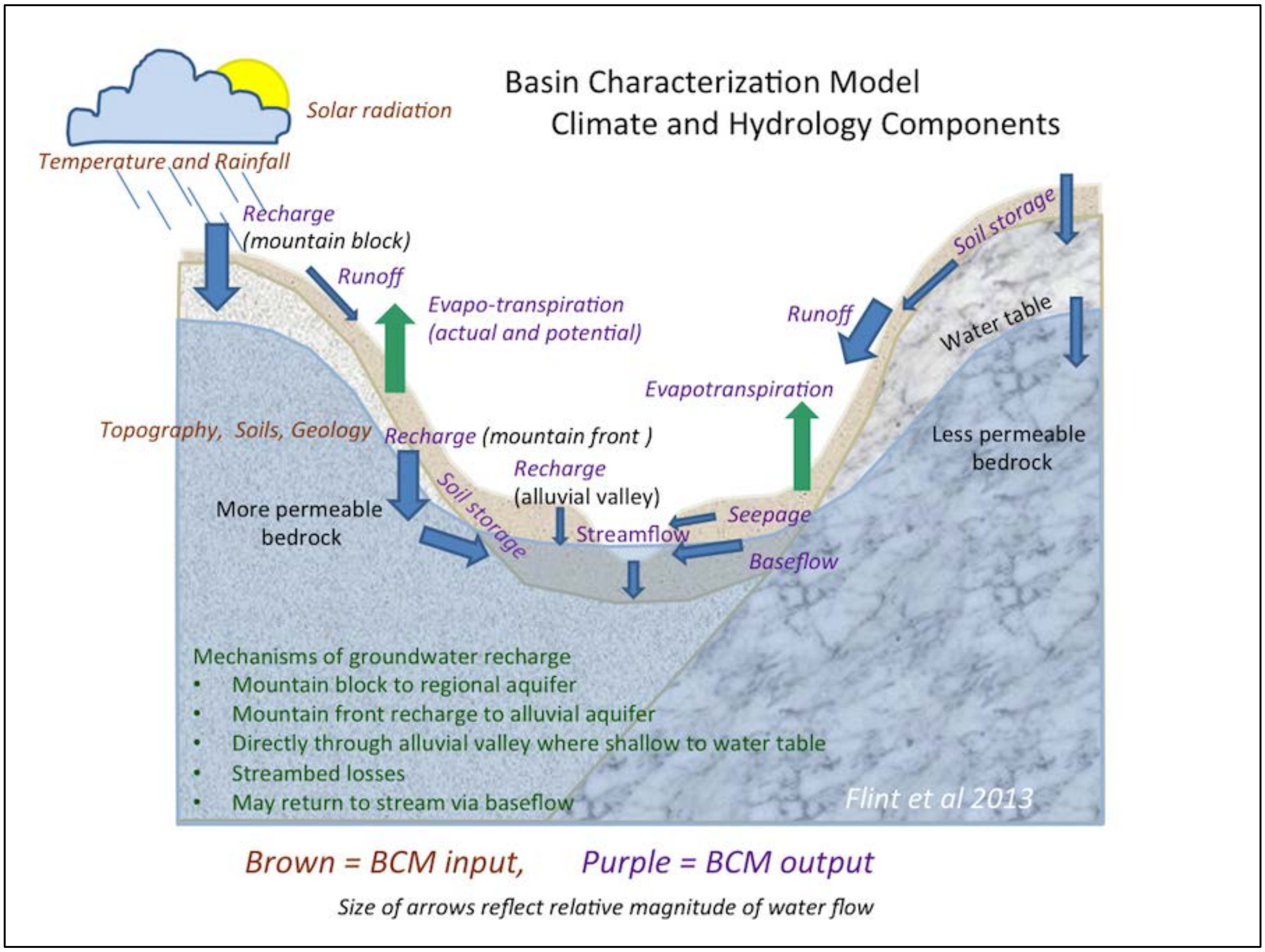


Figure 6. The Basin Characterization Model – Climate and Hydrology Components (Flint et al. 2014).

Table 1. CA-BCM 2014 climate change scenarios used in the SMBNEP CCVA.

Model	Emissions Scenario	Scenario Detail	IPCC Assessment Report	Originating Group
GFDL	A2	moderately warmer, drier future	4	U.S. Department of Commerce/ NOAA/ Geophysical Fluid Dynamics Laboratory (USA)
MIROC-ESM	RCP 8.5	warmest, driest	5	Japan's Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC) (Japan)
CCSM4	RCP 8.5	mid-range, closest to ensemble mean	5	National Center for Atmospheric Research (USA)
CNRM-CM5	RCP 8.5	wettest and warm	5	Météo-France/Centre National de Recherches Météorologiques (France)

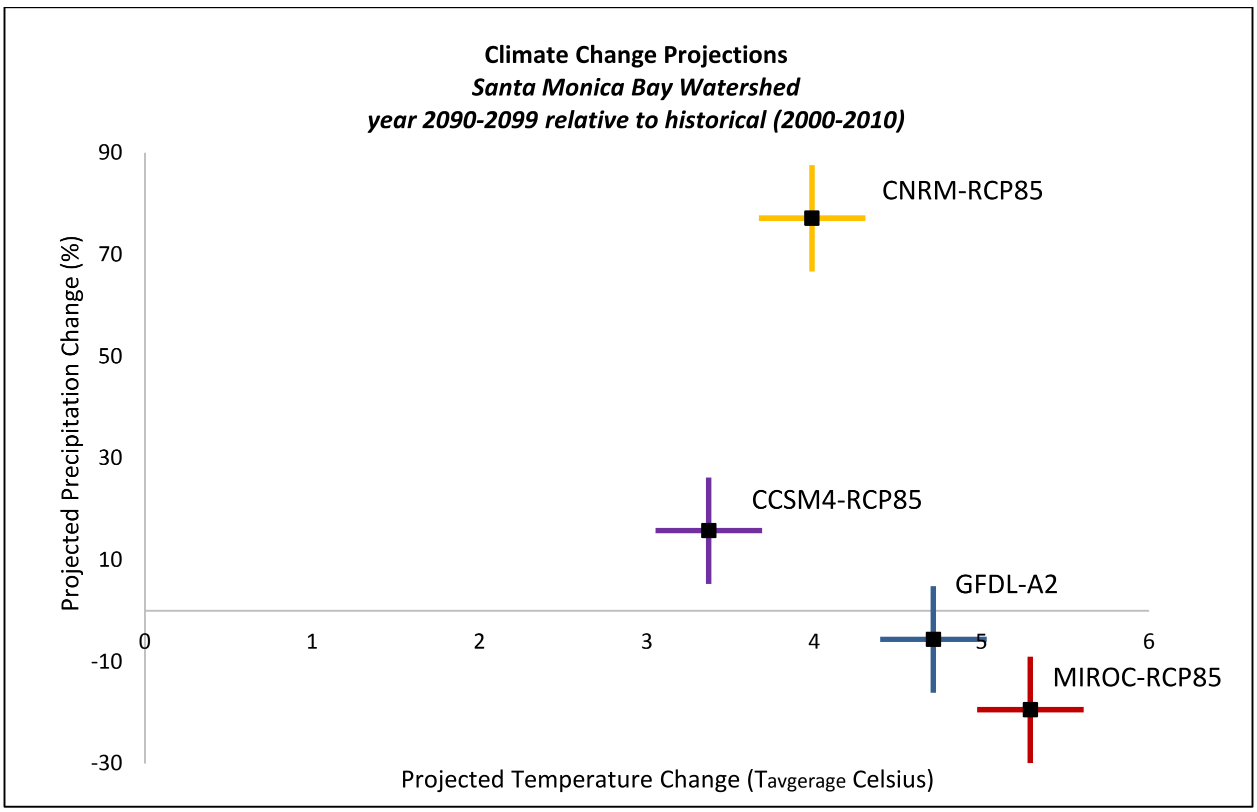


Figure 7. Climate change model projections for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

CA-BCM 2014 data for historical conditions and the four climate change scenarios were downloaded for the Santa Monica Bay Watershed Basin (designated Hydrologic Region #18070104) and the variables listed in Table 2 were plotted using a simple moving 10-year average. A 10-year moving average reduces noise caused by short-term weather and allows the overall pattern and distribution of historical and forecasted climate change variables to be visualized.

Table 2. CA-BCM 2014 historical and forecasted climate variables used in the SMBNEP CCVA.

Climate Variable	Unit	Description	Associated CCVA Climate Change Stressor
Average Monthly Temperature	Celsius	Derived from maximum and minimum monthly temperature	Warmer temperatures
Precipitation	Millimeter	Precipitation	Increased storminess + increased drought
Runoff	Millimeter	Amount of water that becomes stream flow	Increased storminess + increased drought
Climatic Water Deficit (CWD)	Millimeter	Potential minus actual evapotranspiration	Increased drought
Recharge	Millimeter	Amount of water that penetrates below the root zone	Increased drought

Warmer water was evaluated in a global context, utilizing NOAA and IPCC working group modelling efforts which include historical to current sea surface temperature anomalies and projected scenarios based off 12 atmosphere-ocean general circulation models (AOGCMs) under four various future emissions conditions.

SLR and coastal storminess relating to storm surge and wave related flooding were analyzed for the Santa Monica Bay region using a 2013 Natural Resource Council SLR report and USGS Coastal Storm Modelling System (CoSMoS) datasets. OA was evaluated in a global context, utilizing the US National Center for Atmospheric Research Community Climate System Model 3.1 (CCSM3) and existing model literature.

In addition, a variety of literature specific to Southern California was used to supplement model projections and inform current and potential climate change effects.

Warmer Temperatures

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (IPCC 2014). Regional and local topography, geography, and local weather drive variability in climate change induced warming. In a 2015 report published by the California Department of Water Resources (CDWR), the South Coast region, which includes the Santa Monica Bay, shows a high observed temperature change over the last century, relative to other California regions (CDWR 2015) (Figure 8). Projected temperature increases by the mid-21st century for the South Coast region are estimated between 3 to greater than 4 degrees Fahrenheit (CDWR 2015) (Figure 9).

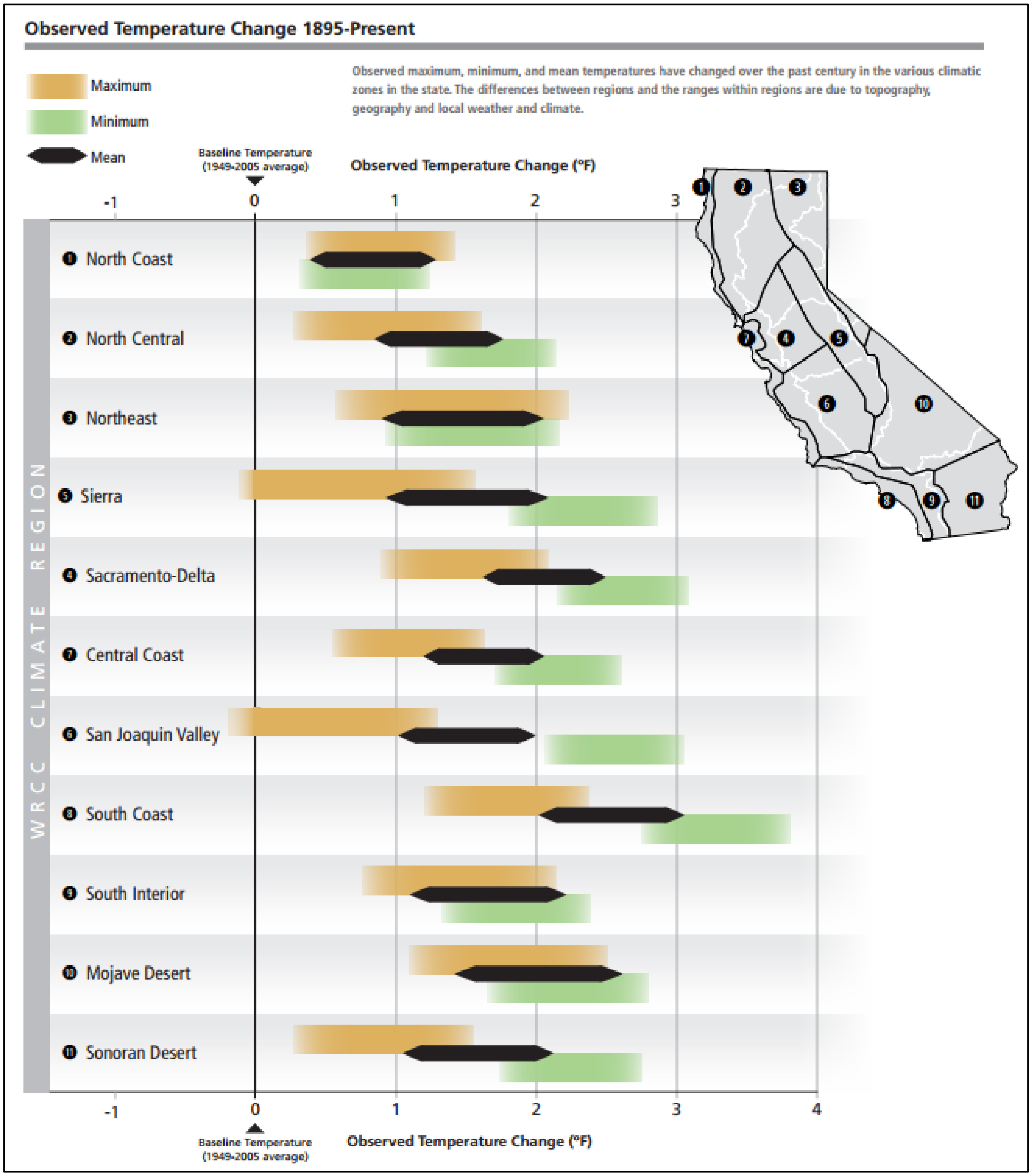


Figure 8. Observed temperature change over the last century for California climatic zones (Figure replicated from CDWR 2015).

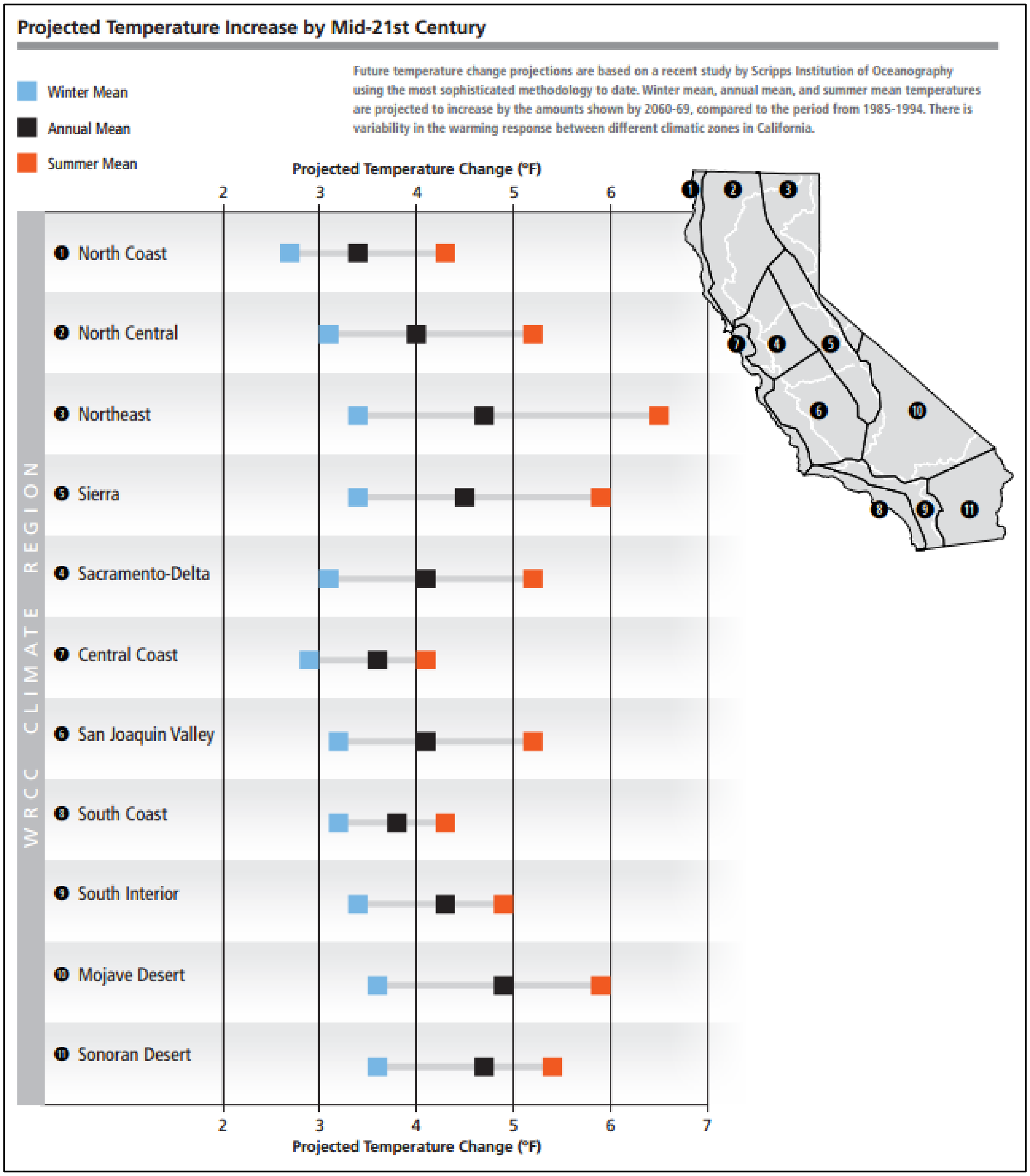


Figure 9. Projected temperature change for climatic zones in California (Figure replicated from CDWR 2015).

Local projected annual average temperature increases for the Santa Monica Bay region based on the CA-BCM 2014 model and four chosen scenarios, to the end of the 21st century, are shown in Table 3. While variation is visible between model scenarios, all model scenarios show a consistent rise in average annual temperature within the Santa Monica Bay Watershed (Figure 10). The change in temperature projected by 2050 ranges from 0.43˚C to 1.57˚C, and by 2099 the change in temperature ranges from 3.37˚C to 5.29˚C.

Table 3. Projected annual average temperature increases for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Santa Monica Bay Region		Change in Temperature (˚C) *	
Model	**Scenario**	**Projected by 2050**	**Projected by 2099**
GFDL-A2	moderately warmer, drier future	1.57˚C	4.71˚C
MIROC-RCP85	warmest, driest	0.43˚C	5.29˚C
CCSM4-RCP85	mid-range, closest to ensemble mean	0.60˚C	3.37˚C
CNRM-RCP85	wettest and warm	0.76˚C	3.99˚C

* change relative to average historic temperature data (2000-2010)

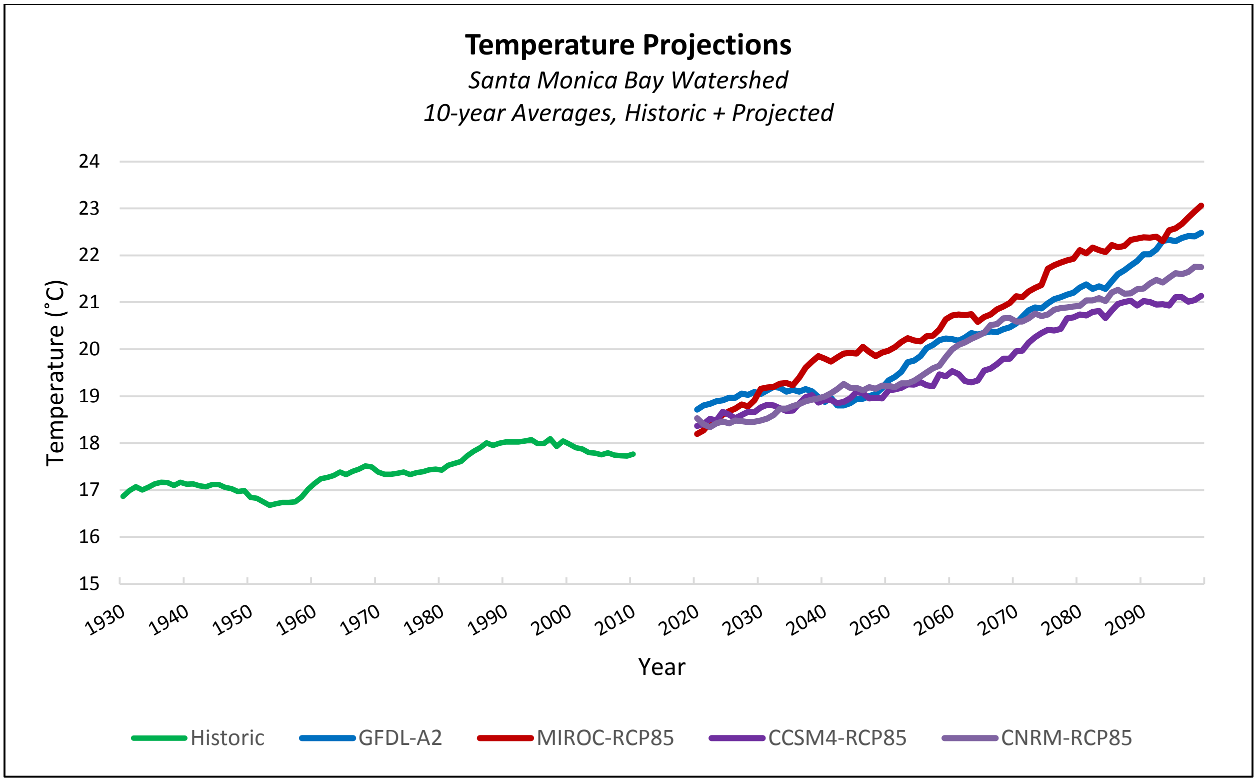


Figure 10. Santa Monica Bay Watershed average temperature projections (Data source: 2014 California Basin Characterization Dataset).

Warmer Water

For every 10 joules of energy that our greenhouse gas pollution traps here on Earth, about 9 of them end up in an ocean. There, the effects of global warming bite into fisheries, ecosystems and ice. But those effects are largely imperceptible to humans – as invisible to a landlubber as an albatross chomping on a baited hook at the end of a long line. John Upton, Climate Central 2014

At a global scale the ocean dominates energy uptake with most of the warming absorbed in the top 700m (2300ft) and even a large amount of warming reaching the deep ocean depths (Rhein et al. 2013) (Figure 11). The increase in ocean energy uptake has led to a warming trend in the top few meters of the ocean, as observed by the average global sea surface temperature (SST) increasing an estimated 0.13˚C per decade since the beginning of the 20th century (Figure 12).

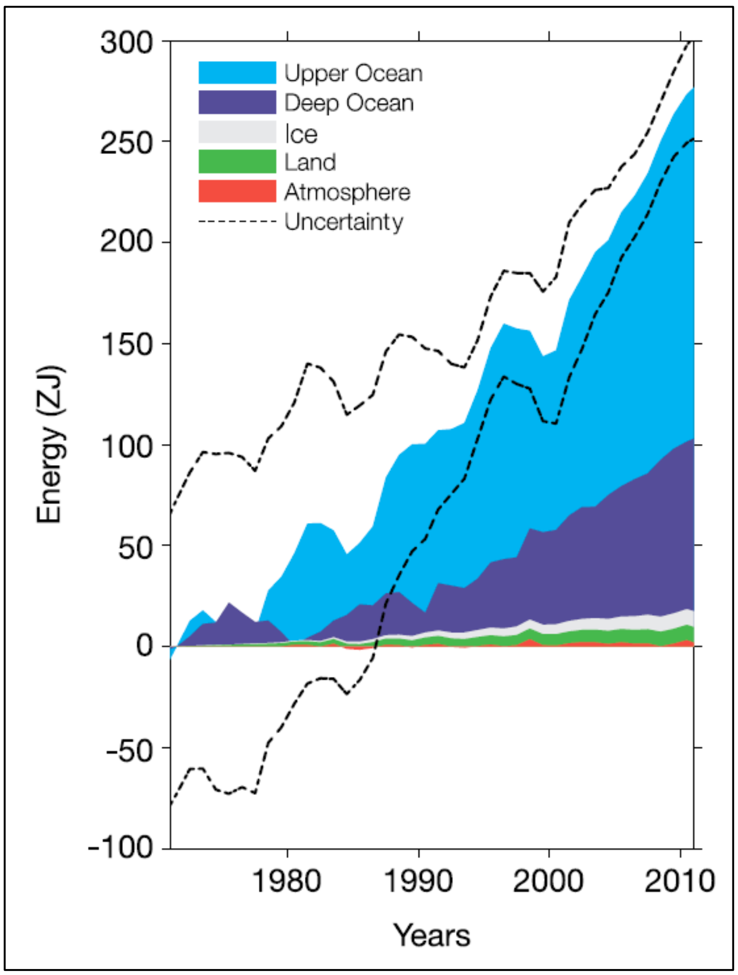


Figure 11. Time series of yearly ocean heat content (Rhein et al. 2013)

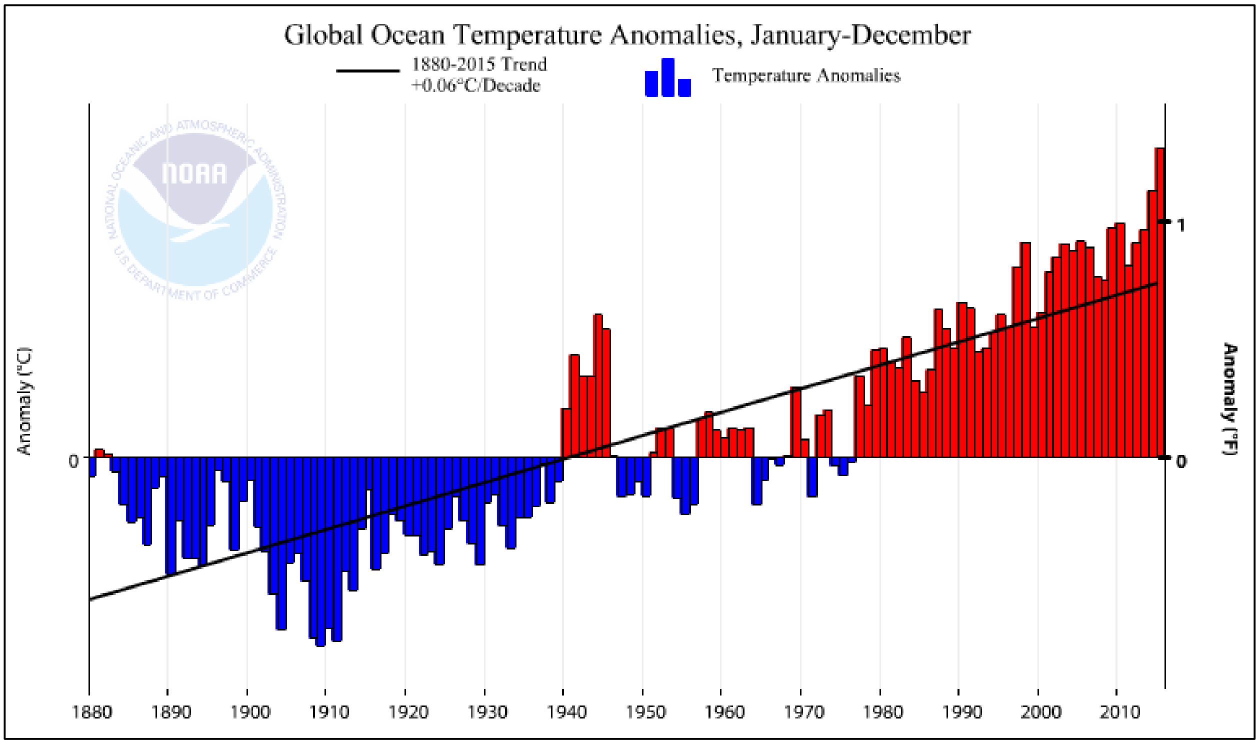


Figure 12. Global ocean temperature anomalies from 1880 to 2015 with superimposed linear trend (Base period 1951-1980), red positive, blue negative (NOAA 2016).

Because the oceans cover ~71% of the earth's surface, the additional heat absorbed by the ocean has led to a plethora of effects including (Reid 2016):

- an increased ocean heat content (OHC);
- changes in the strength/position of currents and heat transport;
- warming of adjacent land masses;
- rising sea levels;
- melting of ice;
- intensification of the hydrological cycle;
- negative feedback on the ocean carbon sink;
- deoxygenation;
- potential feedback from OA;
- the occurrence of more extremes in natural variability such as the El Niño/Southern Oscillation; (ENSO) and in weather events;
- and, changes in biological processes at cellular to ecosystem scales.

Historical sea surface temperature trends have been rising, and future projections show a continuation of this trend. With the lack of a regional-scale downscaled model, global sea surface temperature predictions averaged over 12 different atmosphere-ocean general circulation models and over 4 different emissions scenarios were used to inform changes that may occur in the Santa Monica Bay into 2099 (Figures 13 and 14).

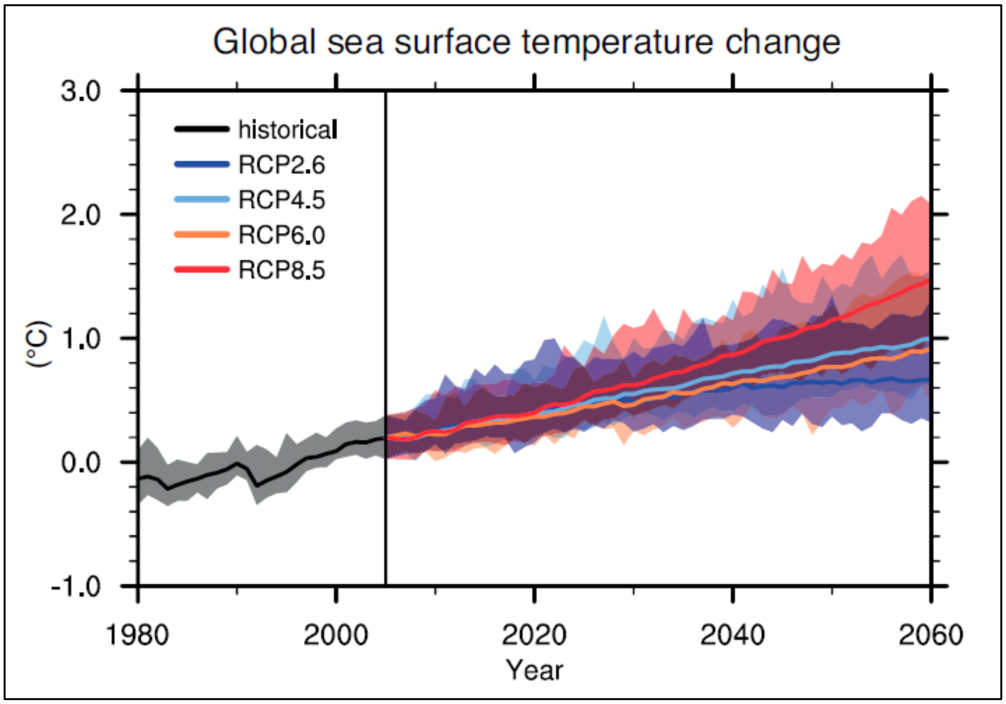


Figure 13. Global sea surface temperature change based on 12 Atmosphere-Ocean General Circulation Models (AOGCMs) from the CMIP5 (replicated from Meehl et al. 2007).

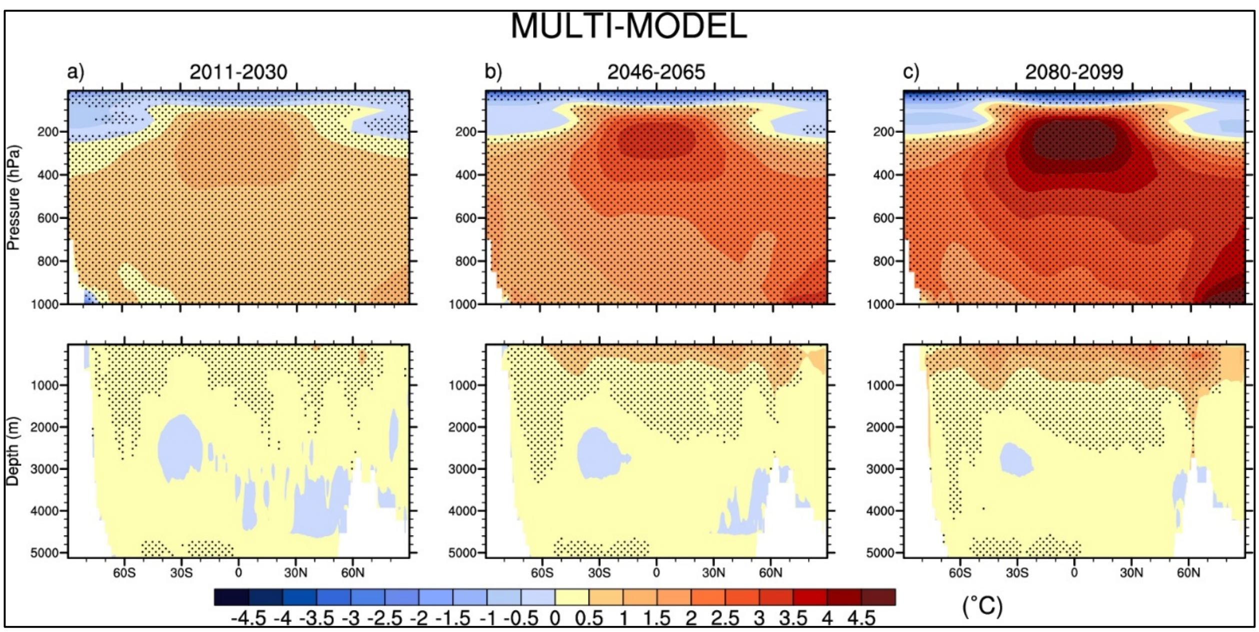


Figure 14. Global sea surface temperature change based on 12 Atmosphere-Ocean General Circulation Models (AOGCMs) from the CMIP5 (replicated from Meehl et al. 2007).

Regional monitoring in Southern California, including the Santa Monica Bay, continue to inform temperature changes occurring in coastal waters. Additionally, extreme temperature anomalies, as apparent with the recent 2015-2016 El Niño conditions, provide a unique opportunity to study the effects warm water have on the Santa Monica Bay.

Increasing Drought

Climate change model variables including precipitation, climatic water deficit (CWD), and recharge were analyzed for the Santa Monica Bay Watershed to inform future drought scenarios. It is important to note that drought conditions also have a human component, with factors like water demand and management playing a crucial role in determining the impact that drought has in the region. Precipitation models are discussed in the "Increased Storminess" section below.

CWD, a hydrological variable in the CA-BCM 2014 model, quantifies annual evaporative water demand exceeding available soil moisture. CWD is a measure of how much more water could have been evaporated or transpired in an area; therefore, CWD has been used as a measure of absolute drought (Stephenson 1998). CWD is highly sensitive to increasing temperatures and has been correlated with the distribution of different vegetation types across the landscape (Stephenson 1998). All climate projection models show trends of CWD increasing by 2050 with continued increase by 2099 (Figure 15). Table 4 summarizes the change in CWD between the four scenarios in the CA-BCM 2014 model. The change in CWD projected by 2050, ranges from 11.66 mm (0.46 in) to 117.21 mm (4.61 in), and by 2099 CWD continues to increase with ranges from 148.34 mm (5.84 in) to 277.60 mm (10.93 in).

Table 4. Projected future change in Climate Water Deficit (CWD) for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Santa Monica Bay Region		Change in CWD (mm/in) *	
Model	**Scenario**	**Projected by 2050**	**Projected by 2099**
GFDL-A2	moderately warmer, drier future	109.72 mm/ 4.32 in	277.60 mm/ 10.93 in
MIROC-RCP85	warmest, driest	117.21 mm/ 4.61 in	293.17 mm/ 11.54 in
CCSM4-RCP85	Mid-range, closest to ensemble mean	86.24 mm/ 3.40 in	157.19 mm/ 6.19 in
CNRM-RCP85	wettest and warm	11.66 mm/ 0.46 in	148.34 mm/ 5.84 in

* change relative to average historic CWD data (2000-2010)

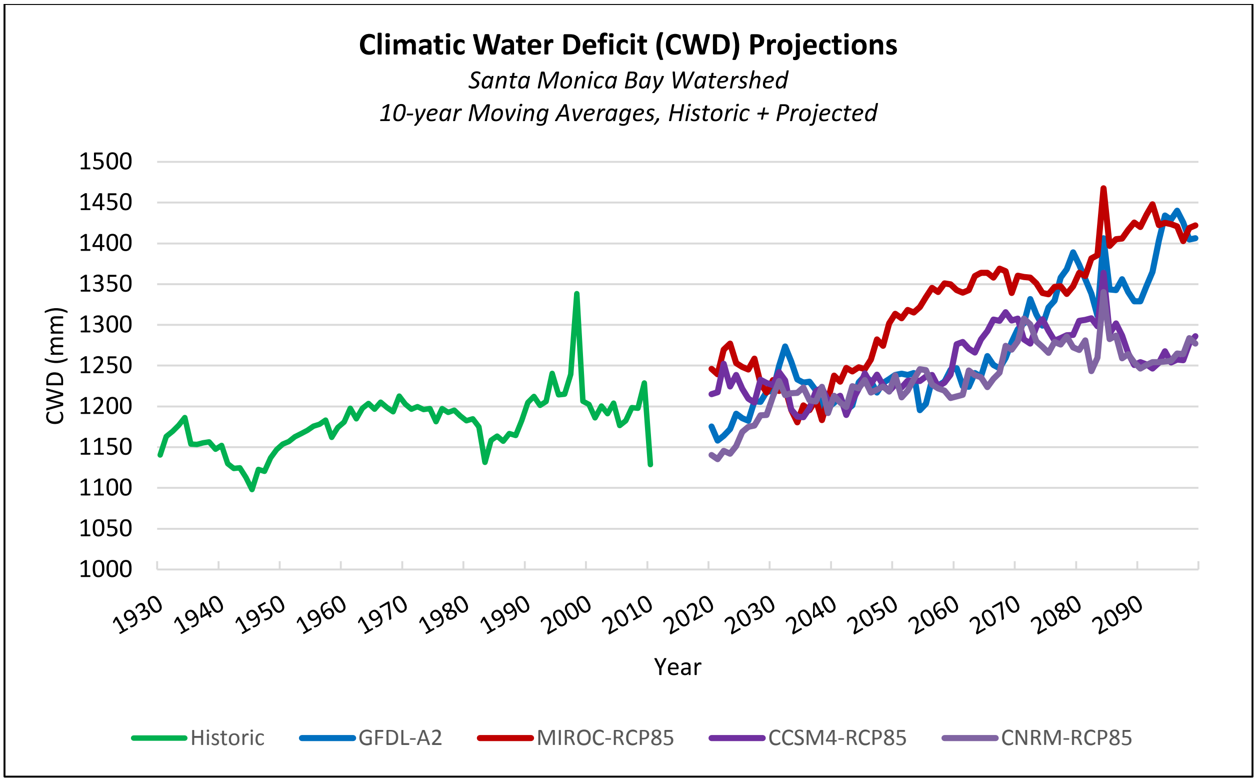


Figure 15. Santa Monica Bay Watershed Climatic Water Deficit (CWD) projections (Data source: 2014 California Basin Characterization Dataset).

Recharge, a hydrological variable in the CA-BCM 2014 model, quantifies the amount of water that penetrates below the root zone. The amount of annual recharge in the Santa Monica Bay Watershed shows substantial variability between the four models (Figure 16). Model predictions for annual recharge range from -16.19 mm (-0.64 in) to 36.95 mm (1.45 in) by 2050 and from -8.50 mm (-0.33 in) to 42.37 mm (1.67 in) by 2100 (Table 5). Recharge, combined with precipitation, runoff, and CWD projections, can be used to inform possible future drought conditions in the Santa Monica Bay Watershed; however, these hydrological variables alone are insufficient, and in order to fully assess drought conditions, water use and management, impervious surfaces and development, and other factors should be considered. Additionally, between 60%-70% of Southern California's water supply originates from imported sources, the majority of which is derived from spring snowmelt (Freeman 2008).

Table 5. Projected future groundwater recharge change for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Santa Monica Bay Region		Change in Recharge (mm/in) *	
Model	**Scenario**	**Projected by 2050**	**Projected by 2099**
GFDL-A2	moderately warmer, drier future	33.26 mm/ 1.31 in	-7.80 mm/ -0.31 in
MIROC-RCP85	warmest, driest	-16.19 mm/ -0.64 in	-8.50 mm/ -0.33 in
CCSM4-RCP85	Mid-range, closest to ensemble mean	17.36 mm/ 0.68 in	9.98 mm/ 0.39 in
CNRM-RCP85	wettest and warm	36.95 mm/ 1.45 in	42.37 mm/ 1.67 in

* change relative to average historic recharge data (2000-2010)

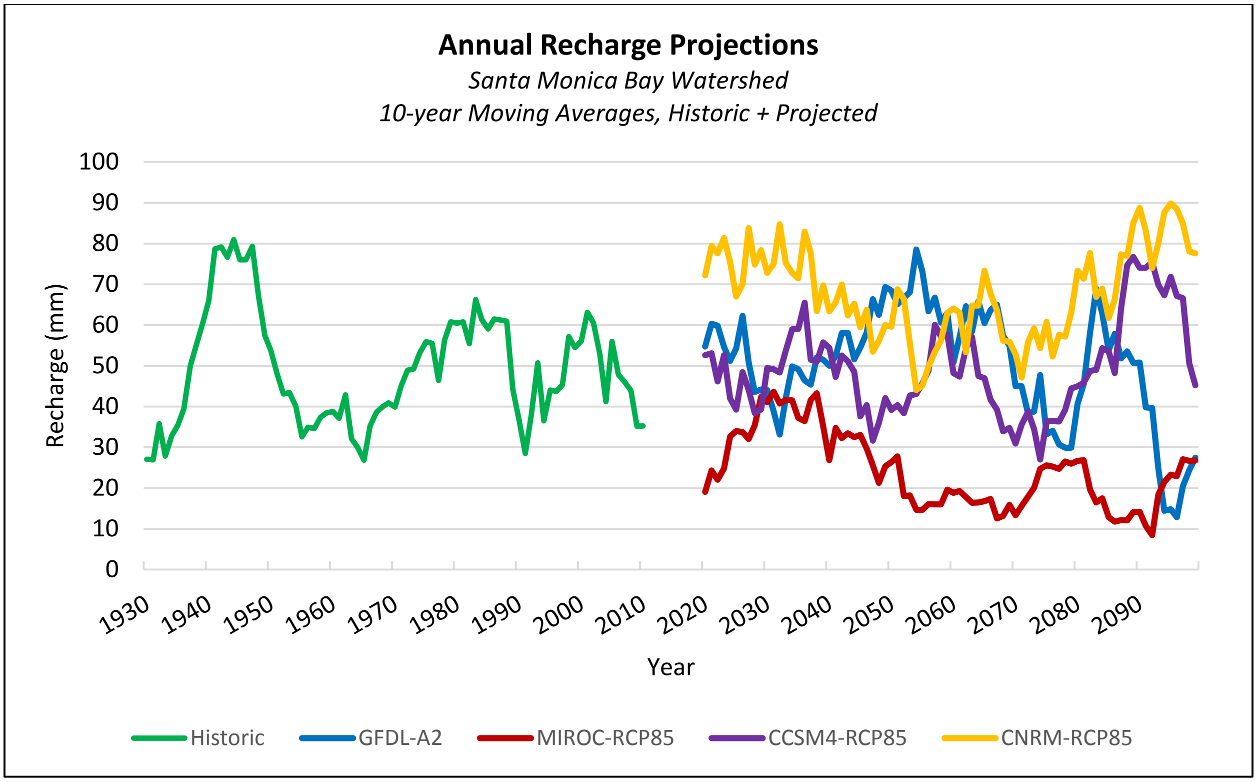


Figure 16. Future groundwater recharge projections for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Increasing Storminess

Annual precipitation, modeled by the CA-BCM 2014 show a high degree of variability between the four models, with projected annual changes ranging from -44.04 mm (-1.73 in) to 263.44 mm (10.37 in) by 2050 and from -75.88 mm (-2.99 in) to 301.73 mm (11.88 in) by 2099 (Table 6) (Figure 17). Another recent regional scale high-resolution ensemble modelling for California shows that while little to a slight increase in annual precipitation is projected, the increase in extreme hydrological events, including high intensity winter rainfall events and a greater probability of drought, are likely (Pagán et al. 2016).

Table 6. Projected future change in precipitation for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Santa Monica Bay Region		Change in Precipitation (mm/in)*	
Model	Scenario	Projected by 2050	Projected by 2099
GFDL-A2	moderately warmer, drier future	131.72 mm/ 5.19 in	-21.83 mm/ -0.86 in
MIROC-RCP85	warmest, driest	-44.04 mm/ -1.73 in	-75.88 mm/ -2.99 in
CCSM4-RCP85	Mid-range, closest to ensemble mean	98.30 mm/ 3.87 in	61.62 mm/ 2.43 in
CNRM-RCP85	wettest and warm	263.44 mm/ 10.37 in	301.73 mm/ 11.88 in

* change relative to average historic precipitation data (2000-2010)

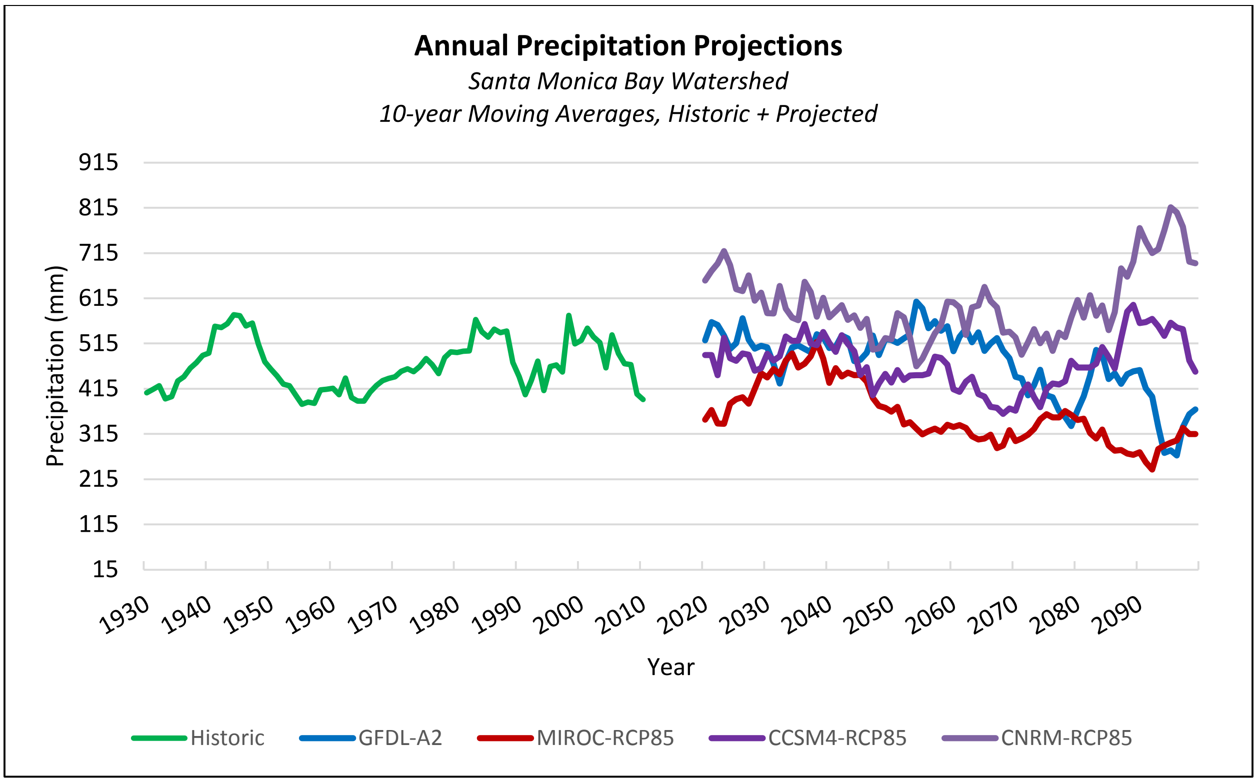


Figure 17. Future precipitation projections for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

The CA-BCM 2014 hydrological runoff variable, defined as the amount of water that becomes stream flow, varies in future projections based on dry to wet model scenarios (Figure 18). Model scenarios show a change in total annual runoff to range from -41.00 mm (-1.61 in) to 98.06 mm (3.86 in) by 2050 and from -32.2 mm (-1.27 in) to 183.67 mm (7.23 in) by 2100 (Table 7).

Table 7. Projected future change in runoff for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Santa Monica Bay Region		Change in Runoff (mm/in) *	
Model	**Scenario**	**Projected by 2050**	**Projected by 2099**
GFDL-A2	moderately warmer, drier future	41.15 mm/ 1.62 in	10.57 mm/ 0.42 in
MIROC-RCP85	warmest, driest	-41.00 mm/ -1.61 in	-32.2 mm/ -1.27 in
CCSM4-RCP85	Mid-range, closest to ensemble mean	32.57 mm/ 1.28 in	-2.24 mm/ -0.09 in
CNRM-RCP85	wettest and warm	98.06 mm/ 3.86 in	183.67 mm/ 7.23 in

* change relative to average historic runoff data (2000-2010)

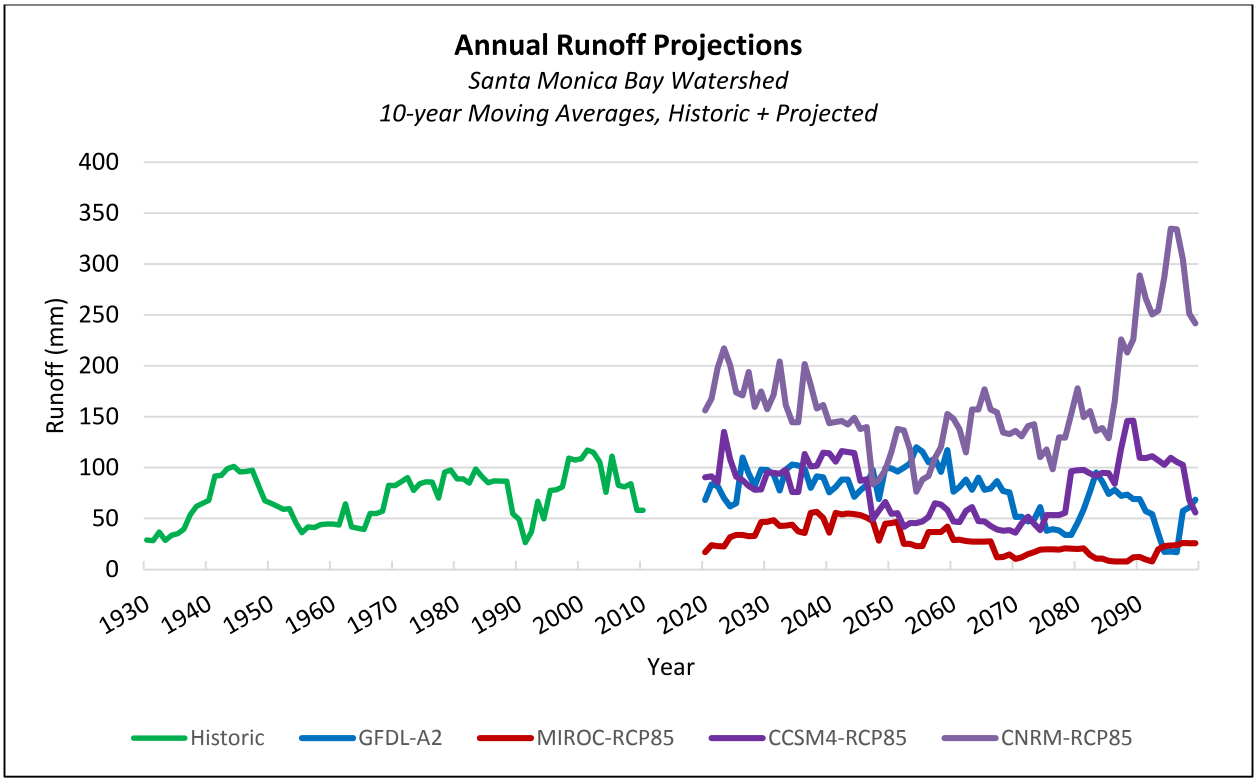


Figure 18. Future runoff projections for the Santa Monica Bay Watershed (Data source: 2014 California Basin Characterization Dataset).

Sea Level Rise

From 1901-2010, global mean sea level rose by 0.19 [0.17 to 0.21] m (Figure 19) (IPCC 2014). Historical data collected from west coast tide gauge records show that from the period of 1933-2008 relative SLR in Santa Monica has been increasing at a rate of 1.41 mm per year (NRC 2012). Climate change induced SLR models project an increase of 0.1-0.6 m (0.3-2.0 ft) from 2000-2050 and 0.4-1.7 m (1.3-5.6 ft) from 2000-2100 for the Los Angeles coastal region (NRC 2012). Over the last decade, scientists and planners have worked to down-scale global SLR models into regional high-resolution models that incorporate coastal topography, storm and flood scenarios, cliff retreat, and infrastructure, which can be utilized for local planning efforts. In addition to climate warming induced SLR, factors such as tides, wave-driven run up, and storms play a critical role in coastal flooding in Southern California (Grifman et al. 2013). A recent manifestation of this effort is apparent in the USGS Coastal Storm Modelling System (CoSMoS), which makes detailed predictions (meter-scale) of storm-induced coastal flooding and erosion for both current and future SLR scenarios, as well as long-term shoreline change and cliff retreat (Bernard et al. 2016). CoSMoS 3.0 modelling results for the Santa Monica Bay region are highlighted in Figure 20 and show flood extent may be more severe for low lying coastal areas of Malibu, Venice, Marina del Rey, and Playa del Vista. Wetland and lagoon areas as well as low-lying development are particularly exposed to rising sea level and storm induced flooding.

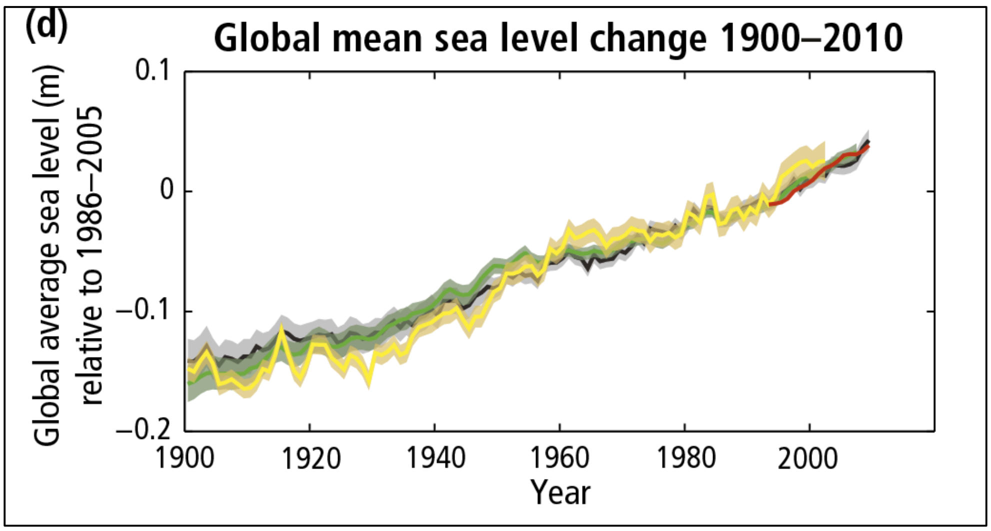


Figure 19. Global mean sea level change 1900-2010 (replicated from IPCC 2014).

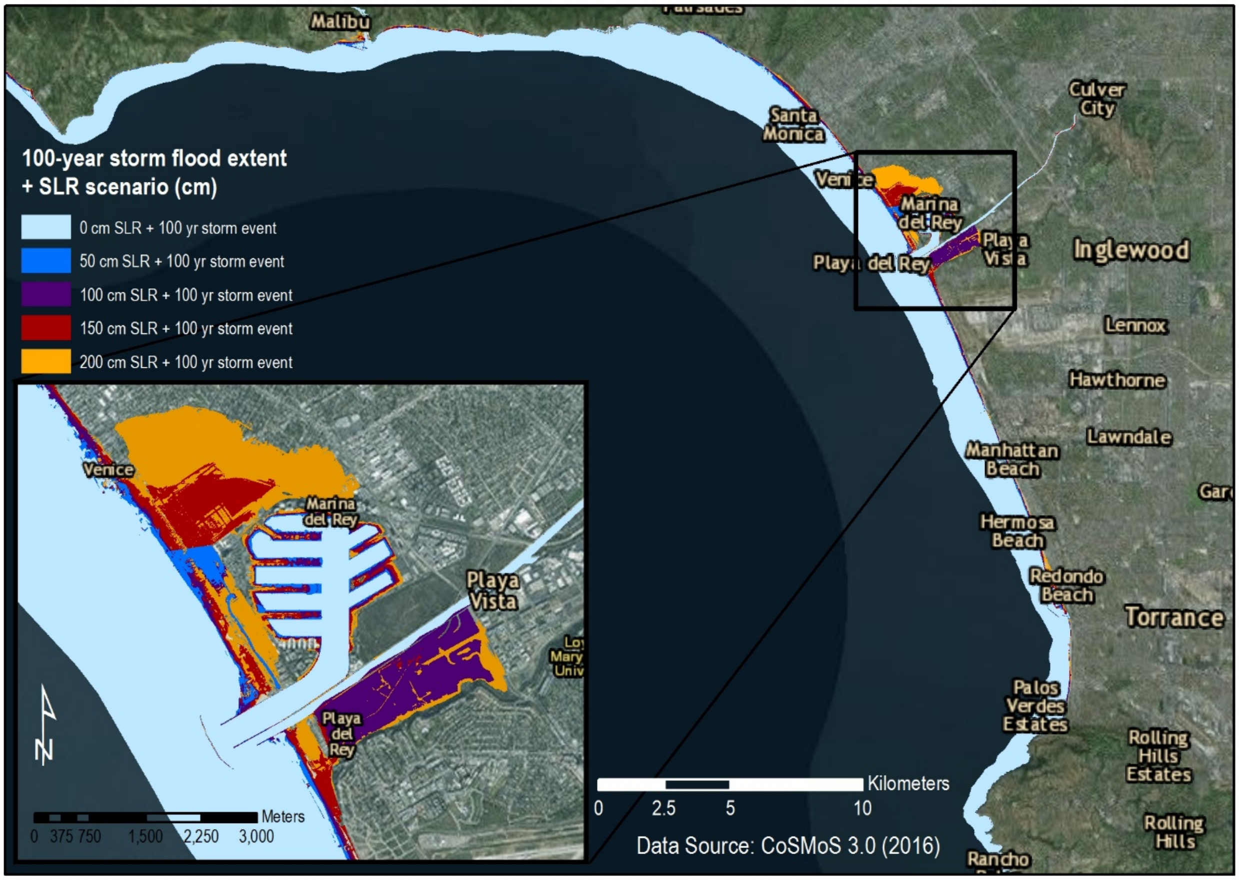


Figure 20. 100-year storm flood extent and SLR scenarios for Santa Monica Bay region (Data Source: CoSMoS 3.0 2016).

Ocean Acidification

Ocean acidification (OA) is a global problem triggered by the world's oceans absorbing CO2 emissions from the atmosphere. The close relationship between CO2 in the atmosphere, CO2 dissolved in the ocean, and the effect of the latter in falling pH, is illustrated by the graph below (Figure 21).

CO2 in the atmosphere has increased from 278 ppm in pre-industrial times to 390 ppm today. During this time, the amount of CO2 dissolved in the ocean has risen by more than 30%, decreasing the pH of the ocean by 0.11 units. The most-widely cited projection for rising acidity of the ocean in the future is the modeling results of the US National Center for Atmospheric Research Community Climate System Model 3.1 (CCSM3) which estimated decadal mean pH at the sea surface centered around the years 1875, 1995, 2050, and 2095 (Figure 22). It projected that by 2095, the average ocean surface pH will drop from a pre-industrial value of about 8.2 to about 7.8. (Feely et al. 2009)

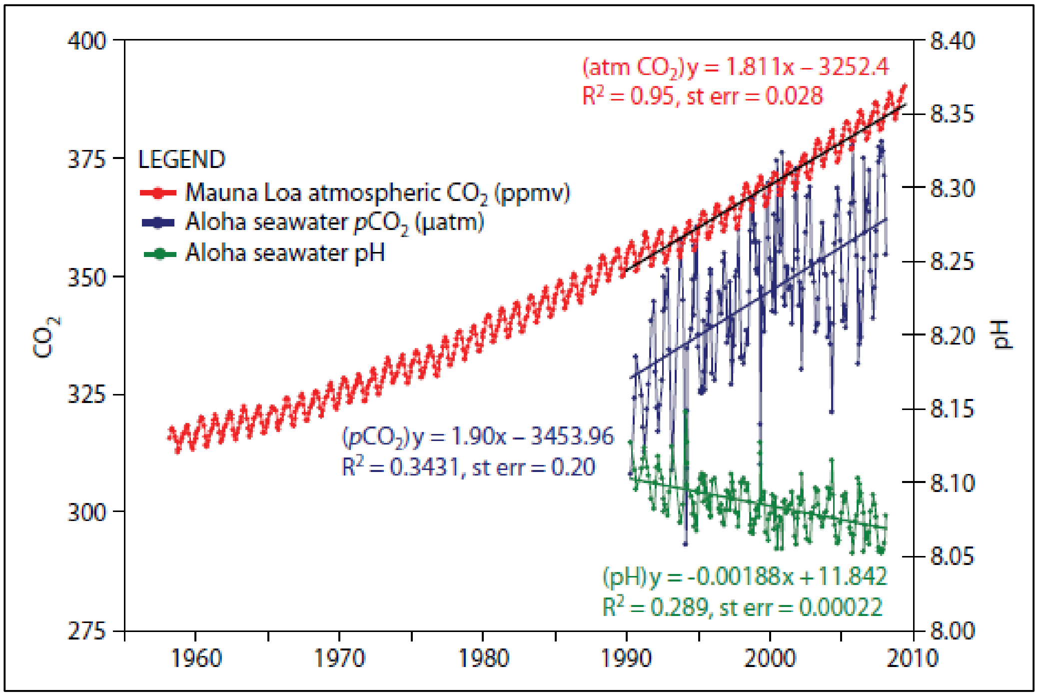


Figure 21. Atmospheric CO2, seawater pCO2, and seawater pH relationship (replicated from Feely et al. 2009).

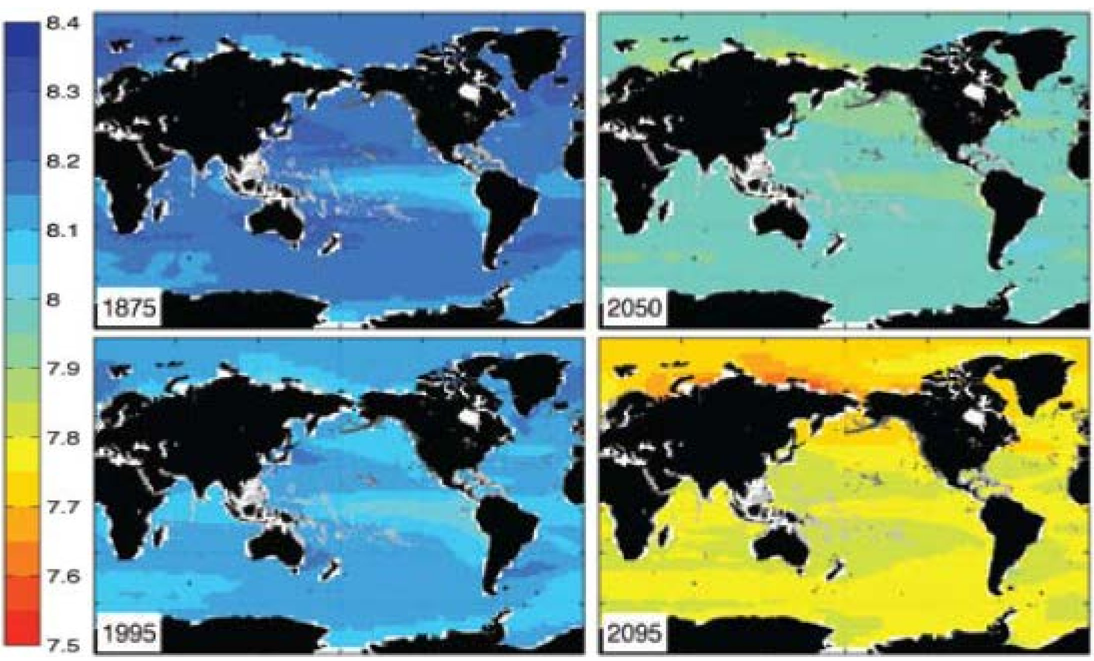


Figure 22. US National Center for Atmospheric Research Community Climate System Model 3.1 (CCSM3) – modeled decadal mean pH at the sea surface centered on the years 1875, 1995, 2050, and 2090 (replicated from Feely et al. 2009).

The effects of OA manifest unevenly in different regions of the world. The West Coast of North America is especially vulnerable and among the first and most prominent regions being impacted by OA because of a confluence of factors. One primary factor is the oceanic currents that transport waters across the northern Pacific Ocean from Asia to the West Coast. Surface waters as far as off the coast of Japan absorb atmospheric CO2 produced through global human activity and then sink hundreds of feet beneath the ocean's surface. As these subsurface waters move toward the West Coast, the enriched CO2 in these deep waters combines with CO2 from atmospheric emissions and results in a disproportionately large impact on ocean chemistry. Another primary factor is coastal upwelling. Along the West Coast, winds that blow southward push surface waters away from the coastline. As surface waters are displaced, the deep waters rich in CO2 and poor in dissolved oxygen (DO) are pulled to the surface. Compounding these CO2 enrichment and rise of pH value are other factors associated with global climate change. As the world's oceans warm, which are also triggered by rising CO2 emissions, seawater will become less able to hold DO and upwelling will intensify, and both trends will result larger and more severe low oxygen, or hypoxic zones.

The impacts of ocean acidification and hypoxia (OAH) are already being felt across West Coast systems and are projected to grow rapidly in intensity and extent. An increasing number of studies are documenting the progression of OA and already observing effects, including studies showing that many local taxa, such as sea urchins, corals, mussels, coralline algae, and calcareous planktons, exhibiting signs of vulnerability (Hauri et al. 2009). Models predict that much of the nearshore California Current System will experience 'corrosive' waters all summer long in the upper 60 meters within the next 30 years (Gruber et al. 2012). Localized impacts can also have an additive effect, as human inputs of nutrients into coastal waters can lead to the excessive production of algae, a process known as eutrophication. This co-occurrence of hypoxia poses further challenges for organisms already subject to OA stress.

Although the state of knowledge about OA and its interaction with hypoxia is rapidly evolving, it is still limited and is able to inform only a limited suite of management options to date. Recent progress includes the California Current Acidification Network (C-CAN), which is an interdisciplinary collaboration dedicated to advancing the understanding of OA and its effects on biological resources along the U.S. West Coast. C-CAN is currently working to standardize OA monitoring and data management practices to ensure data comparability and quick public access. One important need and next step is to build capacity for downscaling existing physical models, extending them closer to shore, and integrating them with biogeochemical models to create high-resolution, coupled models (The West Coast Ocean Acidification and Hypoxia Science Panel 2016). It will also be critical to have precise instruments to detect when important biological thresholds are breached (Booth 2015).

Risk Identification

Methods

Step 3 in the EPA Workbook is categorized as "Risk Identification," which was followed in the SMBNEP evaluation. The goal of the risk identification step was to generate a broad list of reasonably foreseeable ways that climate change stressors may affect organizational goals. This was primarily a staff-driven brainstorm exercise conducted at the milestone level (lowest tier) and subsequently scaled up to the objective level (second tier).

Potential risks associated with climate change stressors were identified and organized on a spreadsheet. According to the EPA Workbook, a risk is identified as something that:

"…threatens things of value. In the context of climate change, a risk is the possibility that a given climate change stressor will affect your organization's ability to meet its goals. A risk is a problem to be managed by finding ways to lower its principal characteristics: likelihood and consequence. In this step, you will cross your goals with climate change stressors to identify risks."

Stressors and goals may be inherently embedded within the risk. Risks may prevent the organization from reaching the milestone in some way due to environmental changes or detrimental impacts to a project. If there is any potential sequence (i.e. identified climate change stressor and subsequent impact) that includes an unwanted consequence which may prevent the organization from reaching that milestone, then that is identified as a risk. The path may be simple, i.e. increasing storm intensity may cause flooding, or complex, i.e. increased storminess combined with drought may alter stormwater runoff frequency and the associated "first flush" of pollutants or nutrients, potentially increasing the possibility of associated impacts to water quality limits or monitoring. Similarly, the climate change stressor warmer waters may lead to eutrophication in coastal waters and subsequent reduction in dissolved oxygen, leading to impacts to the benthic invertebrate or fish communities.

No risks were dismissed as part of this exercise. Even risks that were identified as potentially insignificant were captured in this step. In some instances, further analysis might show that a risk is not trivial at all and dismissed risks would not have been able to support the next step, or the vulnerability analysis. For analysis purposes, it was more productive to have the world of potential risks identified than those that were prioritized as having a higher likelihood of occurrence.

This step required an in depth understanding of the tasks covered by each milestone in the BRP and a high degree of staff expertise. Risks were identified for each milestone for each of the six climate change stressors. Some identified risks were categorized as potentially occurring due to multiple climate change stressors. The likelihood of the risk occurring was not analyzed as part of this step;

instead, the milestone was interpreted broadly, identifying risks both through analyzing risks to the milestone itself and also to the habitat type that it described (when appropriate).

In some instances, an identified risk potentially affected the vulnerability of many milestones. For example, warmer waters causing an increase in potential for eutrophication and subsequent lowering of dissolved oxygen in coastal waters could affect many of the Bay's estuaries, streams, creeks, and other waterways. Similarly, warmer waters offshore could have impacts throughout nearshore habitats such as kelp beds, rocky intertidal areas, and deeper waters. Thus, one risk may cause more than one problem to multiple milestones.

Table 3.1A from the EPA Workbook provides a snapshot example of the initial risk identification process for two goals and six climate change stressors (Figure 23).

TABLE 3-1A. POTENTIAL CLIMATE CHANGE RISKS FOR POLLUTION CONTROL

Clean Water Act goals	Warmer summers	Warmer winters	Warmer water	Increasing drought	Increasing storminess	Sea level rise
Controlling point sources of pollution and cleaning up pollution		☐ Loss of melting winter snows may reduce spring or summer flow volume, and raise pollutant concentration in receiving waters	☐ Temperature criteria for discharges may be exceeded (thermal pollution) ☐ Warmer temperatures may increase toxicity of pollutants	☐ Critical-low-flow criteria for discharging may not be met ☐ Pollutant concentrations may increase if sources stay the same and flow diminishes	☐ Combined sewer overflows may increase ☐ Treatment plants may go offline during intense floods	☐ Treatment plants may not be able to discharge via gravity at higher water levels ☐ Treatment infrastructure may be susceptible to flooding ☐ Sewage may mix with seawater in combined sewer systems ☐ Contaminated sites may flood or have shoreline erosion ☐ Sewer pipes may have more inflow (floods) or infiltration (higher water table)
Controlling nonpoint sources of pollution	☐ Wildfires may lead to soil erosion	☐ Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	☐ Higher solubility may lead to higher concentration of pollutants ☐ Water may hold less dissolved oxygen ☐ Higher surface temperatures may lead to stratification ☐ Greater algae growth may occur ☐ Parasites, bacteria may have greater survival or transmission	☐ Pollution sources may build up on land, followed by high-intensity flushes	☐ Streams may see greater erosion and scour ☐ Urban areas may be subject to more floods ☐ Flood control facilities (e.g., detention basins, manure management) may be inadequate ☐ High rainfall may cause septic systems to fail	☐ Tidal flooding may extend to new areas, leading to additional sources of pollution

Figure 23. Table 3-1A. Potential Climate Change Risks for Pollution Control from the EPA Workbook (EPA 2014).

In addition to risks, some potential outcomes were identified as "opportunities." These are circumstances arising from any of the six climate change stressors that may have beneficial effects instead of harmful impacts. For example, the sea level rise stressor may provide opportunities to engage in more and varied types of communications strategies and media outreach. In this case, the outcome was identified as an opportunity ("O") in the spreadsheet, instead of a risk ("R") and was highlighted in light green to distinguish opportunities from the risks. Opportunities may provide additional discussion and input to the subsequent action planning steps of the BRP analysis, but should not be evaluated as "cancelling out" risks for a particular milestone.

Each staff member drafted the risks for the milestones in their department or those that they were working directly on, and the list was circulated internally. Several staff members also reviewed the entire set of risks identified for all milestones. Working at the milestone level was shown to be less effective, and with a significant amount of extra repetition that was not conducive to a vulnerability analysis. Therefore, once the milestone risks were identified, the whole list was reviewed, reorganized, and scaled-up to the objective level. Once the objective level risks were compiled, they were sent out for external expert scientific review. No risks were removed, but many were added, and some additional climate change stressors were "checked" for a particular risk that may have been more broadly applicable to multiple stressors (e.g. both warmer waters and warmer temperatures may have similar risks in intertidal areas).

Constraints

Time and funding were both significant constraints in both the risk identification steps and the application of the framework for the vulnerability analysis. It was important to SMBNEP to have the expert climate scientist panel review all steps of the evaluation. Therefore, an abbreviated turn-around time for staff review and development of each piece was often quite fast. We were incredibly fortunate to have the expert panel volunteer their time, and this assessment would not have been possible without their help. We are indebted to them. Initially, SMBNEP considered contracting to an outside organization for help with the evaluations, but it was quickly determined that individual staff expertise on each objective was necessary for a more accurate evaluation.

Results

Appendix B contains a full list of all risks for each objective and each stressor identified as part of this step in the CCVA process. As discussed in the methods section, these objective-level risks were scaled up from the milestone level to provide a more effective analysis. Risks were frequently identified as having the potential to occur due to more than one climate change stressor, and were subsequently identified with an 'x' in each stressor column that was applicable. Additionally, opportunities were identified in a similar manner and within the same Appendix B.

As many risks as possible were identified by staff and reviewed and supplemented by the expert climate scientist panel, but as climate science contains many unknowns, this Appendix was intentionally designed to be a living document that can easily be supplemented over time as new information, or new models, becomes available. Additionally, implementing adaptive management strategies to address climate change risks may cause them to be removed from the list in the future. Similarly, as SMBNEP goes through the BRP update process, including drafting new objectives, this list of identified risks will grow and evolve over time.

The total number of risks identified as part of the BRP evaluation was 474 across 59 objectives. Many of them were not independent. For example, a risk of eutrophication and lowered dissolved oxygen may apply to many of the objectives relating to coastal water bodies. The number of identified risks and opportunities varied significantly by goal (ranging from 7 to 101) and by objective. Objectives relating to land acquisition or education and outreach tended to have more opportunities identified and fewer overall risks, while those relating to coastal habitats that are vulnerable to many climate change stressors had significantly more. For example, Goal 3 (two objectives) had 7 identified potential risks, while Goal 8 (also two objectives) had 40 potential risks or opportunities identified. However, it is important to understand that these risk counts should not be evaluated quantitatively, which is why the expert climate scientist panel decided not to include the number of risks in the CCVA Framework. The number of risks identified is not necessarily correlated to its overall vulnerability, as some identified risks may contribute disproportionately more to an objective's vulnerability score. Some risks may eventually end up making some objectives infeasible or requiring immediate management action.

The list of risks for each objective contained in Appendix B contributed to the overall vulnerability analysis, and some are discussed in more detail in the individual narratives found in the CCVA section of this report (below), including mention of individual risks identified for each objective that may be adding vulnerability to achieving that objective. Table 8 gives an example risk list for Goal 9, Objective 9.1, restore rocky intertidal and subtidal habitats.

Table 8. Example risk list for Objective 9.1.

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
9.1 Restore and monitor sixty acres of kelp forest		x					Kelp becomes stressed due to warmer water reducing reproduction and slowing restoration response	R
				x			Large storm events may rip out kelp, slowing restoration response	R
				x			Increased urban runoff from storms may increase contaminants, slowing kelp growth	R
				x			Increased sediment flow from storms may prevent kelp from seeding onto the reef	R
					x		Sea level rise may shift distribution of kelp dependent on depth	R
						x	Ocean acidification will affect urchins, a calcifying species, which may change the abundance of urchins in kelp forests	R
				x			Increased wave action may impact reefs	R
	x	x					New invasive species may occur	R
		x		x		x	Impacts to fish reproduction	R
		x		x	x	x	Changes in coastal phytoplankton community and food web	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
	x	x					Increase in disease	R
	x	x	x	x	x	x	Incorporate climate change planning into dam removal and positioning of material	O

Climate Change Vulnerability Assessment

Methods

Following the identification of climate change stressor associated risks for each BRP objective, results and proposed risk analysis methods (following the EPA Workbook: Step 4 and 5) were presented to SMBNEP staff, the SMBRC Technical Advisory Council (TAC), as well as external experts for review.

Climate Change Vulnerability Analysis Framework

Based on organizational needs to provide a customized product in the form of a Climate Change Vulnerability Assessment (CCVA) that could inform future planning, recommendations were made by staff and experts familiar with the SMBNEP BRP to modify the existing EPA Workbook risk analysis framework (Figure 24a). The EPA Workbook risk analysis framework evaluates risks by qualitatively categorizing the consequence, likelihood, spatial extent of impact, and time horizon as well as documenting associated habitat type and confidence levels.

TABLE 4-1. RISK ANALYSIS

Organizational goal	Climate stressor	Risk	Is this an opportunity instead of a risk?	Consequence (a–c)	Likelihood (a–c)	Spatial extent of impact (a–c)	Time horizon (a–c)	Habitat type	How confident are you in your risk analysis? Do you have sources that support your determinations?
1.									
2.									
3.									
4.									
5.									
n.									

Consequence:
- (a) Low (life will go on; not as important as many other things; could adjust)
- (b) Medium
- (c) High (major disruption; goal is out of reach or not even attainable)

Likelihood:
- (a) Low
- (b) Medium
- (c) High

Spatial extent of impact:
- (a) Site (e.g., a few waterfront lots, a bridge, a sewage treatment plant)
- (b) Place or region (e.g., community, harbor, state park, wildlife refuge, sub-watershed)
- (c) Extensive (most of the watershed or most of the estuary)

Time horizon:
- (a) More than 30 years
- (b) 10–30 years
- (c) Already occurring or 0–10 years

Figure 24a. EPA risk analysis (Task 4) framework (EPA 2014).

With over 400 risks identified over the 14 BRP goals, the practicality and feasibility of assessing each individual risk based on the EPA framework would not have been possible. Additionally, many risks identified in the previous step spanned across multiple climate change stressors. It became apparent that while risks inherently have an associated level of uncertainty on whether or not they will occur in the future, the ability to assign a qualitative likelihood value to each risk is difficult without supporting model data and research. The likelihood of a risk occurring, while not certain, is inherently tied to the climate change stressor it is associated with. Instead of evaluating individual risks, the CCVA was restructured to evaluate the vulnerability of BRP goals to climate change stressors, at the objective level.

Adaptive capacity and sensitivity components were included as categories to evaluate as these components play a significant effect on overall vulnerability. Adaptive capacity refers to the potential, capability, or ability of a system to adapt to a specific climate change stressor, while sensitivity refers to the degree to which a system will respond to a change in climatic conditions. Spatial extent of impact was incorporated into an exposure criteria, defined as a combination of the impact and extent of a climate change stressor in the context of a particular objective. The exposure criteria was broken down into current exposure, year 2050 exposure, and year 2100 exposure, justified by these time periods being common across many climate change model projections. While the breakdown of exposure into current, 2050, and 2100 time periods allowed staff to utilize climate change model projections in making ranking decisions, the CCVA remained a qualitative analysis guided by classification definitions of high, medium, and low associated with each criteria. Identified risks were used as a supplement to help inform the vulnerability analysis of climate change stressors for each milestone. Figure 24b shows the modified CCVA Framework and Figure 25 shows the associated framework methodology flowchart.

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #___
(Goal Topic)										
Goal # ___- (Goal Description)										
Objective	**Objective Description**	**Climate Stressor**	**(A) Adaptive Capacity** 3-Low 2-Med 1-High	**(S) Sensitivity** 3-High 2-Med 1-Low	**(E1) Exposure** (current) 3-High 2-Med 1-Low	**(E2) Exposure** (2050) 3-High 2-Med 1-Low	**(E3) Exposure** (2100) 3-High 2-Med 1-Low	**(V1) Vulnerability** (current)	**(V2) Vulnerability** (2050)	**(V3) Vulnerability** (2100)
		Warmer Temperatures						0.00	0.00	0.00
		Warmer Water						0.00	0.00	0.00
		Increasing Drought						0.00	0.00	0.00
		Increasing Storminess						0.00	0.00	0.00
		Sea Level Rise						0.00	0.00	0.00
		Ocean Acidification						0.00	0.00	0.00

Figure 24b. Blank CCVA Framework.

Definitions of the adaptive capacity, sensitivity, and exposure criteria of the CCVA framework were further defined with specific examples given to staff to guide analysis. Details on the high, medium, and low rankings for each of the CCVA criteria are detailed below:

Adaptive Capacity

Definition: Adaptive Capacity refers to the potential, capability, or ability of a system to adapt to a specific climate change stressor (warmer temperatures, warmer water, drought, increased storminess, SLR, OA). Additionally, this can be defined as the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate. Adaptive capacity can be spontaneous or planned, and can be carried out in response to or in anticipation of changes.

Assign one of the following rankings for each climate change stressor associated with a particular objective:

1 = High: Implies that the particular objective has a high adaptive capacity in the context of a climate change stressor. This is a good characteristic to have, project objectives which have a high adaptive capacity will generally be able to adapt to climate change stressor impacts in the future.

2 = Medium: Not high, but not low. Implies that the particular objective has somewhat of an adaptive capacity in the context of a climate change stressor.

3 = Low: Implies that the particular objective has a low adaptive capacity in the context of a climate change stressor.

Sensitivity

Definition: the degree to which a system will respond to a change in climatic conditions.

Assign one of the following values for each climate change stressor associated with a particular objective:

1 = Low: The objective and corresponding system has a low sensitivity to a climate change stressor. Meaning, there will be little to no change observed in response to a climate change stressor

2 = Medium: Not high, but not low. The objective and corresponding system is somewhat sensitive to a climate change stressor.

3 = High: the objective and corresponding system is highly sensitive to a climate change stressor.

Exposure (current, 2050, 2100)

Definition: Exposure is a combination of the impact and extent of a climate change stressor in the context of a particular objective. Consider the size of the area and/or system affected and the magnitude of the stressor. All objective exposure rankings are assumed to increase over time. For example, SLR will be greater in 2050 than currently, and even greater in 2100.

Assign one of the following values for each climate change stressor associated with a particular objective:

1 = Low: A climate change stressor will have low to no impact and/or extent to an objective.

2 = Medium: Not high, but not low. A climate change stressor will have a moderate impact and/or extent to an objective.

3 = High: A climate change stressor will have high impact and/or extent to an objective.

The framework was designed to highlight the vulnerability of individual BRP objectives to the six climate change stressors. Overall the most vulnerable BRP objectives would be those that met the following criteria:

- Experience the most exposure to perturbations or stresses,
- Are the most sensitive to perturbations or stresses,
- And, have the weakest capacity to respond and ability to recover.

Adaptive capacity and sensitivity criteria were assumed to remain fixed, while the exposure criteria was evaluated for current conditions, and 2050 as well as 2100 future projections. While both adaptive capacity and sensitivity may have the capacity to change over time, they were fixed to simplify the purposes of the analysis. It is important to realize that this evaluation was conducted with the purpose of being adaptable over time as new models, data, or information arises. For example, many of the assessments that include some degree of vulnerability to OA may change over time as new models are applied to our region.

The final CCVA Framework resulted in three separate vulnerability ranks for current, 2050, and 2100 conditions. The final vulnerability ranks were taken by averaging adaptive capacity, sensitivity, and exposure (current, 2050, 2100). The vulnerability ranks remain a combination of a qualitative ranking system, providing a method to visualize potential climate change vulnerability of BRP objectives.

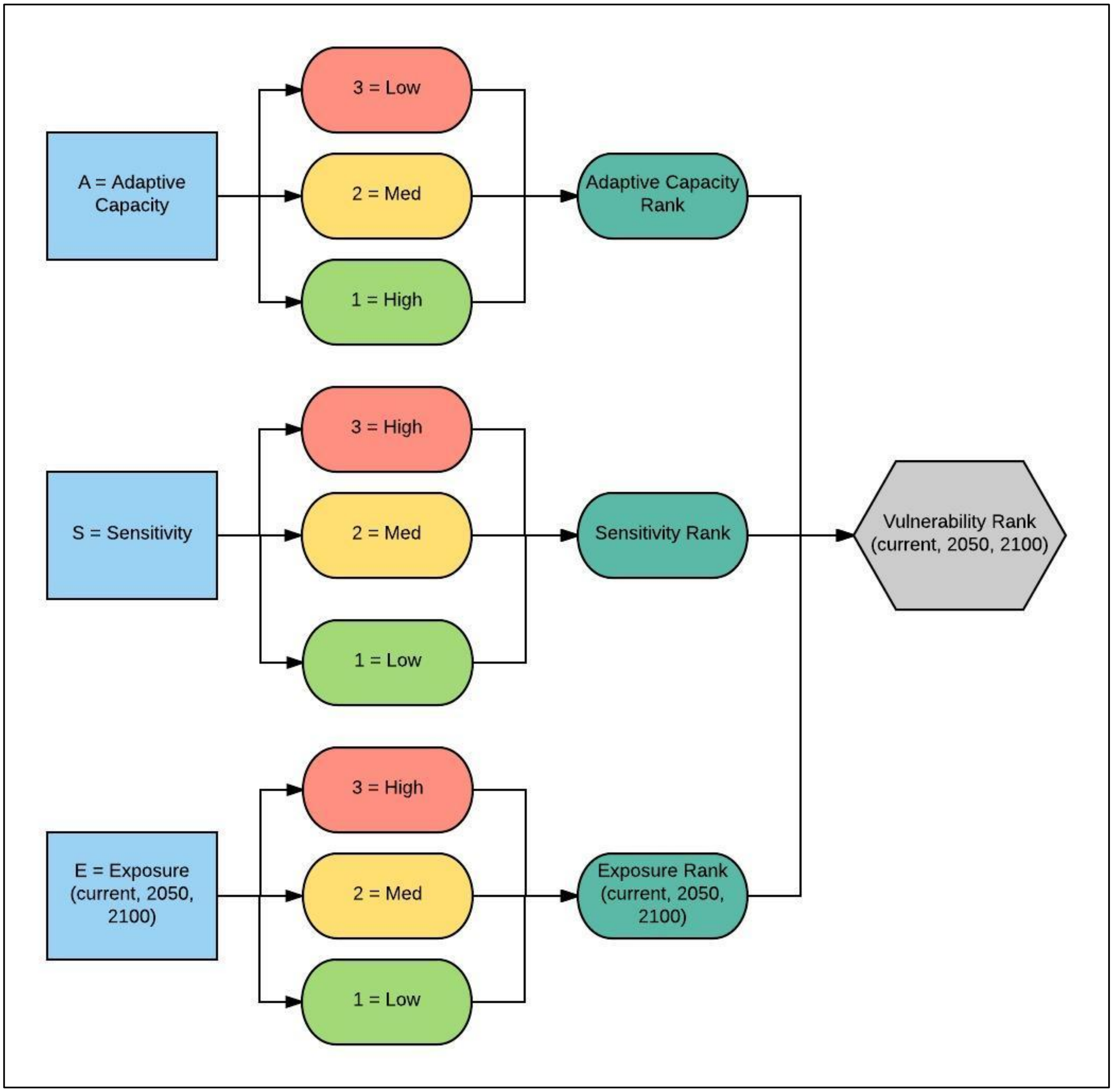


Figure 25. Climate Change Vulnerability Analysis (CCVA) Framework.

Visualizations

Visualizing the CCVA results was a key component in developing a final product that could be used for future action-based planning. A visualization model, adapted by a NASA-JPL climate change risk/natural disaster hazard assessment, was proposed by SMBNEP staff and approved by the Expert Climate Change Panel and TAC. The visualization resulted in a 3-dimensional bar graph representing the qualitative CCVA rankings per objective. Objectives with low to no vulnerability to climate change stressors displayed a small (or no) bar while those objectives with high vulnerability displayed a large bar.

CCVA completion

Similar to the process involved in identifying climate change associated risks for each objective, the CCVA process begun by individual SMBNEP staff populating rankings for goals associated with their areas of expertise. Given guidance and direction, through a series of meetings, staff was instructed to complete the CCVA for specific goals individually, followed by coming to a consensus over CCVA ranking assignments as a group (i.e. Marine Program area, Water Quality area, etc.). The CCVA project leads on multiple occasions served as mediators between staff when needed. Further fine-tuning of the CCVA results involved groups coming to a consensus on CCVA ranking assignments. When final consensus for CCVA goal rankings were made, those goals along with association visualizations were sent to select Expert Climate Change Panel reviewers. Final CCVA rankings represent multiple rounds of internal expert staff review and outside Expert Climate Change Panel review. Over the course of completing the CCVA, communication with both internal staff and the expert climate science panel was key. Figure 26 outlines the general communication workflow involved in completing both the risk identification task and the CCVA.

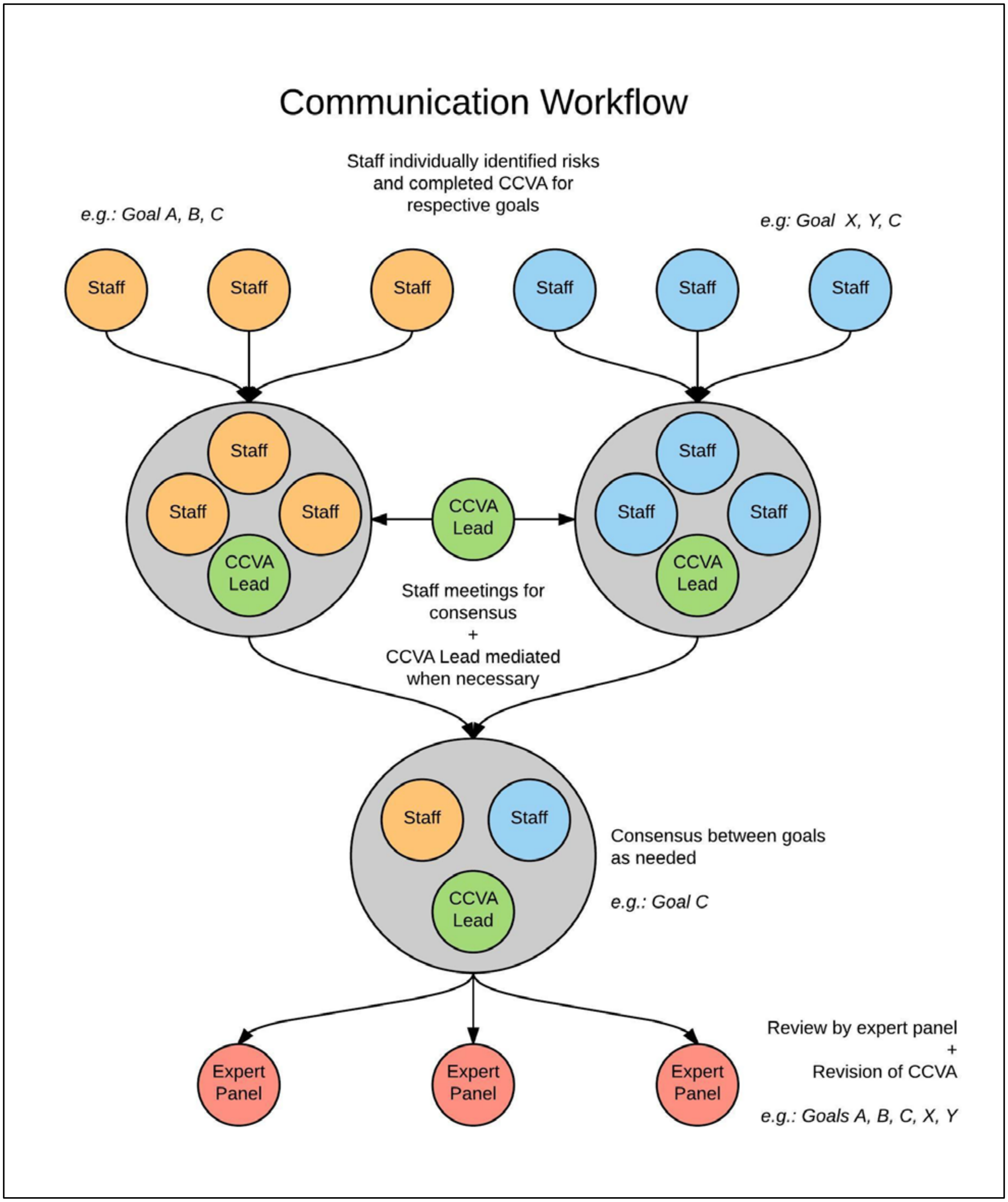


Figure 26. Risk Identification and CCVA Communication Workflow.

Communications and Expert Engagement

Step 1 in the EPA Workbook is identified as "Communication and Consultation," and is described as "an opportunity to inform your key stakeholders and partners about why a climate change adaptation plan is necessary, as well as to describe the process and the expected products." Due to the broad range of partners who are vital in their efforts working together to implement the BRP, this step is an important part of the CCVA process, and is much broader than just being the initial step of the assessment. Instead, SMBNEP took a broad view of general engagement – bringing notices about the process to many public meetings throughout the duration of the grant. Additionally, at the beginning of this project, options for various types of stakeholder engagement were explored. Initial communications and engagement began with students and faculty at UCLA (see climate change stressor sections, above), who reached out in many different directions to compile relevant research, models, reports, data, and information for the climate change analyses. Subsequently, it was determined that the most effective form of input would be from expert climate change scientists, and thus, a panel was developed consisting of a subset of TAC members, outside experts, partner scientists, and other researchers who had helped facilitate a vulnerability assessment project in the past and could provide direction and review at key stages in the process (Figure 26).

Ultimately, several TAC meetings, a dedicated CCVA Workshop, and additional expert engagement throughout the project was responsible for guiding the process of developing a comprehensive CCVA framework and reviewing the final draft results of the CCVA. Key stakeholders, listed under the expert climate scientist panel in the beginning of this report, provided an opportunity for consultation and expert review during both the risk identification and the vulnerability assessment itself (CCVA). Particular interests and concerns about identified climate change risks and the adaptation planning process were voiced and engagement provided opportunities to learn about other CCVA efforts in the region. Additionally, engaging experts through meetings and the workshop has help build support for continued participation in the next steps following this project, action-based planning.

In addition to the expert panel engagement, broader notices about the process and how it will tie to the eventual update of the BRP has been generally discussed with many stakeholders, partner agencies, and members of the public. Examples include discussions during the staff report of the WAC meeting, Governing Board meetings, and at several climate change conferences and meetings throughout the duration of the project. This communication will continue far beyond the life of this grant/project as SMBNEP moves into the action planning stages of BRP update and implementation. More and varied stakeholder groups will be engaged, and this report will be made broadly available to the public. It is our hope that in addition to providing a much-needed tool to supplement BRP planning efforts, the regional models analyzed and summarized here will provide a synthesis of climate change data for the LA and southern California region.

Results: Climate Change Vulnerability Assessment (CCVA) Interpretation and Visualizations

The overarching results from the CCVA and the interpretation of the visualizations was highly variable, and often individual and objective-dependent. Interpretations of the vulnerability of objectives that were broader often had more potential associated risks, and therefore a higher susceptibility to vulnerability from one or more climate change stressors. Objectives that were more specific may have had targeted associated risks identified as well as specific stressors. In general, outreach, education, and policy objectives were not very vulnerable and had a high associated adaptive capacity. Objectives or goals that were linked to a vulnerable habitat were often susceptible to multiple climate change stressors that increased the potential vulnerability of that habitat, e.g. objectives related to intertidal habitats and coastal wetlands. Additionally, objectives or goals that were related to a habitat with a low adaptive capacity to a particular stressor were often more vulnerable, e.g. kelp forests and their associated biological communities will have trouble adapting to OA and warmer waters, and the effects of both stressors may interact over time. In many cases, OA was identified as being a data gap with more research needed to increase the confidence of vulnerability evaluations associated with the OA stressor.

The following CCVA results are grouped by goals and their respective objectives. Individual goal narratives are immediately followed by CCVA result visualizations for current, 2050, and 2100 scenarios.

Goal 1 – Improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state regulatory framework

In general, among the seven objectives under this goal, those that are directly tied to compliance of existing water quality standards such as TMDLs have the highest vulnerability to various impacts of climate change. This is especially the case for Objective 1.1, 1.2, and to a lesser degree for Objective 1.4, which all call for elimination of the sources of water pollution and prevention of water quality impairment. All six major climate stressors have various levels of impacts, especially for Objective 1.1, primarily because Objective 1.1 is far-reaching through addressing compliance of TMDLs that cover a broad range of pollutants. Some of the pollutants are more sensitive to impacts upstream, while others are more sensitive to impacts downstream or along the beaches. Despite this, the vulnerability to warmer water and drought are noticeably higher than the other stressors. This higher vulnerability is due to the possibility of more direct impacts on regulated contaminants because adverse effects of pollutants such as eutrophication and toxicity on water bodies increase with increasing temperatures. In the case of drought, one impact is potentially higher concentrations of contaminants, which typically result in more severe adverse effects.

Though addressing water quality, the vulnerability of Objectives 1.6 and 1.7, in general, are lower because they deal with a specific issue: non-storm urban runoff and septic systems, which are subject to a narrower set of stressors and are considered more manageable with focused efforts.

Objective 1.1 – Attain water quality goals in TMDLs adopted for 303(d) listed waterbodies in the Santa Monica Bay Watershed

Objective 1.1 is highly vulnerable to many of the six climate stressors because it encompasses all TMDLs adopted within the Bay watershed and for coastal waters. Therefore, the objective includes a variety of contaminants, each with a unique origin and treatment regime that may respond differently to individual climate change stressors. The adverse impacts of some of the TMDL regulated contaminants may be augmented by warmer waters and drought, while the impacts of other contaminants may be influenced by storminess and SLR. Warm water was the highest ranking stressor as it would directly influence water quality related to TMDL regulated pollutants. For example, there may be need to tighten standards on nutrients because warmer water exasperates eutrophication. Warmer water may also increase bacteria survival rate and the adverse impacts such as toxicity of other contaminant. Drought ranked the second highest because it leads to reduced water supply and stream flow, which may directly increase the concentration of many pollutants. If drought also results in more concentrated wastewater due to water conservation, POTWs may find it increasingly difficult to treat and meet effluent water quality standards with current wastewater treatment technologies and infrastructure. The impacts of other stressors are more limited to certain specific TMDLs instead of across-the-board. Warmer temperatures might increase the scale and frequency of wild fire, thus increasing sediment loading to water bodies. Increasing storminess may increase the likelihood that MS4 permit holders would violate the bacteria TMDL load allocation (in terms of number of allowed exceedance days/events). SLR may impair operation of beach front runoff diversion and treatment facilities. Finally, the nutrient discharge limits may need to be tightened because of its potential local cumulative effect on OA.

Initially, the adaptive capacity for this objective is considered high because agencies should have the capacity and flexibility to revise TMDLs and other related water quality regulations to cope with the impacts of various stressors. However, adaptation becomes much more challenging if retrofits of existing facilities and new capital projects are needed to attain water quality goals under the new climate change scenarios.

Objective 1.2 – Eliminate and prevent water and sediment quality impairments from both point and nonpoint sources for waterbodies in the Malibu Creek Watershed

Objective 1.2 addresses water quality issues specific to the Malibu Watershed and is highly vulnerable to four of the six climate stressors that are more associated with land-based impacts, including warmer temperatures, warmer water, increasing drought, and increasing storminess. Although Malibu Lagoon, which is located in the watershed, may be subject to additional impacts from SLR and OA, the Lagoon and associated impacts are addressed in the wetland Goal 7 (Objective 7.2) to avoid duplication. Among the identified climate stressors, warmer water and drought appears to have the greatest impacts, mainly because issues that are more prevalent and specific in the Malibu Creek Watershed including nutrient loading, bacterial contamination, and sedimentation are all highly sensitive to those stressors. Eutrophication is likely to increase in response to warmer water. Bacterial loading is also likely to increase, rather than decrease, under warmer water conditions. The benthic invertebrate community can be highly sensitive to temperature change and cold water fishes are likely to suffer as well. However, overall the adaptive capacity to warmer water is among the lowest because there are few control measures one can adopt to address temperature increases. Drought condition can have many effects, some are similar to warmer temperatures. There may be more incidence of eutrophication due to higher nutrient concentration. Benthic community may change and likely to shift to more drought-tolerance regime. On the other hand, the impact of drought on the rate(s) of erosion and sedimentation are less certain and may not be very significant. The stressors warmer water and warmer temperatures may not be independent within waters in the upper watershed because warmer temperatures may also increase the temperature of shallow water systems.

Though lesser than drought, increased storminess may have many effects, including changes in the rate of stream bank erosion and sedimentation, and impacts on the benthic invertebrate community. Although natural systems are relatively adaptable to periodic or episodic storm patterns, the extensive hydromodifications in the watershed make the system more sensitive and less adaptive to extreme storms. The impact of warm temperature to benthic communities should be limited (warm water is far more impactful), but it can be more impactful if the rising temperature results in increased wild fire and subsequently increases erosion and sediment loading. Fire, erosion, and increased sedimentation would all have significant negative effects on this objective.

Objective 1.3 – Eliminate biological impacts of water intake and discharge from coastal power and desalination plants

The vulnerability of this objective in general is comparatively moderate and limited to three of the six climate stressors. One direct impact is from warmer water, which makes the cooling water intake less practical and feasible, and therefore may present a more significant reason to terminate this practice. OA may affect the effect of brine discharge as a result of change in strength and type of chemical reactions. SLR may also have some direct impacts on shoreline power generation and desalination facilities through increasing the vulnerability of the coastal infrastructure itself. The most significant vulnerability will probably come from the impacts of drought. More severe drought may increase demand for desalination, which, in turn, could result in increased ocean water intake and would increase the scale of impingement and entrainment, thus cancelling the improvement made by ceasing of intake by coastal power plants. However, using desalination to address water shortage as a result of drought will not be done easily and any biological impacts that remain are likely to increase with additional water intake. Impacts also may be compounded based on the interaction of several climate change factors together, increasing over time, e.g. warmer water and OA.

Objective 1.4 – Eliminate all harmful discharges to Areas of Special Biological Significance (ASBS)

The vulnerability of this objective in general is comparatively moderate and limited to two of the six climate stressors. Severe drought may reduce dry-weather runoff/discharge into ASBS due to water conservation and may even increase the need to relax the discharge prohibition in order to maintain minimum stream flow needed for the health of riparian habitats. Increasing storminess may have an opposite but more impact effect on this objective than drought. The impact is moderately sensitive because most of the streams adjacent to, and discharging into the ASBS are short and highly episodic, and therefore less adaptable to extreme events.

Objective 1.5 – Institute a reliable regional funding mechanism for storm water quality improvement

Objective 1.5 addresses an institutional issue which is not directly subject to the impacts of the climate stressors and inherently has a high adaptive capacity for all stressors, as it is policy- and funding-related. However, it is still considered vulnerable due to indirect impacts from three of the six stressors. More funding, thus larger assessment fees may be required to treat, store, and infiltrate more storm water, responsive to water supply concerns under increasing drought conditions. A similar argument can be made for more funding needed to treat, store, and infiltrate more storm water under increasing storm conditions. In addition, coastal storm water infrastructure can be sensitive to SLR and require more funding to upgrade or relocate. Costs associated with adapting to the impacts of drought and storminess will likely rise in the long-term, as the exposures to these stressors are expected to increase. The exposure to SLR may not increase because it is considered more predictable and planning around it is respectively easier via, upgrading coastal facilities.

Objective 1.6 – Reduce and prevent non-storm water runoff from urban land uses

This objective addresses a relatively narrow subject, which is vulnerable primarily from the impacts of increasing drought only. Similar to Objective 1.4, severe drought may reduce dry-weather runoff and discharge due to water conservation, and may even increase the need to relax discharge regulations to maintain minimum stream flows required for the health of riparian habitats. The impact is considered not very sensitive because it deals mainly with human-controlled activities in a dry weather urban setting. Thus, the adaptive capacity of this objective is also considered high due to the potential to apply water conservation strategies and new policies for dry weather runoff.

Objective 1.7 – Eliminate nonpoint pollution from on-site wastewater disposal systems (OWDSs)

Objective 1.7 addresses on-site wastewater disposal systems (OWDS) located primarily along the coast of Malibu area. Septic systems are vulnerable to increasing storminess with the likelihood of septic failures increasing due to water seepage into systems. Large wave events associated with coastal storms may erode sand/sediment leading to functional and structural failures. The impact of SLR on septic systems of beach properties also contributes to the vulnerability of this objective, as these systems can fail to function and cause beach pollution if they are inundated by sea water. The exposure and thus the rate of failure are expected to rise in the long term. Septic systems may also be vulnerable to drought, but the impact is potentially more positive than negative, as drought may reduce water use and discharge, thus the capacity and need for maintenance.

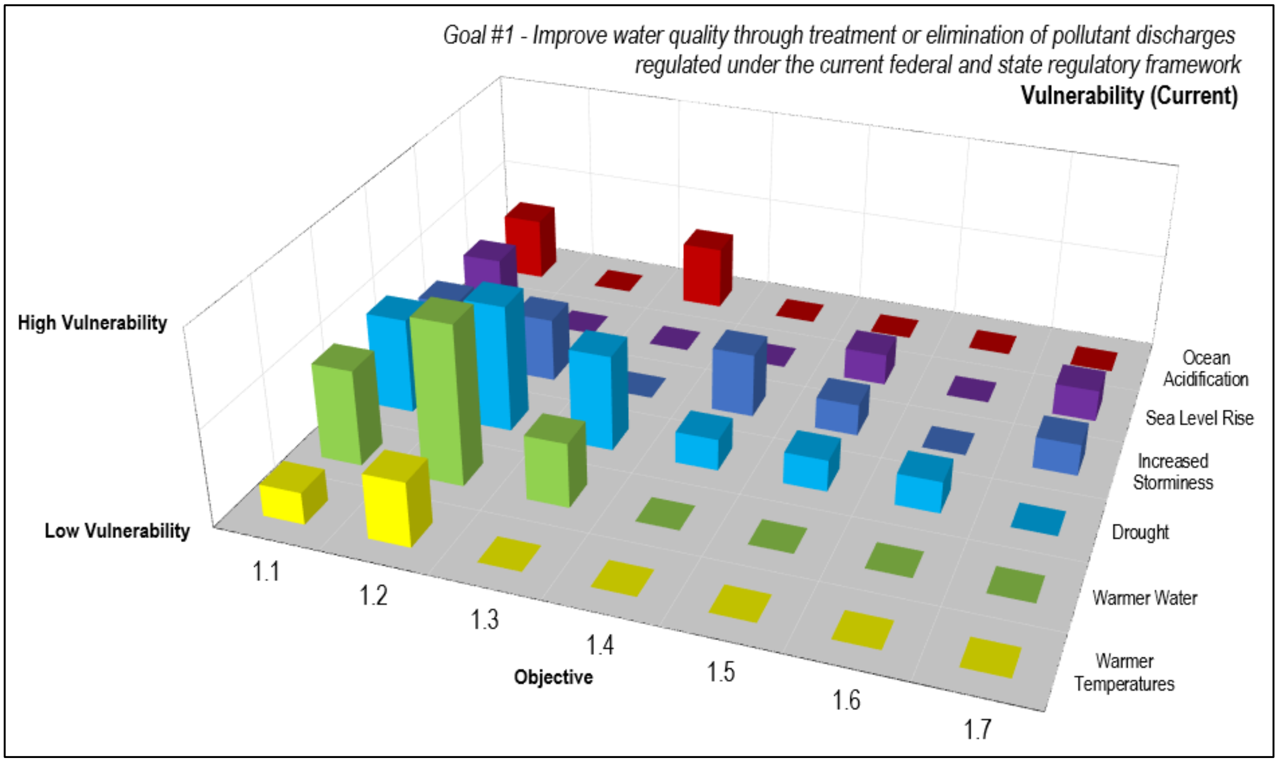


Figure 27. Goal 1 – Current Vulnerability.

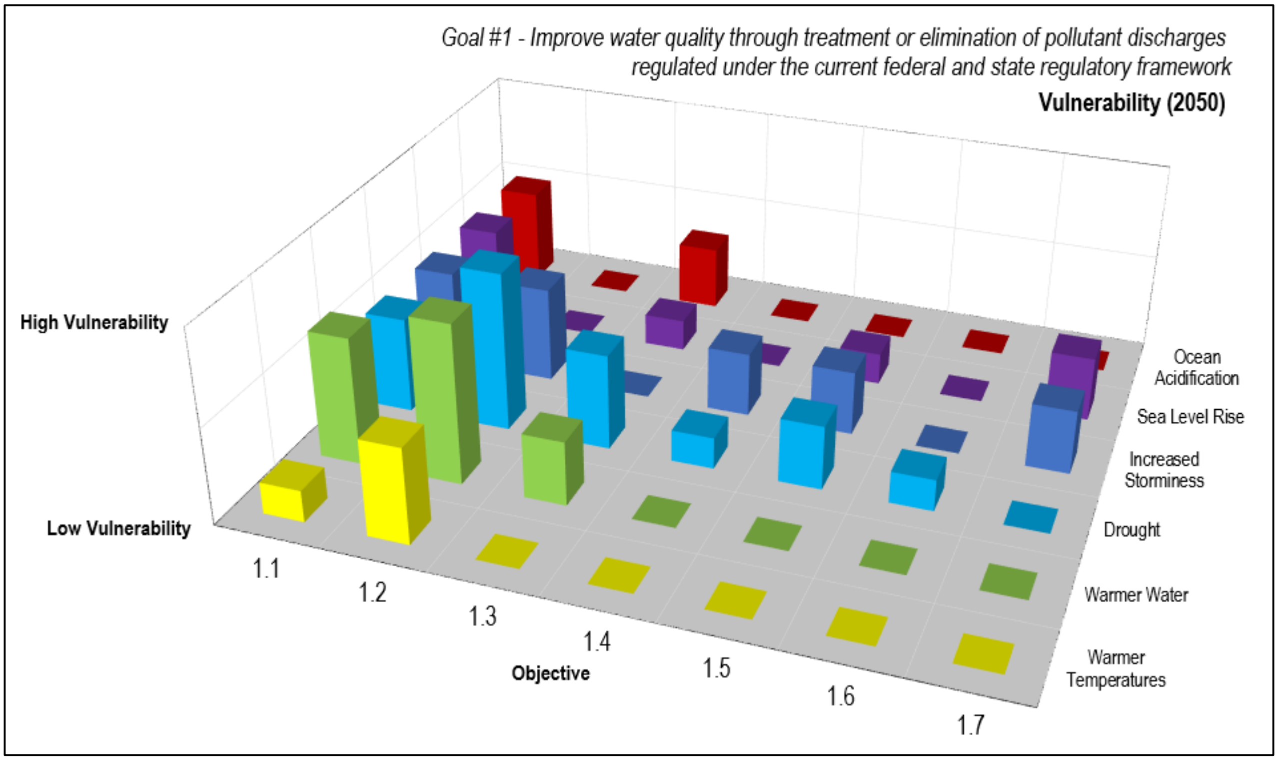


Figure 28. Goal 1 – 2050 Vulnerability.

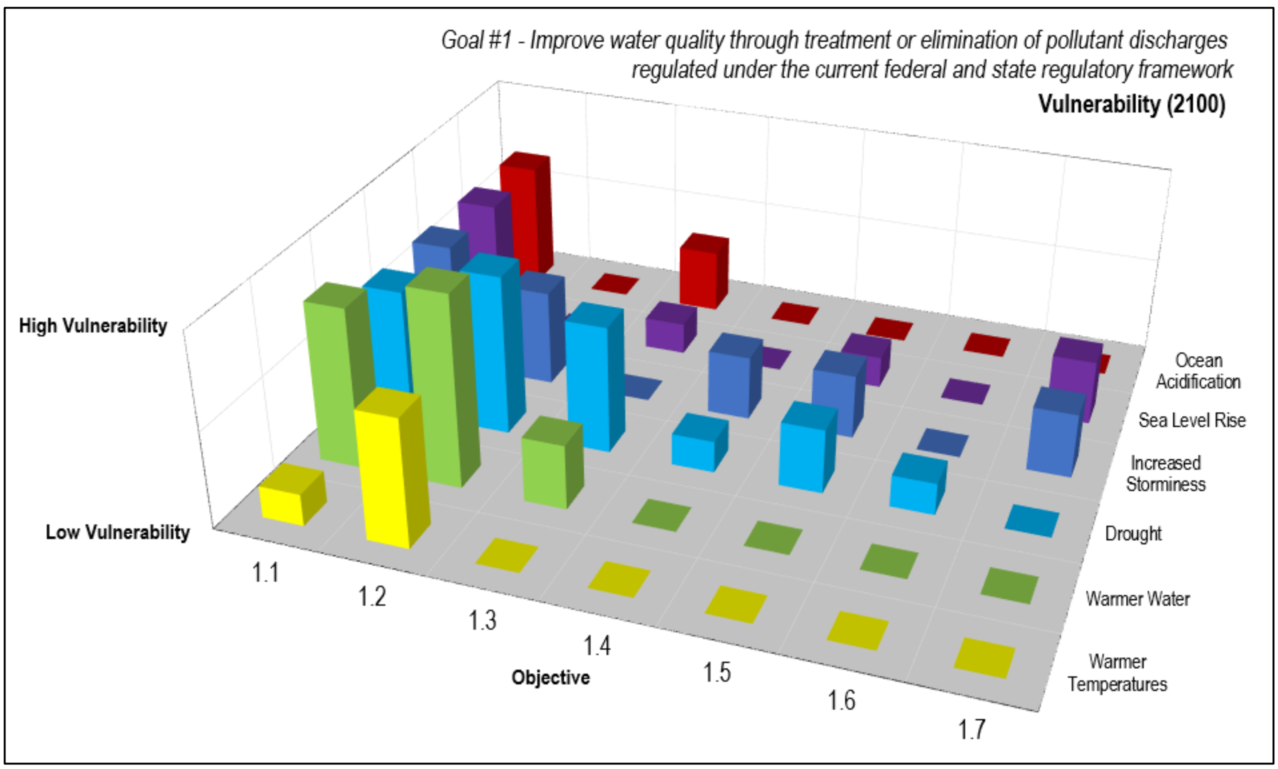


Figure 29. Goal 1 – 2100 Vulnerability.

Goal 2 – Improve water quality through pollution prevention and source control

In general, there does not seem to be any identifiable similarities or common trends among the seven objectives under this goal, primarily due to the fact that the sources of pollutants addressed in this section are highly diverse, each of which are sensitive to one or two specific climate stressors. For example, Objective 2.1 focuses on the issue of impervious surfaces in the watershed, which is more influenced by factors affecting the amount and intensity of water falling on the ground, e.g. drought and storminess. Objective 2.3 focuses on aerial deposition, for which warmer atmospheric temperature plays an important role, in addition to drought and storminess. Objective 2.5, on the other hand, deals with pollution from boating activities, which in addition to storminess is also affected by ocean-focused stressors such as SLR and OA. Objective 2.7 is unique in its inclusiveness as it is a broad-based education program objective, significantly increasing its adaptive capacity more than the other objectives. Despite the lack of a prevailing pattern or trend, drought and increased storminess appear to have more effects on objectives in this section than the other stressors. SLR and OA do not seem to induce noticeable vulnerability at present, but start to exhibit impacts in the future time horizons in the subject areas of several objectives.

Objective 2.1 – Increase pervious surfaces and storm water infiltration where feasible by supporting green infrastructure

The issue of imperviousness of land surfaces in the watershed is by commonsense more tied to factors affecting the amount and intensity of water falling on the ground, primarily drought and storminess. Increasing drought and storminess actually may provide more incentive and momentum to fund and implement green infrastructure, but if the drought becomes more and more severe, it would make storm water infiltration through increased pervious surfaces less effective and productive. Similarly increased storminess may render the increased perviousness and other green infrastructures less productive because most those measures currently work more effectively in more evenly distributed precipitations events. Rising air temperature results in higher evaporation rate and less absorption and infiltration.

Despite the potential obstacles imposed by these climate change stressors on implementation of this objective, increasing pervious surfaces and green infrastructure have been and will continue to be promoted as important components of a comprehensive adaptation strategies to alleviate the impacts of drought, storminess, and rising temperature.

Objective 2.2 – Reduce generation of trash through restricting and reducing the use of disposable plastics and polystyrene products

Plastics and polystyrene products are the most prevalent materials found in marine debris and what washes up along the coastline. Much of this is due to stormwater runoff, which picks up contaminants as it drains towards the ocean. Increased storminess is likely to magnify the amount of trash that ends up in the ocean, specifically plastic and polystyrene products. The vulnerability to increased storminess may increase over time as weather patterns change (i.e. 2050 and 2100). The potential risk is that any progress made in the reduction of trash may be countered by the higher chance of trash entering local waterways. Source control of plastics and polystyrene products can increase adaptive capacity. As indicated in the vulnerability graph for year 2100, SLR may also impact Objective 2.2., as amenities along the coast (i.e. trash receptacles, stormwater trash capture devices, storm drain diversions) may not be adequate to capture litter when rain events co-occur with storm surges of the progression of SLR.

Objective 2.3 – Reduce aerial deposition of storm water pollutants to the Bay and the Bay Watershed

Because the subject issue of this objective is atmospheric, the two climate stressors more related to the atmosphere, warmer temperatures and drought (which results in more sunny days) are predicted to have the greatest impacts. Higher air temperature and more sunshine may exasperate air pollution and result in more aerial deposition. Meanwhile, in light of significant progress made over the past several decades in improving air quality, additional, more stringent measures to further improve air quality may become harder and harder to develop and implement, reducing the efficacy of further measures to limit the synergistic impacts of air pollution/air deposition induced by climate change. A secondary effect may occur from increased storminess if emissions are not controlled, through increased runoff and associated pollutant input to the Bay's waterbodies.

Objective 2.4 – Reduce pollution from commercial and recreational boating activities

Pollutants of concern from boating activities include used oil, vessel sewage, trash, metals leaching from boat hull treatments (i.e. copper, zinc), aquatic invasive species, and household hazardous waste. Environmental amenities for the proper disposal of used oil, sewage, trash, and household hazardous waste (HHW) may be impacted by increased storminess and SLR if they are inadequately protected from these climate stressors. Warmer waters may lead to increased toxicity of pollutants, increased bacteria and algal growth, less dissolved oxygen, and greater survival or transmission of parasites and bacteria. This could counter efforts to reduce bacteria levels in the water from illegal discharge of boat sewage. New maintenance strategies may be needed for several of the climate change stressors before storm events to prevent accidental spills, such as increased frequency for emptying used oil and household hazardous waste collection drums, securing pumpout stations, and more vigilant maintenance of sewage plumbing in marinas.

At a later exposure date, drought may have an impact on Objective 2.4, as infrequent rain events may cause the accumulation of pollutants such as oil and trash on impermeable surfaces, which are washed into waterways during the "first flush" of a storm. OA may increase the rate at which zinc anodes on a boat degrade and copper leaches from bottom hull paints, both of which can have severe adverse impacts on aquatic life. With all of these stressors, Objective 2.4 may become more vulnerable over time as stressors are expected to build in intensity.

Objective 2.5 – Reduce discharge of trash, oil and grease, and other pollutants from commercial and other high density areas control and prevention

When managed improperly, trash, oil, grease, and other pollutants end up in the storm drain systems, contaminating billions of gallons of untreated runoff that ends up in Santa Monica Bay each year. Objective 2.5 is most vulnerable to increased storminess of all the stressors. With increased storminess, the amount of pollutants in stormwater may rise due to increased frequencies of rain events and higher volumes of water (associated with increased precipitation rates per precipitation event). In either scenario current infrastructure may experience reductions in efficacy to capture pollutants from storm water flows. On a lessor vulnerability level, drought conditions could allow more time for pollutants such as trash, oil, and grease to accumulate on impervious surfaces, soil, and vegetation, which would be transferred into waterways during a "first flush". Warmer temperatures may draw more visitors to commercial areas, such as restaurants, along the coast where temperatures would be cooler. Thus, efforts to reduce discharge of trash, oil and grease and other pollutants could be countered by the increased number of people frequenting these areas. An increase in exposure to all three stressors (warmer temperatures, drought, and increased storminess) will likely increase the vulnerability of this objective over time.

Objective 2.6 – Sustain and expand annual Coastal Cleanup

Overall, because it deals with an organized non-capital activity, Objective 2.6 is only moderately sensitive to a couple climate stressors that may affect accumulation of trash on beaches and other coastal areas, and its associated movement through the watershed during storm events. Drought may provide more time to allow trash to build up in the watershed, and increased storminess may magnify the amount of trash that ends up in the ocean and washed up to beaches. Additionally, SLR could potentially change the location and distribution of trash along the coastline. This objective is considered highly adaptable, as expanding coastal cleanup should relatively easy to implement and can be altered accordingly. The last climate change stressor that has the potential to slightly increase the vulnerability of this objective is warmer temperatures. Increasing heat (depending on the severity) may restrict public participation or encourage it, depending on the specific conditions.

Objective 2.7 – Increase public awareness through Public Involvement and Education program

This objective is a catch-all because it is an education program that can touch on any subject covered in the BRP; however, the program could easily include requirements for adaptability to climate change stressors in the request for proposals. Educational programs are not sensitive to climate change stressors, and the exposure is relatively meaningless. This objective is considered highly adaptable and easily updated or modified to accommodate any climate change stressors. This objective received the lowest overall vulnerability scores for all climate change stressors compared to all evaluated objectives in the BRP. In fact, this program could be shifted slightly in scope to actually target projects that increase adaptability to specific climate change stressors.

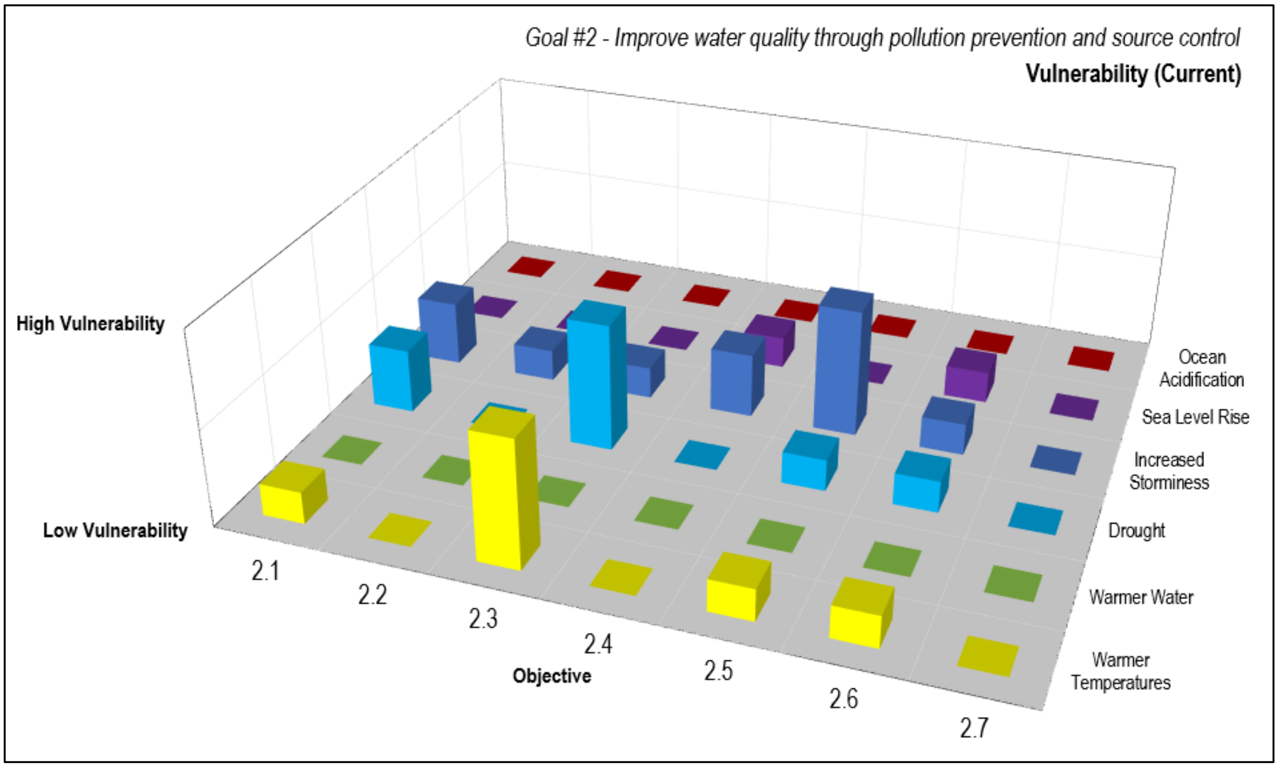


Figure 30. Goal 2 – Current Vulnerability.

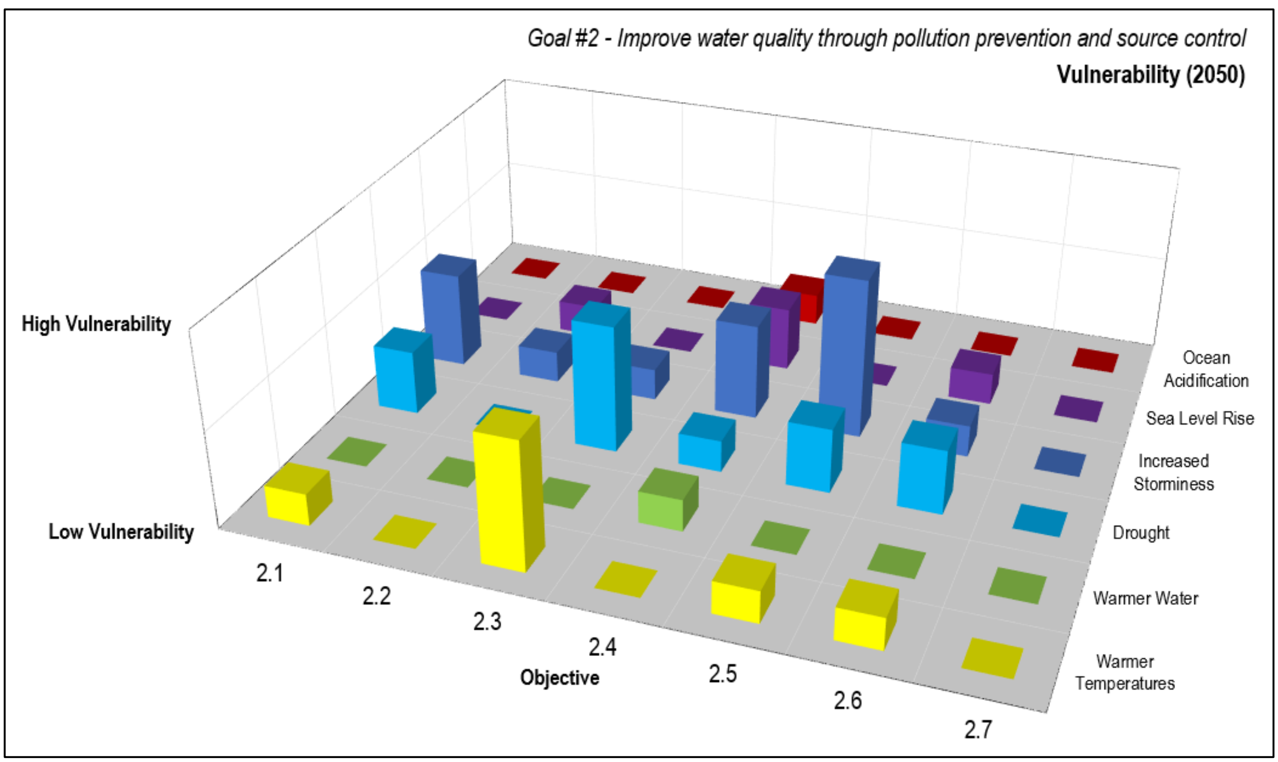


Figure 31. Goal 2 – 2050 Vulnerability.

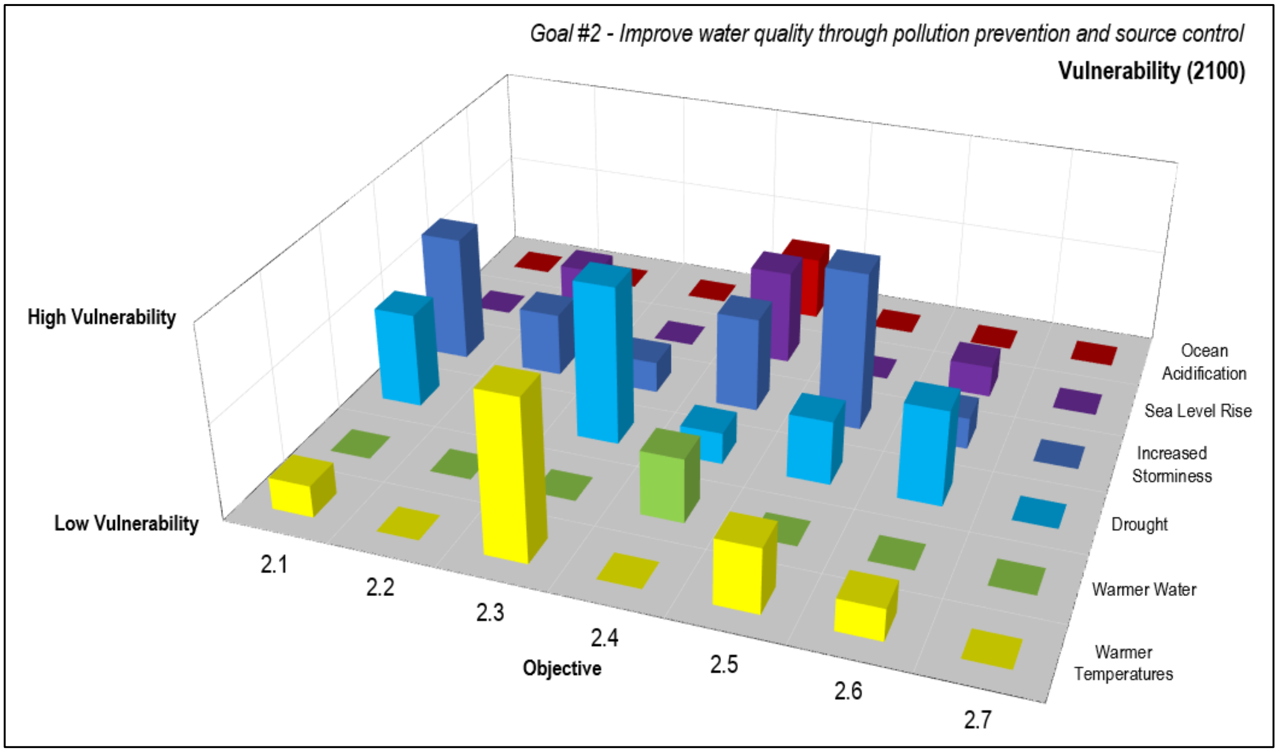


Figure 32. Goal 2 – 2100 Vulnerability.

Goal 3 – Address potential impacts of emerging contaminants

This goal focuses specifically on the issue of emerging contaminants. The list of emerging contaminants is very long, diverse, and continues to expand as research continues. For this goal, there are many unknowns, which makes predictions on the degree of climate change impacts more challenging. On the other hand, partly because of the uncertainty and complexity, the two objectives in this section address the issue only in relatively general terms and focus on institutional measures such as monitoring, education, and legislation. Amid this background, general assessment of the climate change impacts were made and found that loading and effects of emerging contaminants may be influenced by warmer water, drought, storminess, and OA. Warmer water and OA primarily affect the chemical properties (e.g. toxicity) of certain contaminants, while drought and storminess mainly affect the treatment capability of POTWs. Drought in particular can be troublesome because it will likely result in more concentrated contaminants, which are difficult to manage.

Objective 3.1 – Institutionalize monitoring of emerging contaminants

The focus of this objective is monitoring of emerging contaminants, which may need to be adjusted in sampling location and time, frequency, or methodology in response to changes in the chemical property, loading, and the extent of receiving water impacts. For example, drought and consequently the reduction in water use and increased water recycling may result in more concentrated discharge with more concentrated contaminants of concern, although this should not affect the ability of monitoring these contaminants except for the potential to have more frequent monitoring implemented. Alternatively, it may make the monitoring easier due to higher detection limits. Increased storminess may change the concentration, loading, and the extent of the storm water dispersion zone; warmer water and OA may change in strength and type of chemical reactions; and monitoring methodologies and protocols may need to be adjusted accordingly. The effects and impacts of OA are largely unknown. The adaptive capacity of this objective is high because monitoring is generally considered easy to adjust.

Objective 3.2 – Reduce loading of emerging contaminants in waterways

Loading and adverse ecological effects of emerging contaminants may be influenced by warmer water, drought, storminess, and OA. Drought and consequently the reduction in water use and increased water recycling may result in more concentrated discharge with more concentrated contaminants of concern. Increased storminess may change the concentration, loading, and the extent of the storm water dispersion zone. Warmer water and OA may change in strength and type of chemical reactions. Additionally, contaminant loading may be significantly affected by the combination of increased drought and increased storminess, altering loading patterns for many contaminants during the wet season, especially as they are related to the "first flush" of stormwater.

Addressing emerging contaminants could be challenging even just through regulations, and without taking into account of the climate change impacts. Due to the complexity and the lack of understanding on the issue, enacting regulations to control emerging contaminants is more difficult and takes longer time than developing TMDLs. Achieving reduction and elimination of the identified contaminants could be even more challenging given the multiple types, diverse sources, and wide distributions of those contaminants.

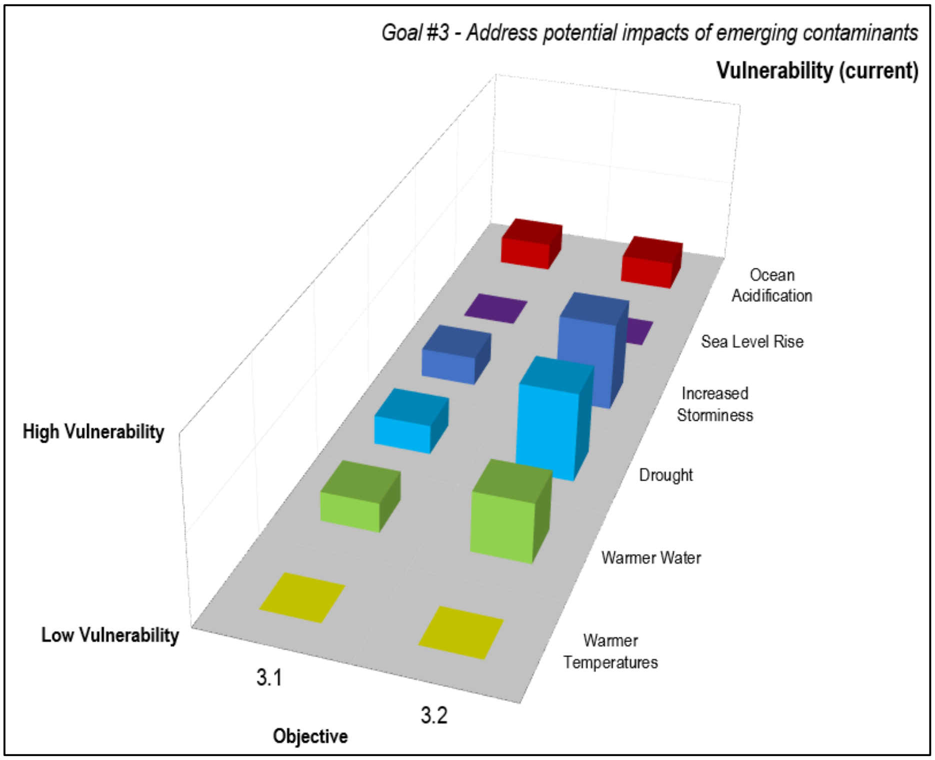


Figure 33. Goal 3 – Current Vulnerability.

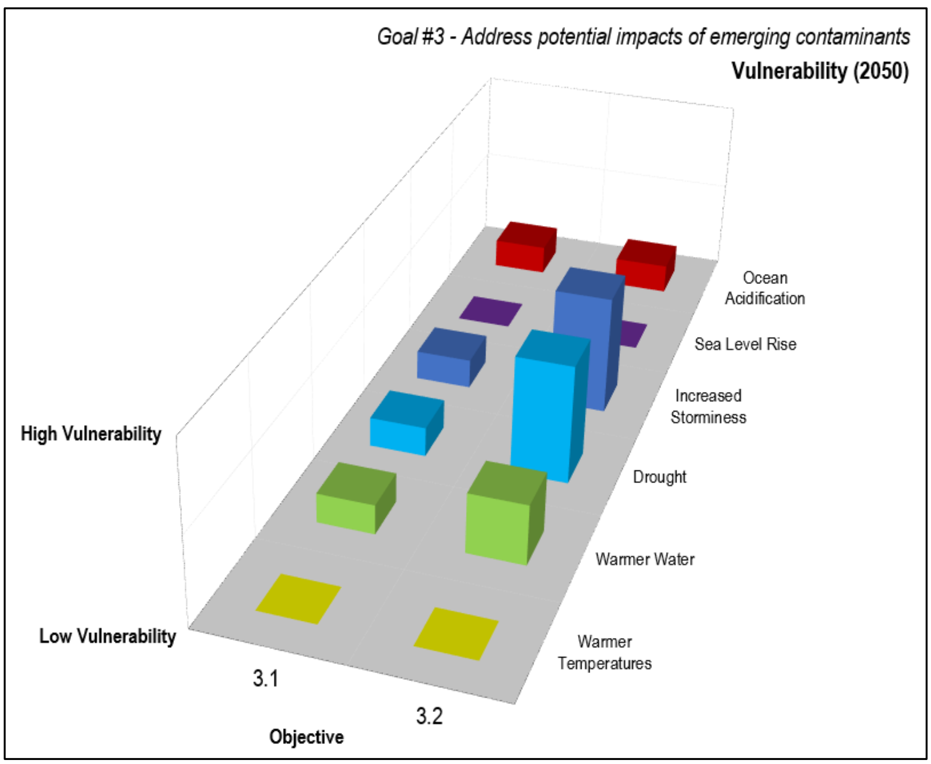


Figure 34. Goal 3 – 2050 Vulnerability.

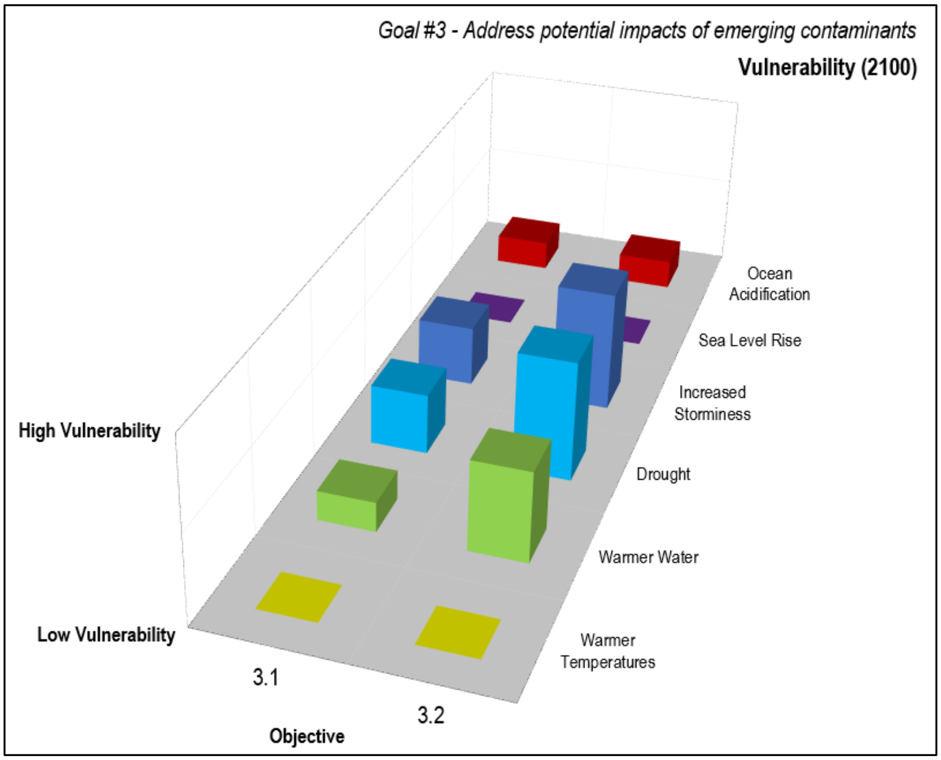


Figure 35. Goal 3 – 2100 Vulnerability.

Goal 4 – Create / support policies and programs to protect natural resources

Goal 4 primarily relates to the creation and support of policies to support the protection of natural resources. The specific objectives vary from stream protection (4.1), to marine programs (4.2 – 4.4), to water quality and watershed-based programs (4.6) to very broad-based objectives that incorporate Bay-wide monitoring (4.5 and 4.7). Trends for this goal vary by objective, but all have some vulnerability to warmer waters, increasing over time. The marine objectives are also vulnerable to OA. In general, objectives within this goal are fairly adaptable and have high rankings for adaptive capacity.

Objective 4.1 – Facilitate development and adoption of natural stream protection ordinances and/or policies

Objective 4.1 should be considered primarily vulnerable to warmer water and increasing drought, of secondary concern are warmer temperatures and increased storminess. These vulnerabilities may increase the difficulty and/or requirements of potential stream protection ordinances and the difficulty of achieving protection for these habitats.

Warmer water is detrimental to the biotic community adapted to cooler water temperatures and high dissolved oxygen levels. Biological communities exposed to these changes may have difficulty surviving due to thermal stress and low dissolved oxygen. Increased drought may result in lower stream flows and increase the duration of dry conditions for numerous ephemeral systems. Persistent periods of low water may also negatively impact flora and fauna that depend on these habitats. With the loss of this vegetation, shading may be reduced allowing for warmer temperatures to more directly elevate the stream temperature, furthering the potential of low dissolved oxygen. Less vegetation on the banks may also cause bank instability leading to an excess amount of sediment in the stream.

Increasing storminess may provide fewer yet more intense precipitation events and drought may intensify the stress on these systems. These storms will likely produce steep hydrographs coupled with persistent xeric conditions resulting from drought, leading to further erosion/bank destabilization and loss of vegetation. If these predicted changes intensify over time the impacts to the natural streams could be significant and exposure may increase over time. This vulnerability underlies the importance for meaningful policies to protect and restore these streams to increase their adaptive capacity.

Even though the habitats described in this objective are vulnerable, the adaptive capacity for this objective is high, due to its focus on policy. Climate change should be incorporated into all future stream policies.

Objective 4.2 – Enhance assessment and effective management of Marine Protected Areas in the Bay

Marine Protected Areas (MPAs) in Santa Monica Bay were established in 2012. A five year period of baseline data characterization has recently been concluded. Data on the biological condition of these MPAs and their impact on fishing, research, education and recreation were to be quantified for the past five years. Trends from these data are expected to inform an adaptive management platform (to be developed) to ensure that the intended benefits of the MPAs will manifest in a reasonable timeframe.

Currently these MPAs are clustered off the two main rocky headlands that border Santa Monica Bay. They contain a diversity of habitats including rocky reefs, kelp forests, soft bottoms, deep offshore prominences, marine canyons, nearshore pelagic and pelagic. Thus many of the stressors associated with Goal 9 and Goal 10 are relevant. Increase storminess, warmer waters, OA, and SLR are the principle stressors of concern. Impacts from these stressors, which are discussed in more detail under Goal 9 and 10, may singly or cumulatively reduce the resilience and sustainability of the habitats protected by these MPAs. This, in turn, impacts the associated benefits of increased education and research and a diversified coastal economy.

However, this objective does have a high adaptive capacity regarding altering effective management to incorporate the stressors, except for warmer waters and OA (medium ranking), because there is really no way to effectively alter management to adapt to those stressors. Further research to inform management as to the condition and performance of these MPAs should be a high priority with considerable attention paid to both biological and socioeconomic factors.

Objective 4.3 – Evaluate and establish additional management measures to improve protection of fishery resources

The direct and indirect responses of the biological communities that migrate through or are resident to Santa Monica Bay will be most profoundly impacted by warmer water, OA and increasing storminess. If current patterns of poleward migration of marine species continue, many of the recreational and commercially targeted species may become rarer over time, being replaced by functional equivalents from warmer water adapted species to the south. This scenario warrants two approaches; 1) the preservation of existing species assemblages so that they retain high adaptive potential to migrate and reestablish themselves northward and 2) development of fishery management plans for species assemblages soon to establish themselves in our project area. Monitoring, research, and restoration are all potentially adaptable approaches to the evaluation of fishery management strategies.

Objective 4.3 may also be vulnerable to warmer temperatures, because some fisheries include species that are intertidal or include an intertidal component of their life cycle. Additionally, OA may increase the vulnerability of fish nurseries (e.g. larval stages of fish or invertebrate species).

Objective 4.4 – Promote and create programs to increase the supply of healthy local sustainable seafood

The vulnerability to predicted climate change stressors associated with this objective are warmer waters, increased storminess, and OA. The bulk of fishing pressure from commercial and recreational sectors targeting Santa Monica Bay focus on rocky reef and near shore pelagic and pelagic species assemblages. The sensitivity to a given stressor will vary depending upon the preferred habitat and distribution of the target species, the capacity or fishery infrastructure and fishery management. This objective also requires that seafood or algae be safe for human consumption, e.g. no public health concerns due to mercury, PCB, DDTs, or other contaminants. Thus, this objective is directly tied to Objectives 11.3, 11.4, and 11.5. Objective 4.4 is not vulnerable to SLR or warmer temperatures.

Sustainability should focus on the status of the stock to ensure that it isn't being over exploited and that stock remains resilient to climate change stressors. Warmer water and OA could significantly disrupt the ecological structure and function of the remaining populations. Another concern is to enable the marketability and necessary infrastructure for the fishery to remain functional and sustainable itself through investment in vessels, processors, storage and distribution. In our project area, shore-based infrastructure is not considered highly vulnerable to warmer water, SLR, OA, or increased storminess at present time, vulnerability of coastal infrastructure may increase over time. Additionally, future infrastructure and investments should be designed and installed with these stressors in mind.

Objective 4.5 – Evaluate and address potential impacts of climate change on Santa Monica Bay

The potential impacts of climate change on Santa Monica Bay are currently being evaluated via this CCVA. Because this objective states that it directly addresses impacts of climate change, it is inherently highly adaptable across most climate change stressors. SLR, OA, and increasing storminess are ranked as 'medium' for adaptive capacity due to their broad and multi-faceted significant impacts ranging across many habitat types. These three would require significantly more effort to 'address' at a Bay-wide scale.

The next step in the process is to determine what maybe done on a local scale to diminish the relative strength or increase the adaptive capacity of any goal or objective being impacted by a single or suite of associated climate change stressors. As many of these stressors are driven by global scale phenomena, addressing them via local solutions maybe limited, with little or no opportunity for source control or means to limit the signal strength of a given stressor. Overall Objective 4.5 is ranked highly vulnerable as it encompasses all climate change stressors and in many cases responses will be limited in their effectiveness especially if the stressors increase, (over time) in intensity, frequency and scale.

Objective 4.6 – Facilitate and coordinate water quality improvement and habitat restoration programs in key subwatersheds

Water quality improvement and habitat restoration are the core of the BRP. Current integrated management at the watershed level to reduce pollutant loading and increase infiltration rates is in the early stages of implementation. Multi-benefit approaches to these infrastructure projects increase greenspace, provide habitat for wildlife, and improve public health via recreational opportunities. Broad implementation could be very challenging as estimates for the construction of various projects throughout the watershed exceed 10 billion dollars. Increasing drought, increasing storminess, warmer water and SLR are considered the most impactful to this objective. Construction plans, plant pallets, water volumes and changes in water chemistry resulting from these stressors are likely to change due to increased frequency, strength and duration of any stressor(s) impacting the surface waters of key subwatersheds in our project area. Additionally, these stressors will particularly increase the vulnerability of coastal habitats such as beaches, wetlands, and intertidal habitats such as tide pools.

Increasing drought is shown in this analysis as increasing the vulnerability of this objective and should be notable in our considerations to achieve this objective. Generally, projects conceived to promote better water quality and improve habitat should be inherently adaptive and informed by appropriate monitoring to ensure that program values are being met and maintained over the coming decades. Coordination leads to the ranking of 'high' adaptive capacity across the board for this objective.

Objective 4.7 – Implement a Comprehensive Bay Monitoring Program

The implementation of a Comprehensive Bay Monitoring Program was considered to be only moderately impacted by climate change stressors. Inherently within this objective is a high adaptive capacity for all climate change stressors, due to the ability to alter a monitoring plan, sampling design, and specific protocols or methods to accommodate climate change-driven factors such as alterations to species ranges, and changes in water quality constituent detections.

The most direct impacts are likely to be physical or chemical damage caused by increasing storminess and OA of vulnerable monitoring arrays and their associated sensors. The costs of maintenance and replacement of these devices can easily exceed the modest budgets available to SMBNEP and its partner organizations. Frequent disruption to timely and effective deployment, recovery and maintenance of the aforementioned monitoring equipment may also result from increasing storminess. In essence rough seas will limit the opportunities for teams to access the equipment by boat leading to malfunction and data gaps which will directly impact the efficacy, accuracy and applicability of the monitoring plan.

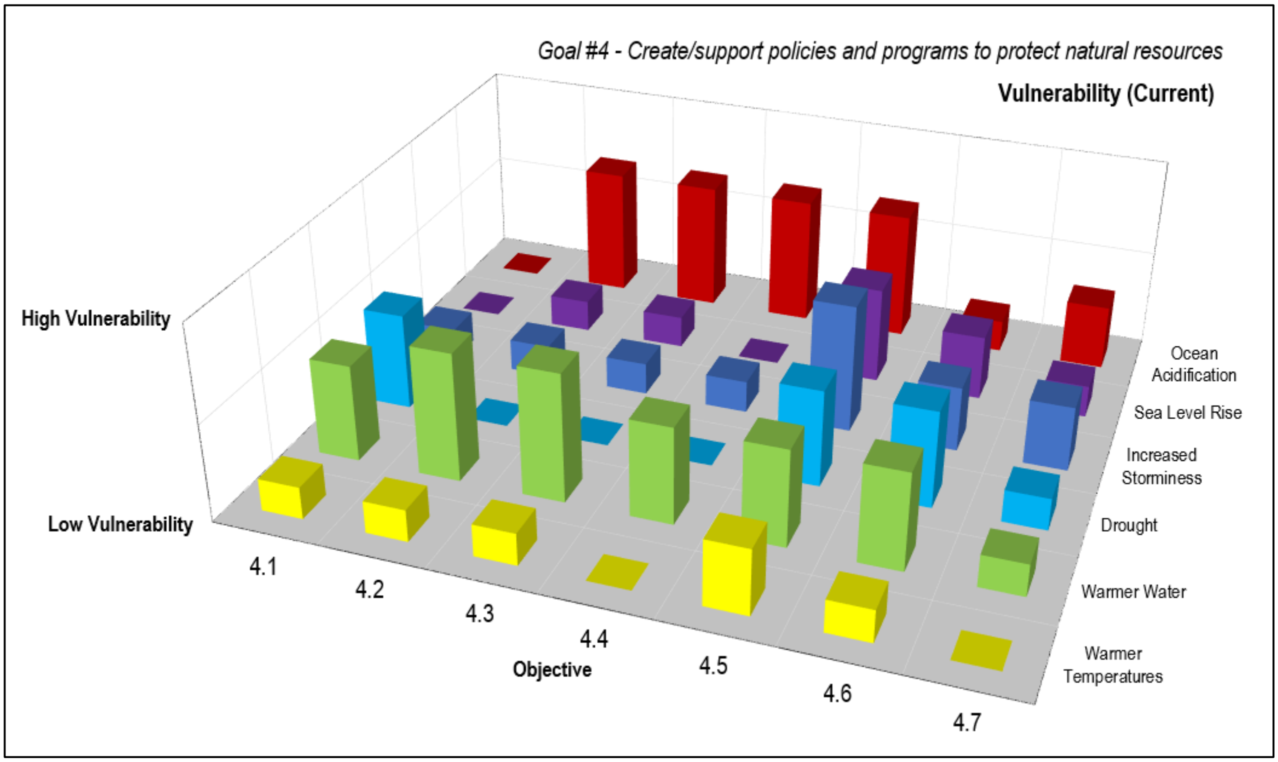


Figure 36. Goal 4 – Current Vulnerability.

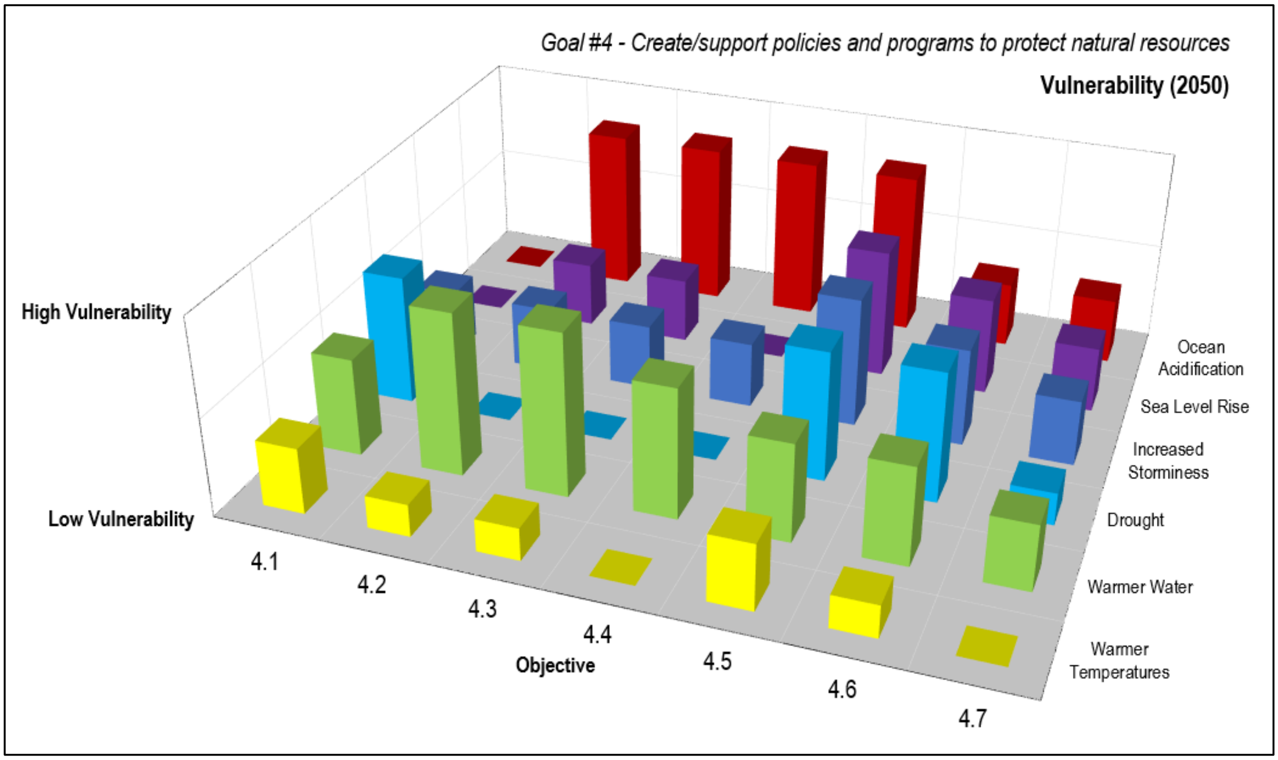


Figure 37. Goal 4 – 2050 Vulnerability.

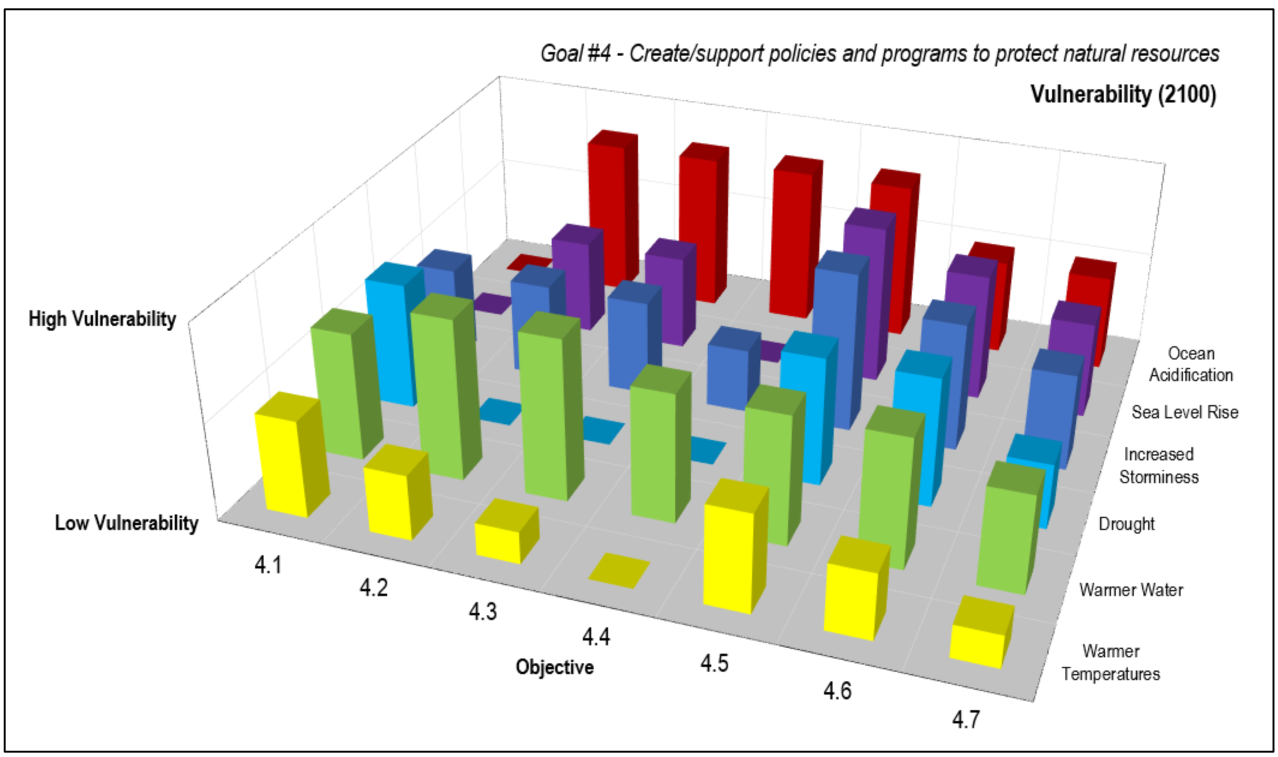


Figure 38. Goal 4 – 2100 Vulnerability.

Goal 5 – Acquire land for preservation of habitat and ecological services

Goal 5 is primarily related to land acquisition and preservation, thus the climate change stressors of OA and SLR do not really affect the vulnerability of this BRP goal. Conversely, drought makes both objectives in this goal more vulnerable to climate change due to the possibility of wildfires and associated landslides or erosion. Similarly, storminess may increase the vulnerability of both Objectives, but primarily 5.2, due to storm surge or flooding. There is an associated increase in the vulnerability for several of the climate change stressors over time, notably both drought and storminess due to increased exposure and intensity. Overall, Objective 5.2 is vulnerable to more stressors than Objective 5.1. Both objectives have an inherently high adaptive capacity for the climate change stressors due to their focus on acquisition.

Objective 5.1 – Acquire 2000 acres of priority open space in the Santa Monica Mountains

Drought, and to a lesser extent, storminess, are the only two stressors in the current vulnerability graph that indicate Objective 5.1 may be vulnerable to climate change impacts. All stressors have a high adaptive capacity as priority acquisitions can be modified easily to accommodate climate change stressors. By 2050 and 2100, both drought and storminess indicate high vulnerability, primarily due to an increase in exposure and intensity over time. Drought has a high sensitivity ranking for both objectives.

Increased vulnerability may occur based on risks of fire or landslides and erosion. Warmer temperatures, warmer waters, SLR, and OA do not really factor into the analyses for Objective 5.1. These stressors all have a fairly high adaptive capacity because they do not significantly affect the ability to acquire open space in the mountains – acquisition is policy-based or opportunistic and is highly adaptable. Lastly, OA clearly does not have any effect on land-based objectives.

Objective 5.2 – Acquire priority parcels in urbanized areas of the watershed

The results for Objective 5.2 are very similar to Objective 5.1, with the added caveat that this objective focuses on acquiring parcels in urbanized areas that presumably may have lower infiltration rates, more impervious surfaces, and higher densities of residents and infrastructure. Drought continues to be the primary climate change stressor increasing the vulnerability of this objective, similar to Objective 5.1, while increased storminess exhibits an even higher vulnerability. Storminess may play more of a role in vulnerability for this objective due to runoff and increased potential for flooding in urbanized areas with low infiltration. Both drought and storminess increase in exposure over time.

Similarly to Objective 5.1, all of the stressors have high adaptive capacity due to the nature of this objective in acquisition and policy. Differences may also be due to the fact that Objective 5.2 could also include parcels of land that are coastal and contain various types of infrastructure that may be impacted with rising sea levels over time.

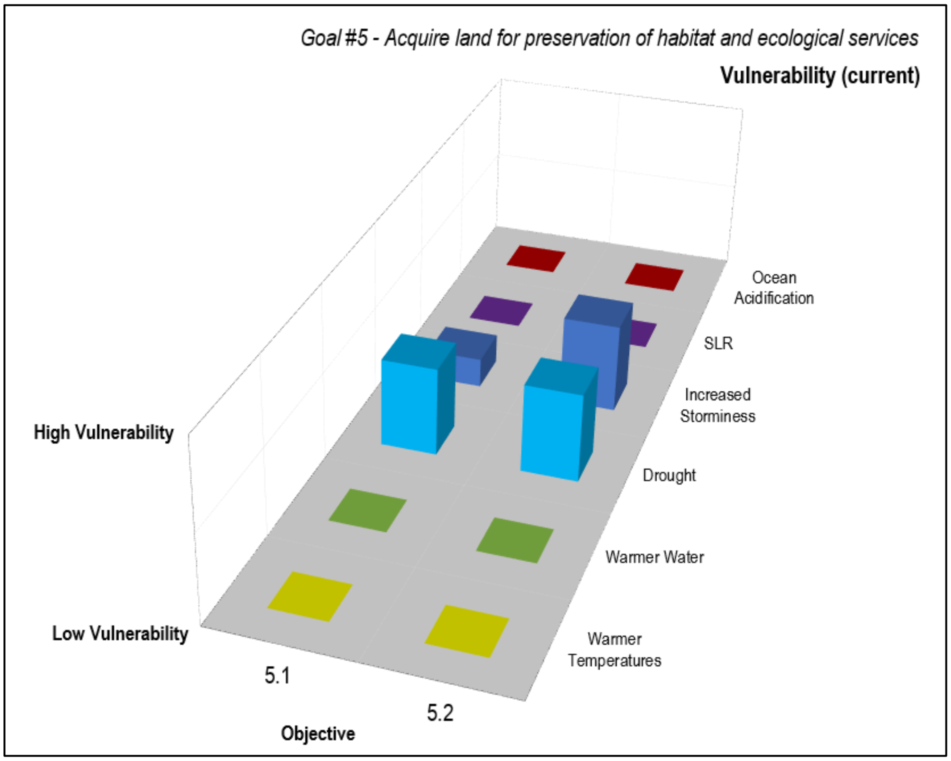


Figure 39. Goal 5 – Current Vulnerability.

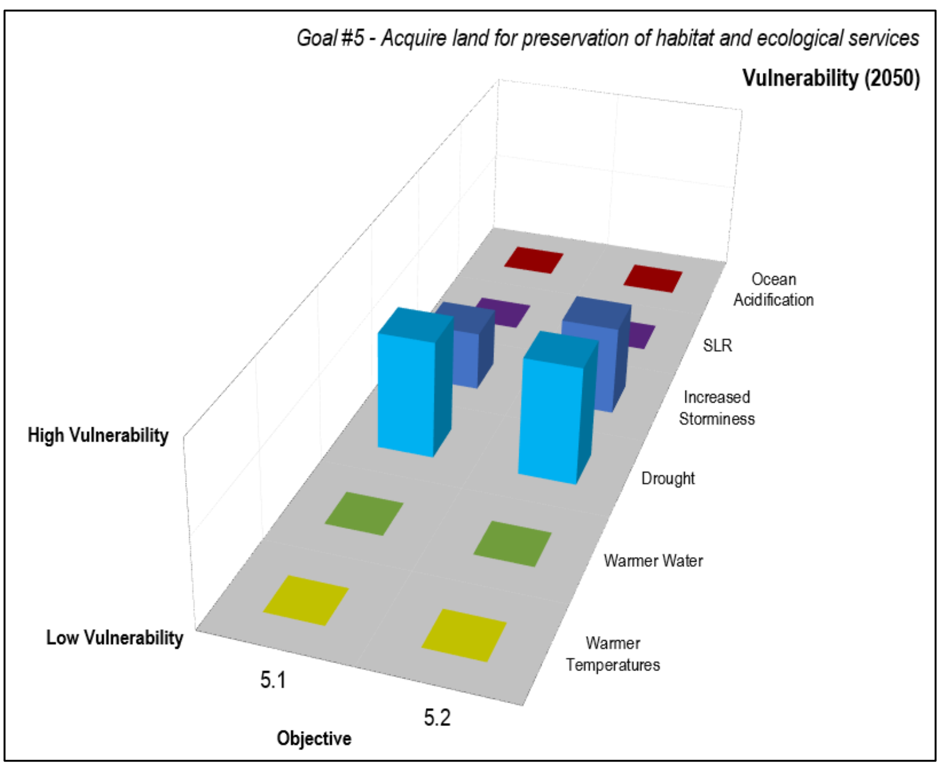


Figure 40. Goal 5 – 2050 Vulnerability.

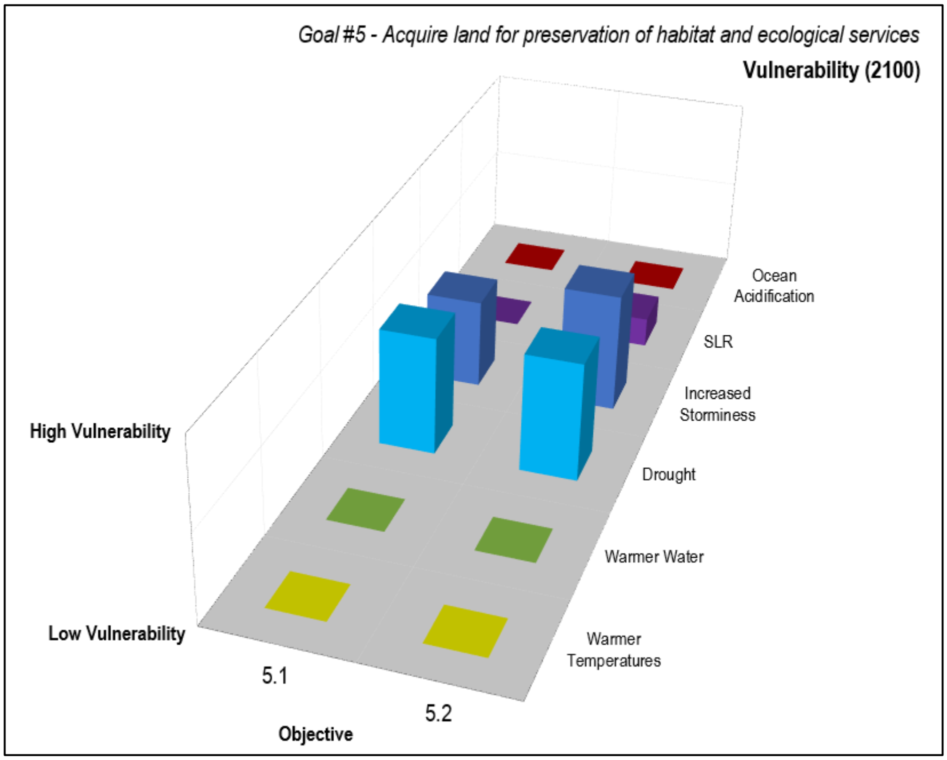


Figure 41. Goal 5 – 2100 Vulnerability.

Goal 6 – Manage invasive species

Goal 6 has five objectives that range in scope from invasive species removal programs to outreach and education, to policy objectives regarding invasive species such as preventing the importation and sale of invasive plants. Objective 6.4 (preventing sale of invasive species) has the least overall vulnerability, the least vulnerability over time, and the fewest climate change stressors that increase its vulnerability. The other objectives are primarily vulnerable to warmer temperatures and warmer waters, in part due to temperature driven redistributions of species ranges, and the increased potential for species invasions in stressed habitats. Drought, storminess, and OA may each play a role in increasing the vulnerability of several of the objectives as well. Migration patterns of various native and non-native species may be affected, and altered water input to various systems (including through increases in drought or storminess) may also impact native species and increase the likelihood of non-native species invasions.

Objective 6.1 – Achieve 303d listing for aquatic invasive species

Objective 6.1 primarily addresses aquatic invasive species in streams in the Santa Monica Mountains, such as the New Zealand mudsnail and crayfish. Thus, this objective is vulnerable, to some extent, to all of the climate change stressors other than SLR and OA. Increasing drought and storminess play a strong role, as both stressors impact the hydrology of the stream system. There is a certain amount of uncertainty in both, and the impacts to the objective will likely also be species-specific. Warmer waters may cause water quality issues such as eutrophication, lowered dissolved oxygen, and alterations of species ranges or migration patterns. Depending on the species, some may survive warmer overall conditions better than natives, increasing their invasion spatially and temporally. This objective has a high adaptive capacity for all stressors, with OA as largely unknown.

Objective 6.2 – Coordinate and fund public education and outreach on invasive species

Objective 6.2 is vulnerable to similar climate change stressors as Objective 6.1, but to a much lesser extent. Outreach and education have a high adaptive capacity for many of the stressors, due to the ability to modify outreach and education activities to incorporate new information, data, and species. The vulnerability of this objective does not substantially change over time and is fairly low across all stressors. OA is largely an unknown factor and has the potential to causes species shifts. Additionally, this climate change stressor is more difficult to translate to the public, both through an understanding of the processes and impacts.

Objective 6.3 – Develop and adopt a plan and policies for invasive species control and prevention

Objective 6.3 is directly tied to invasive species planning and control. As a policy and planning focused objective, a high level of adaptive capacity is inherently associated with this objective. Incorporating climate change stressors into future plans and policies will increase adaptive capacity and potentially lower overall vulnerability. Warmer temperatures, warmer waters, drought, and increased storminess may increase the challenges related to controlling and preventing invasive species. Invasive species can be sensitive to these stressors, as warmer temperatures and warmer waters may cause new invasive species to appear. Additionally, drought may stress native vegetation allowing room for opportunistic invasive species and increased storminess may transport invasive species presenting challenges for control and prevention.

Objective 6.4 – Prevent importation and sale of known invasive species

Objective 6.4 is the least vulnerable of the Goal 6 objectives to climate change stressors, and had a ranking of high adaptive capacity for all of the stressors. The sensitivity for this objective to all of the stressors was low, except for storminess, which was ranked as medium. Overall, the vulnerability of this objective is low because it deals with the prevention of import and sale of invasive species, which is considered relatively easy to implement and not very sensitive to the influence of climate change stressors.

Objective 6.5 – Fund and conduct invasive species removal programs and projects

The vulnerability associated with Objective 6.5 is very similar in pattern to Objective 6.1. As Objective 6.5 is more broadly stated, several of the climate change stressors may have a slight increase in vulnerability due to a broader suite of habitats included in this objective, e.g. OA within oceanic habitats. Removal of invasive species can be very difficult, and may be exacerbated by various climate change stressors. For aquatic species, warmer waters, drought, and storminess will all play a significant role. For intertidal or oceanic aquatic species, OA may play a significant role. Warmer air temperatures may affect migrations or species ranges, and invasive vegetation may be altered by many of the stressors, including drought, storminess, and warmer waters. Unknowns and data gaps may make adopting plans and policies for dealing with invasive species difficult, e.g. OA.

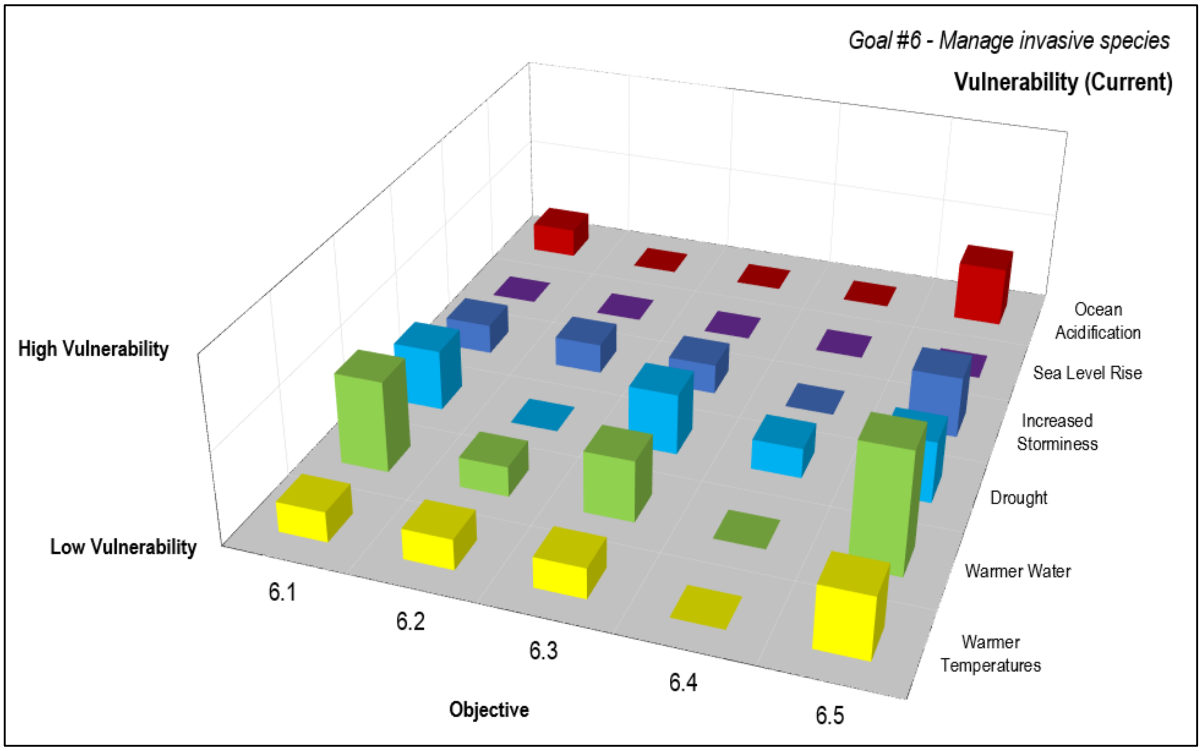


Figure 42. Goal 6 – Current Vulnerability.

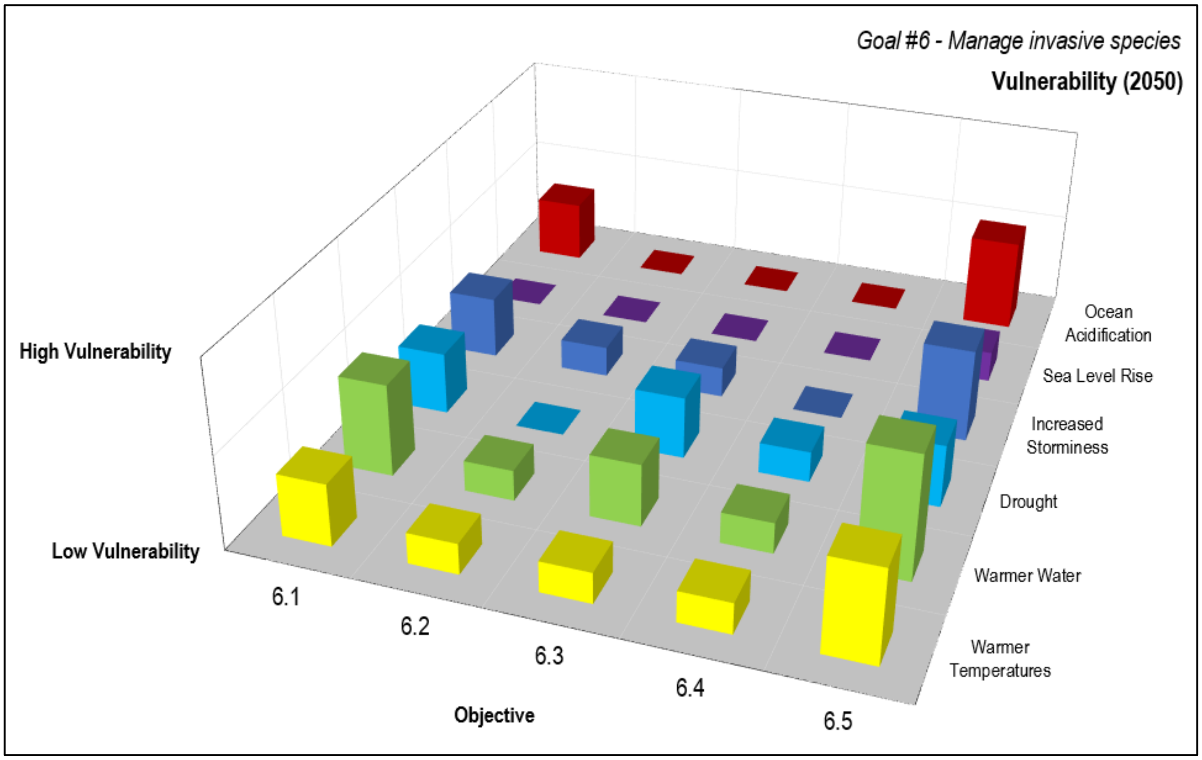


Figure 43. Goal 6 – 2050 Vulnerability.

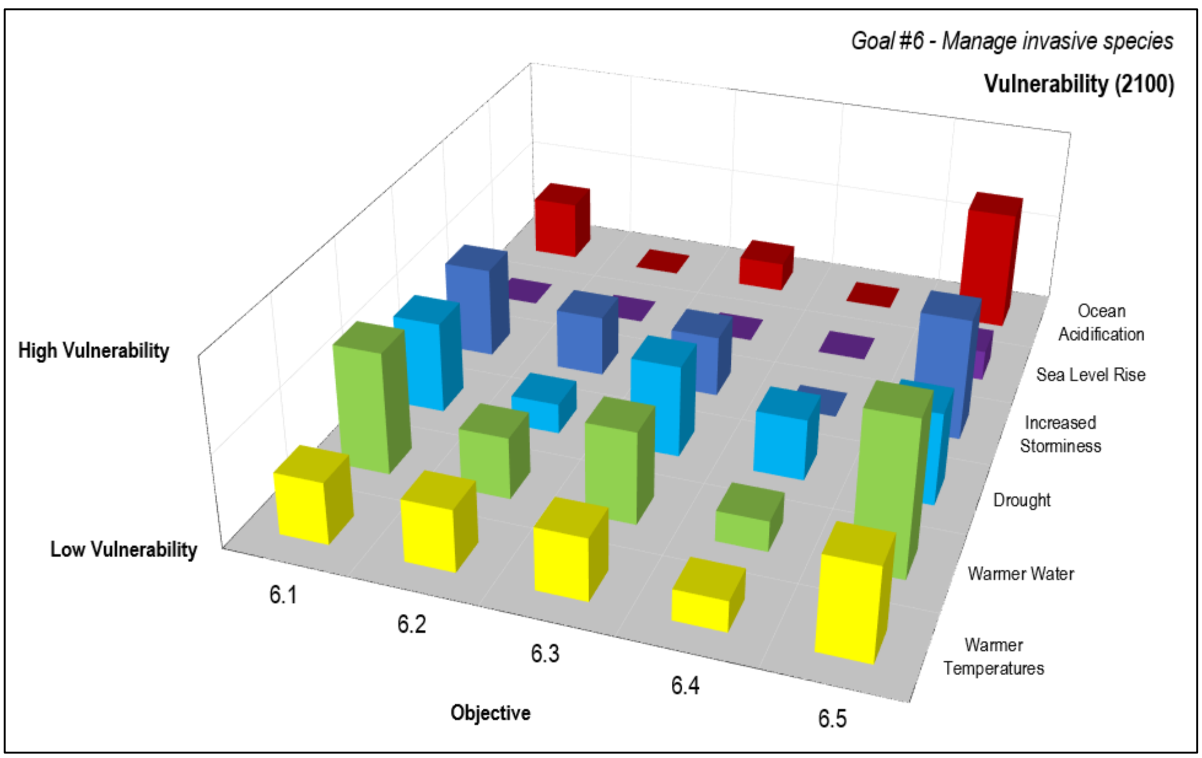


Figure 44. Goal 6 – 2100 Vulnerability.

Goal 7 – Restore wetlands, streams, and riparian zones

There are eight objectives within Goal 7, primarily related to wetland restoration and stream barrier removal in the Santa Monica Bay Watershed. Across the board, this goal has high vulnerability to many of the identified climate change stressors, most notably to warmer water. Impacts to Goal 7 objectives due to warmer waters may include an increase in the potential for eutrophication in shallow water systems, lowering levels of dissolved oxygen, impacting fish and invertebrate life cycles, altering primary productivity, etc. While organisms in shallow water systems may have a higher tolerance (i.e. adaptive capacity) for thermal variation, higher exposure levels are already occurring now, and many species are highly sensitive to warmer water temperatures, thus presenting a high level of vulnerability for all Goal 7 objectives.

Coastal wetlands are highly vulnerable to SLR, but would have some adaptive capacity through transgression upslope, if there was adjacent open space for restoration. However, most of the coastal wetland systems in the Santa Monica Bay Watershed are surrounded by urbanization and have very constrained boundaries, reducing their capacity to shift habitats upslope with SLR, and lowering their adaptive capacity.

The sensitivity ranking for storminess was often indicated as high in many of the objectives in this goal. Both open and closed coastal estuarine systems are sensitive to both wave erosion and flooding from urban, impervious watersheds. Some of the projects (e.g. Objective 7.1: Ballona Wetlands) may have restorations designed to accommodate altered storm patterns, thus increasing their adaptive capacity and lowering the overall vulnerability ranking for that objective.

Drought may potentially impact both streams and coastal wetland systems, altering hydrology, causing less freshwater input to both systems, and having the potential to have cascading trophic impacts over time. Both drought and increased storminess have the potential to alter hydrological patterns, salinity, and water quality.

OA has some level of vulnerability across many of the objectives in this goal, primarily due to potential impacts to shellfish or invertebrates. The exception to OA vulnerability is Objective 7.4, which is related to urban stream restoration.

Overall, Objectives 7.2, 7.5, 7.7, 7.6, and 7.8 have similar vulnerability for many of the climate change stressors because they are all describing small coastal wetland systems. Impacts caused by multiple climate change stressors may be related to species invasions or stress to different groups of species, and impacts to food webs or productivity. Vulnerability for all objectives increases in 2050 and 2100, especially for warmer water in 2050 and for increased storminess and SLR in 2100, primarily due to increases in exposure and intensity of these stressors over time.

Objective 7.1 – Restore Ballona

Several of the objectives in Goal 7 are in the restoration planning stages, including Objective 7.1, so there is the potential to incorporate adaptive management and increase adaptive capacity for things like storminess and, to a lesser extent, SLR, into the planning and restoration design. While this may allow for some transgression of the wetland habitats upslope over time, the Ballona Wetlands Ecological Reserve is constrained on all sides by infrastructure and urbanization, so the area that would allow adaptive capacity to occur is finite. Additionally, the adaptive capacity for Objective 7.1 without restoration is low, and the vulnerability would be high.

Once the restoration begins, drought may have a significant impact on restoration activities, including alteration of water quality and stratification patterns, alterations of dissolved oxygen levels, and increased irrigation. Restored habitats with new plants may require more frequent or longer durations of irrigation, and irrigating throughout longer growing seasons.

Benthic invertebrate and fish nursery communities may be sensitive to OA as a portion of the wetlands are tidal, with oceanic estuarine waters flooding in from the Ballona Creek estuary. It is likely that the adaptive capacity for any organisms sensitive to OA will be low, therefore increasing the vulnerability of the objective. Warmer air temperatures are not likely to increase the vulnerability of this objective to the same extent as several of the other climate change stressors such as warmer water or drought. Over time, several of the stressors indicate high vulnerability for Objective 7.1 by 2100, including warmer water, drought, SLR, and OA.

Objective 7.2 – Restore Malibu Lagoon

Objective 7.2 involves the restoration of the small, coastal, bar-built estuary, Malibu Lagoon. This project has some similarities to Objective 7.1, including sensitivity to many of the climate change stressors, but has a lower adaptive capacity because it is a much smaller system and the restoration project was completed in 2013. The vulnerability of Objective 7.2, overall, displays a similar pattern as 7.1, but with slightly higher vulnerability to warmer water, SLR, and OA. There is an increase in adaptive capacity through a managed sand berm closure pattern to decrease vulnerability to increased storminess from wave erosion, but only to a limited extent. Over time, the vulnerability of this objective to all of the climate change stressors increases. Warmer air temperatures is hypothesized to have the least effect on its vulnerability.

Objective 7.3 – Remove fish barriers and open 20 miles of stream to steelhead

Shallow stream systems in watersheds within the northern Santa Monica Bay area are already experiencing warmer water, drought, and warmer air temperatures, which increase their current and future exposure rankings. Steelhead trout are sensitive to warm waters, and the vulnerability of

Objective 7.3 to warm waters and drought is high, and may increase over time. Increasing water temperatures will also affect the benthic invertebrate community, larval fish, and the productivity and eutrophication potential of the system.

Drought may cause streams to become more ephemeral, and less appropriate as steelhead trout habitat. Similarly, OA may negatively impact the ocean portion of the steelhead life cycle, though the potential impacts are largely undocumented. Increases in storminess over time may increase the potential for erosion, bank failure, turbidity, and impact the overall water quality of a system. Objective 7.3 is not very vulnerable to SLR except at the portions of the stream that are connected to the ocean.

Objective 7.4 – Restore urban streams including daylighting culverted streams

Objective 7.4 exhibited similar trends to Objective 7.3, with the exception that OA is not relevant for this objective because it is not ocean-related. Similarly, SLR may exhibit lower trends of vulnerability, with the exception of potential salt water intrusion into coastal streams and waters. Storminess was identified as having a high sensitivity, primarily due to infrastructure and flooding potential, but also a high adaptive capacity as the act of stream restoration, including daylighting culverted streams, includes the ability to modify restoration design plans to accommodate several climate change stressors. In both the current vulnerability and 2050 vulnerability graphs, this objective was already identified as highly vulnerable to warmer water, with drought, storminess, and warmer temperatures increasing over time.

Objective 7.5 – Restore Topanga Lagoon

Objective 7.5 involves restoring Topanga Lagoon, a very small, coastal, bar-built estuary in the northern Santa Monica Bay Watershed. Topanga Lagoon experiences primarily freshwater input in a closed lagoon scenario (when the sand berm is in front of the mouth of the estuary), and is, thus, likely highly sensitive to warmer waters, drought, and increased storminess. The potential adaptive capacity of this system is fairly low, due in part to its size. Warmer waters are likely to have a more significant effect in a system that is closed most of the year. It is also likely vulnerable to some extent to SLR and OA, increasing over time as the estuary becomes inundated with tidal or oceanic waters more frequently.

Objective 7.6 – Restore Oxford Basin

Objective 7.6 is to restore the Oxford Flood Control Basin, owned and managed by the County of Los Angeles, Flood Control District. The project was intentionally designed to increase the stormwater capacity of the Basin, giving it both a high adaptive capacity and medium level sensitivity to increased storminess. Based on its design, it is not vulnerable to wave erosion.

The project does not have a capacity to adapt to SLR as it is surrounded by infrastructure within Marina del Rey and there is no adjacent room for transgression or expansion of the Basin. Thus, Objective 7.6

has a high vulnerability to SLR. Similarly, during dry weather, the Basin is predominantly salt water, and is therefore vulnerable to impacts due to OA, especially the benthic invertebrate community and juvenile or larval fish stages. Similarly, the Basin is vulnerable to warmer water and the potential for eutrophication and resulting lowered dissolved oxygen levels and impacts to the biotic communities. Warmer waters and drought may have impacts on the planted vegetation during the restoration efforts and/or require more irrigation.

Objective 7.7 - Restore Del Rey Lagoon

The vulnerability results for Objective 7.7 were found to be very similar to Objective 7.5, likely because they are both small coastal estuaries. It was also similar to Objective 7.6. The differences can be seen in that Del Rey Lagoon has tide gates, creating a muted tidal prism throughout the whole year and does not experience the same hydrological closure patterns of a bar-built estuary. Therefore, there is a slight decrease, comparatively, in the potential vulnerability from storminess, drought, and warmer waters.

Objective 7.8 – Restore Trancas Lagoon

The vulnerability results for Objective 7.8 were found to be the same as Objective 7.5, likely because they are both small, coastal, bar-built estuaries with similar physical and hydrological characteristics.

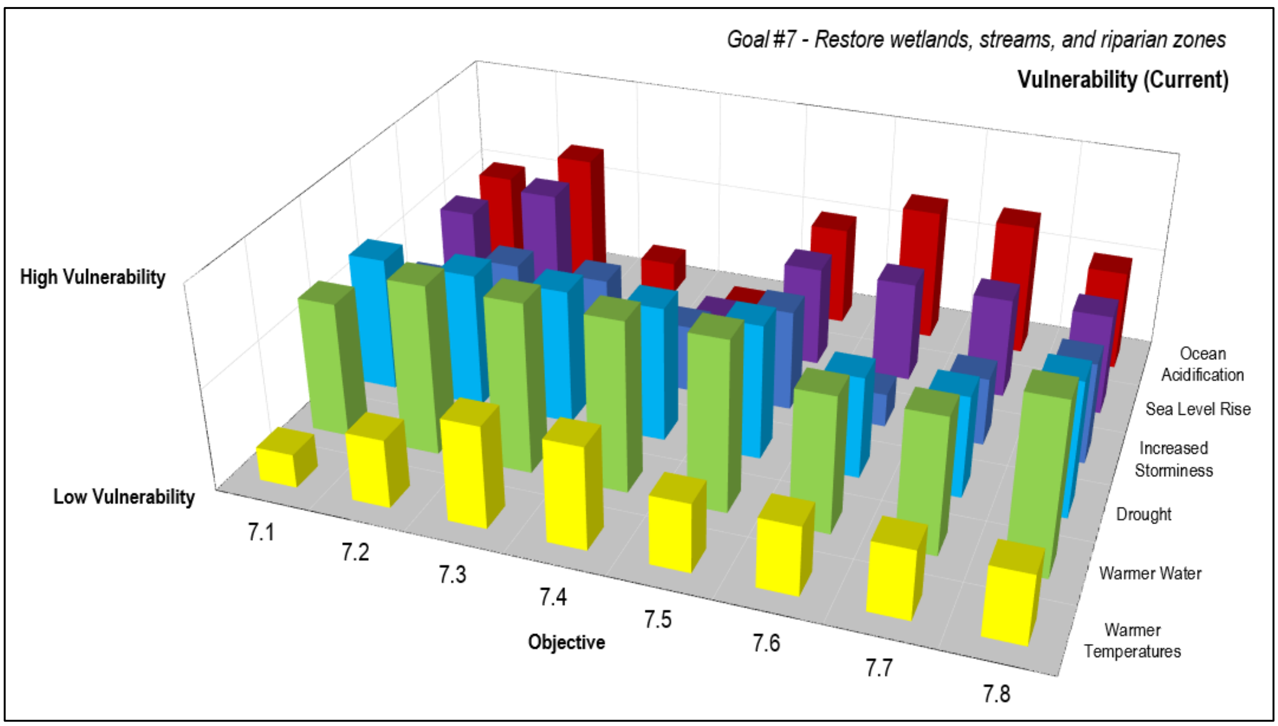


Figure 45. Goal 7 – Current Vulnerability.

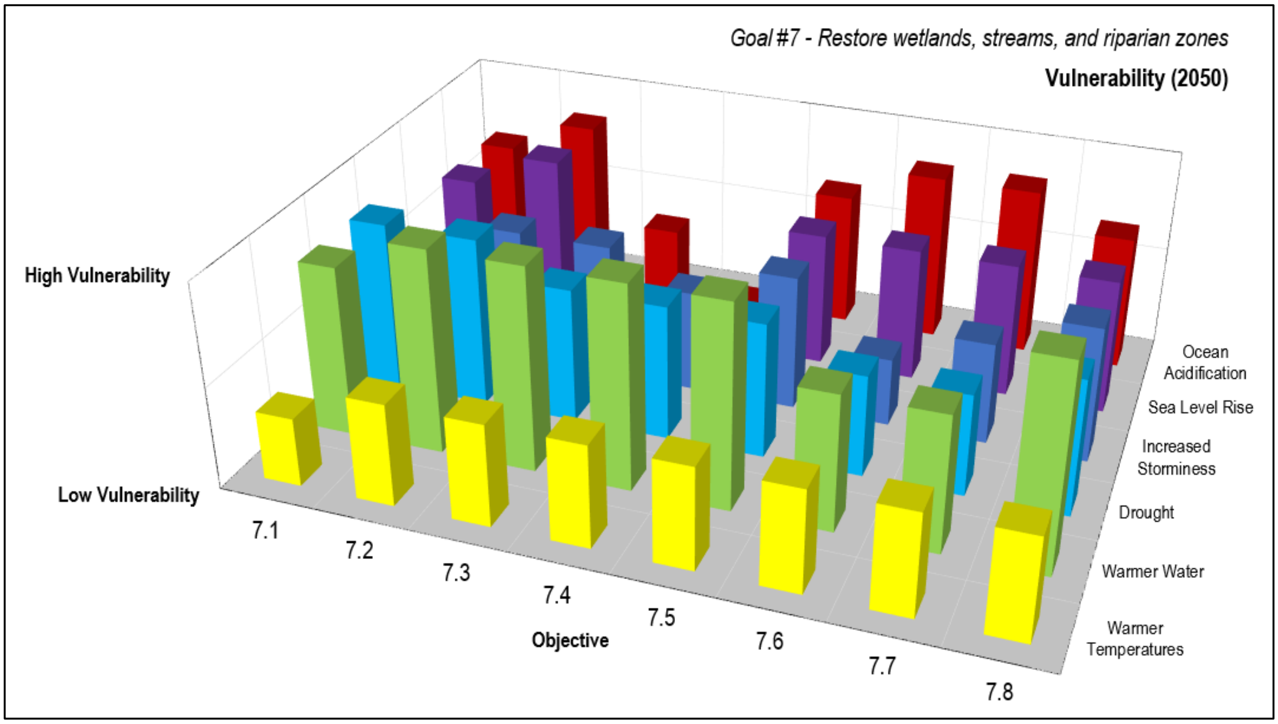


Figure 46. Goal 7 – 2050 Vulnerability.

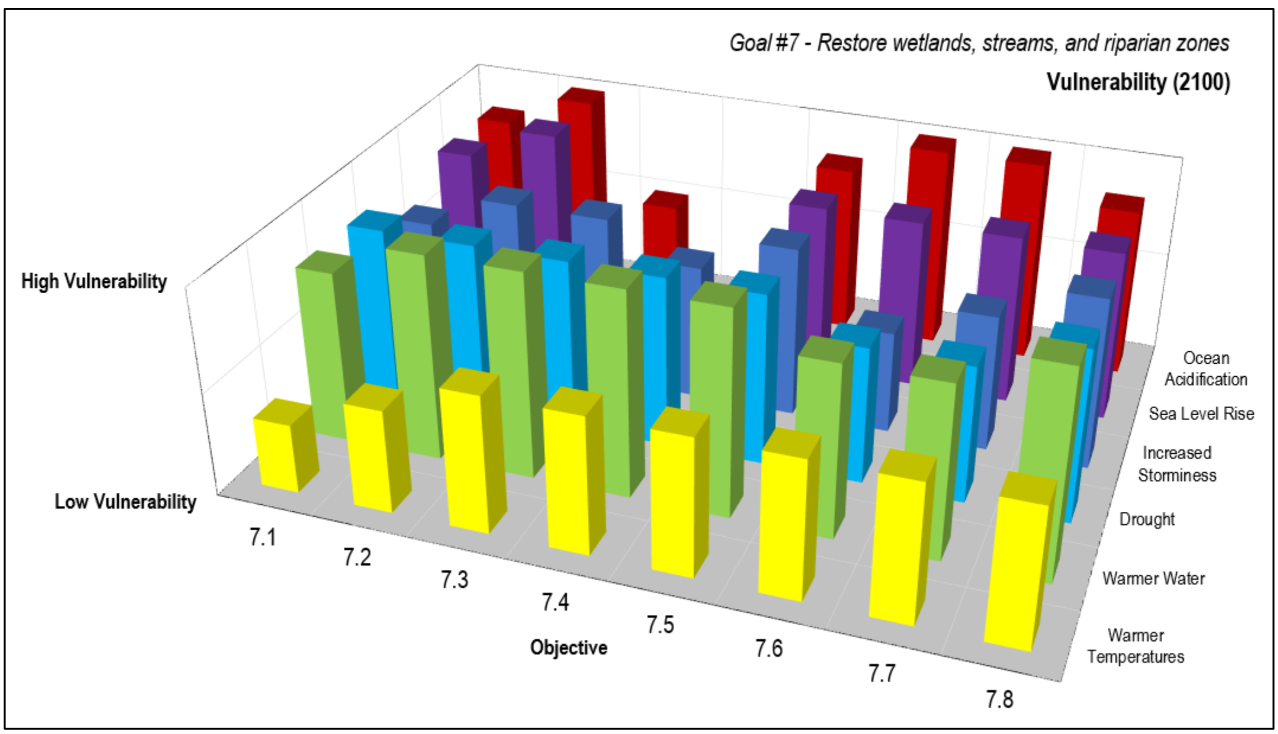


Figure 47. Goal 7 – 2100 Vulnerability.

Goal 8 – Restore coastal bluffs, dunes, and sandy beaches

Goal 8 includes a diverse set of habitats with sandy soils vulnerable to different climate change stressors. However, both objectives in this goal include some similar potential impacts, including species invasions, increased competition and use of water resources, and impacts to bird migration patterns and the Pacific Flyway. Temperature driven species redistributions are likely to be seen in several of these habitat types. Both objectives are likely to see climate change-related impacts to sediment management directly related to drought and increased storminess, potentially increasing the feasibility of management alternatives relating to hard-scape structures (e.g. armoring, levees).

Both objectives are vulnerable to drought and increased storminess, but, due to its geographical proximity to the ocean and associated stressors, Objective 8.2 has several additional climate change stressors and is more vulnerable overall, increasing over time.

Objective 8.1 – Restore native coastal bluff and upland scrub habitat

Objective 8.1 is primarily vulnerable to the drought and storminess climate change stressors. Associated risks from drought include increased risk of wildfires, and an increased need for irrigation over time for upland restoration projects. Alterations of storm intensity and frequency may put these habitat areas at an increased risk of flooding, erosion, altered sedimentation patterns, and an increased potential for landslides. These impacts may be compounded with the impacts of drought and wildfires, or with increased irrigation at restoration projects. Both stressors increase over time with additional exposure in intensity and extent.

While SLR and other ocean-associated stressors are generally not considered an immediate problem for these habitats because they are often located inland, they may be impacted eventually as coastal bluffs have the potential to erode over time. Additionally, there is very little space for retreat (if at all) in the Los Angeles region for these habitats due to urbanization. Future adaptive actions such as hard-scape alternative forms of protection may carry with them their own set of impacts. Planning for SLR and erosion now is critical for the future. There may be associated impacts with warmer temperatures or drought due to restoration of upland habitats potentially requiring more water and irrigation over time.

Objective 8.2 – Protect and manage sandy beaches

Sandy beaches are both one of the most vulnerable and potentially one of the most resilient habitats to climate change, depending on the stressor. These habitats are highly vulnerable to wave erosion from increased storminess and SLR, OA, and temperature changes. Restoration areas may also be vulnerable to drought. Risks associated with these climate change stressors include an increased need for soft- or hard-scape forms of beach protection. Altered management strategies for beaches become more likely over time, and some may significantly increase the vulnerability of this habitat type.

Impacts to biota may also be significant including, alterations of species distributions, bird use of the beach and migration patterns, grunion (fish) reproductive patterns, invertebrates, and vegetation assemblages. Species alterations, especially invasions of nonnatives, may also have indirect impacts. For example, the replacement of giant kelp, *Macrocystis pyrifera,* by invasive *Sargassum*, may alter nutrient subsidies of kelp to sandy beaches, with resulting trophic impacts at several levels. Additionally, patterns of recreational beach use by people may be affected as well, with impacts to various recreational activities as a result of beach loss or increased storminess.

The current vulnerability of several of the climate change stressors is high, in part due to current levels of exposure that indicate these stressors (e.g. drought, storminess, OA) are already present. By 2100, SLR, OA, storminess, and to a lesser extent, drought and warmer water may all increase the vulnerability of this objective significantly. Even warmer waters and air temperatures may play a part in increasing the vulnerability of this objective through indirect impacts on the biota. There is a higher degree of uncertainty with several stressors, especially temperature, but as beaches have flora and fauna that are often intertidal, they may be exposed to both warmer waters and air temperatures over time.

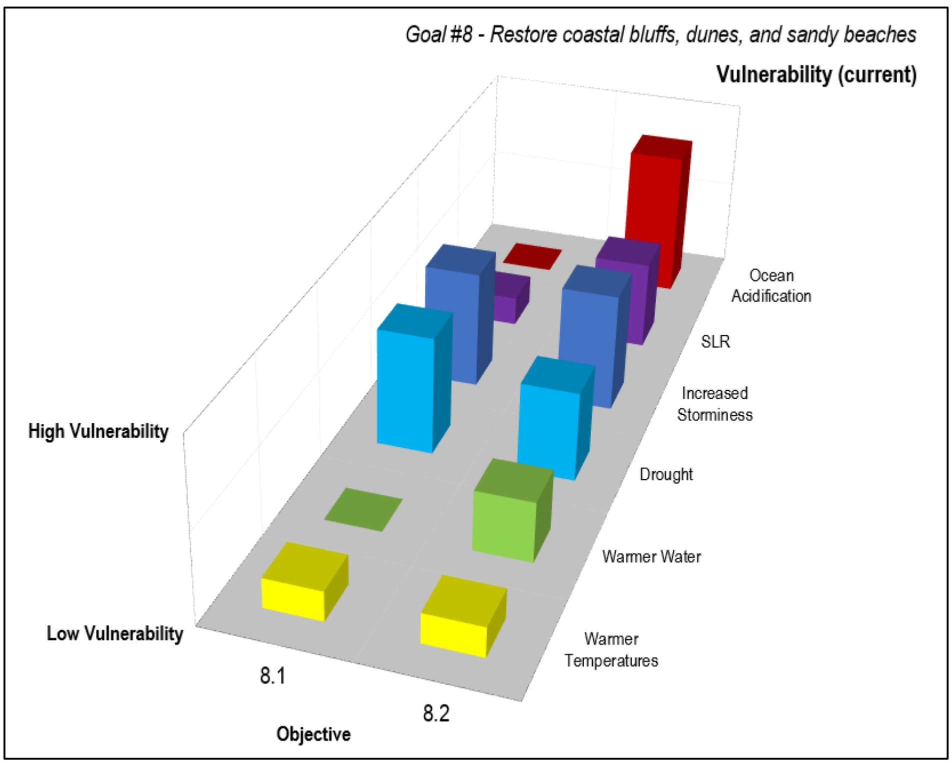


Figure 48. Goal 8 – Current Vulnerability.

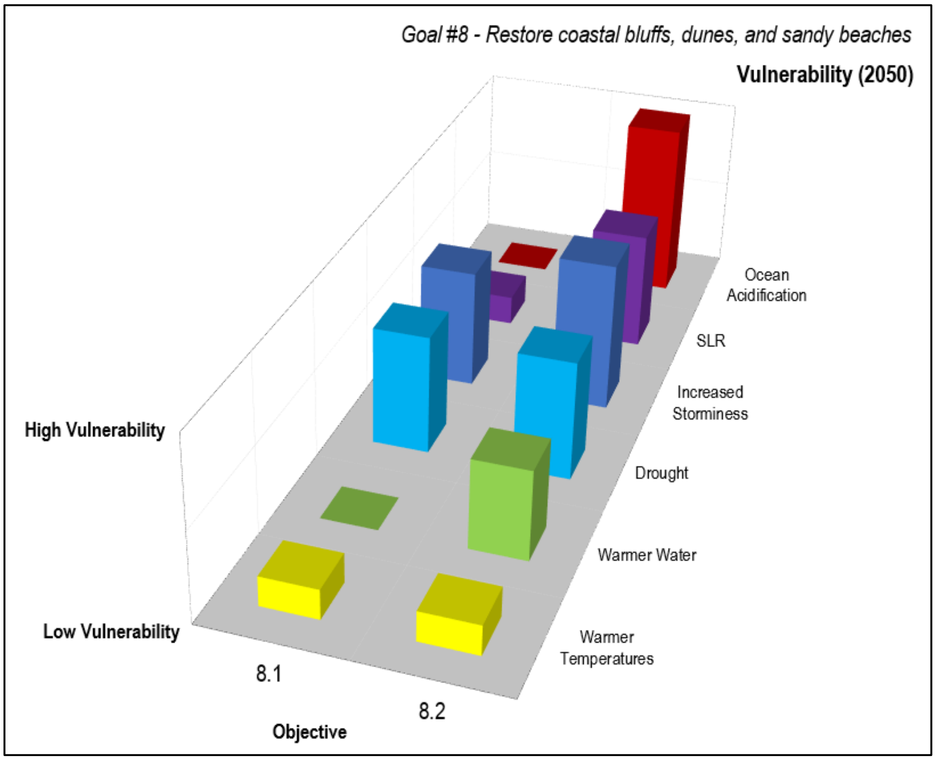


Figure 49. Goal 8 – 2050 Vulnerability.

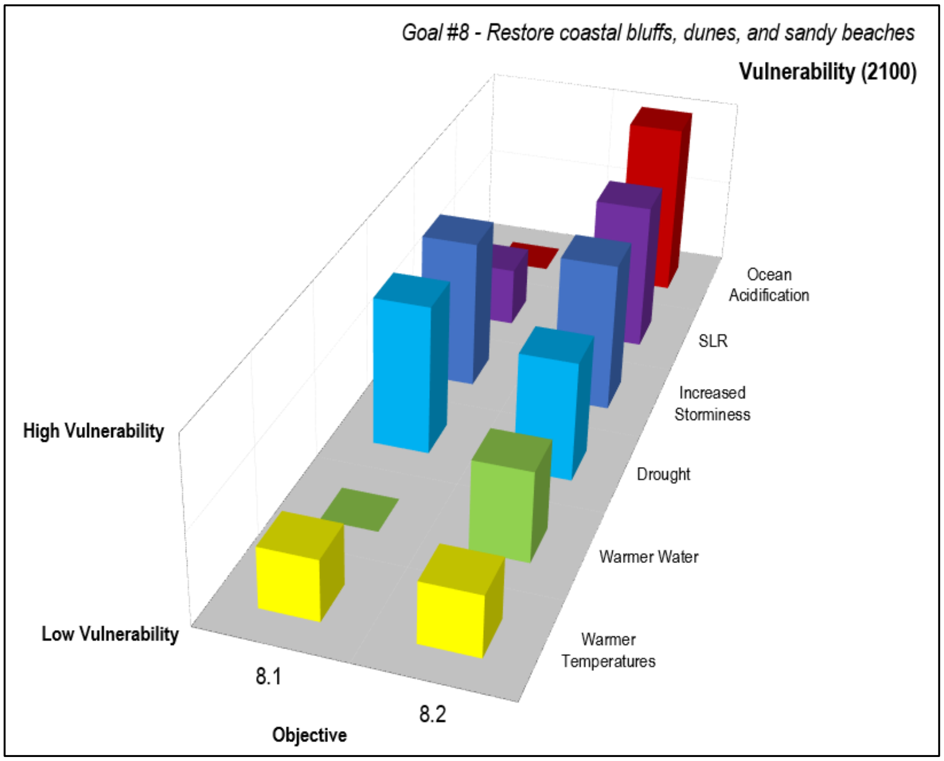


Figure 50. Goal 8 – 2100 Vulnerability.

Goal 9 – Restore rocky intertidal and subtidal habitats

All four objectives under this goal will be affected at varying degrees by climate change stressors. The stressor that was ranked with the highest initial vulnerability for all four objectives was warmer water. This stressor is already affecting these nearshore habitats and is having significant impacts on the community structure. The ability of these systems to be resilient to prolonged exposure to warmer waters is low, and the objectives all have either a medium or low ranking for adaptive capacity to this stressor. The intertidal habitats (i.e. Objectives 9.2 and 9.4) are also vulnerable to SLR, with the potential to convert to subtidal habitats over time.

One of the largest unknowns for this goal is OA. This stressor has the potential to have significant effects on intertidal and subtidal habitats, especially Objective 9.3, restoring abalone to the Bay. Overall, several of the stressors that are prominent in this goal area also showing a medium level of current exposure, as the effects and impacts are already being expressed in the systems (e.g. warmer waters and OA).

Objective 9.1 – Restore and monitor sixty acres of kelp forest

Objective 9.1 is most vulnerable to these three climate stressors: warmer waters, increased storminess, and OA. Warmer water was ranked as the most impactful stressor to this ecosystem. Giant kelp is highly sensitive to warmer water temperatures and has a low capacity to adapt; thus warm water greatly limits its growth and reproduction. The reduced health of kelp forests directly impacts a community comprising hundreds of species that rely on kelp for habitat and food. Kelp forests are frequently disturbed and giant kelp is adapted to rapidly grow or be replaced by juvenile kelp already recruited to the rocky reefs.

A specific concern for the vulnerability of Objective 9.1 is the intensity and frequency of large storms and associated wave energy. With greater frequency and intensity of wave events the adaptive capacity of a kelp bed or reef complex may diminish. OA is another stressor of concern for the sustainability and resilience of kelp forests. Although there is evidence that giant kelp is tolerant of increased acidity, the concern is that the shells of calcareous organisms face dissolution as the waters increase in acidity. If these impacts limit the survivorship or fitness of individuals or numerous phyla, the community structure and function of kelp forests will be altered, perhaps negatively. The impact of OA on kelp forests has an additional dimension because studies have shown that kelp forests have the capacity to raise the microclimate pH of surrounding ocean water, though the effects on surrounding waters is largely unknown.

Objective 9.2 – Protect and manage rocky intertidal habitat

Climate changes stressors that are expected to negatively impact rocky intertidal habitat are OA, warmer water, and warmer temperatures; to a lesser extent, increased storminess and SLR may affect this objective. These stressors are listed in order of increasing likelihood to negatively affect the structure and function of the rocky intertidal habitat. The impacts of OA may be similar to the impacts described for Objective 9.1. Calcareous organisms may experience increased dissolution due to increased acidity, causing direct reductions in the fitness of individuals, potentially resulting in population level impacts. Population level impacts may affect the ability to manage these habitats, especially for fisheries. Increased temperature will likely have a differential effect on this community as organisms adapted to the middle to high intertidal are exposed to the atmosphere during low tide and have phylogenic adaptations to cope with stressors associated with large temperature variation. The same is not generically true for the low intertidal where organisms are only rarely exposed to the atmosphere and associated temperature variation. Over time, changes in water temperature may cause shifts in the distribution and zonation of these organisms resulting in the ecological equivalent of coastal squeeze.

The intertidal is directly impacted by the larger and more frequent stresses associated with increased storminess. The waves can dislodge organisms and flip boulders and other substrate leading to crushing of organisms. Depending on the back shore environment, waves can also increase sediment loading to intertidal areas. These impacts can alter and limit available habitat, and thereby limit the potential of recovery for a given section of the rocky intertidal. SLR will change the duration at which areas of the middle and high intertidal are submerged during any given period of time. This increases the likelihood of predation from marine organisms due to the increase in exposure. Alternatively, organisms solely adapted to the high intertidal face an increased likelihood of a loss of suitable habitat. This ecotype may face austere limits in its local distribution as the marine terrace may not allow for a shoreward and vertical progression.

Objective 9.3 – Re-introduce and restore abalone population

The re-introduction and restoration of abalone populations (Objective 9.1) to Santa Monica Bay is most vulnerable to the stressors of OA and warmer waters. Ocean pH is forecasted to drop over the next century which can dissolve the shells of abalone and may prevent larvae from forming its shell. In addition, ocean water temperatures are forecasted to increase over the next century, which has been detrimental to abalone health, as warmer waters may approach or exceed the thermal tolerances for a variety of species. Transgression to deeper waters containing cooler water is limited in the project area because light attenuation at deeper waters may be devoid of standing foliose algae that these species forage. Thermal stress is also associated with withering syndrome, a disease that can lead to widespread losses of abalone. Community-wide effects associated with rocky reefs will compound the thermal stressors outlined above. Black abalone are found principally in the middle-low intertidal and will be impacted by some of the processes outlined in Objective 9.2. Green and pink abalone are found in the shallow subtidal and are likely to experience impacts associated with increased storminess as outlined in Objectives 9.1 and 9.2. Red, white and pinto abalone prefer colder water and are found in depths greater than 40 feet, direct physical stresses of storminess are less likely to impact these deeper species but indirect impacts due to changes in the quantity and quality of food and sediment transport, are stressors that are expected to increase over time.

Objective 9.4 – Assess and protect seagrass habitats

Populations of eel grass (*Zostera* spp.) and surf grass (*Phyllospadix* spp.) are currently found on soft bottom habitats in the Bay, growing in waters approximately 10 to 40 feet in depth and on rocky reefs in water less than 15 feet. Due to the differing substrate and depths that these seagrasses inhabit, climate change stressors will have differential impacts. Both genera are fairly tolerant of warmer water and warmer temperatures as can be exposed during low tide (when existing intertidally). However, while some seagrass populations are more resistant to extinction as a result of genetic diversity, a broad geographic distribution, or the ability to recolonize, there are limits to population sustainability under high frequency and intensity of high-temperature events (Koch 2016). Increased storminess may limit the distribution and recovery of surf grass due to the processes outlined for Objective 9.2. Increased storminess may alter sediment transport and deposition within given littoral cells causing partial or complete burial of the eel grass. In these cases prolonged periods of light attenuation and a vertical shift upwards in the oxygenated sediment layer may leave the roots of the plant in a deeper, more hypoxic layer, and negatively impacting the fitness or killing the individual plant(s).

SLR will, like warmer water, have a differential impact based upon the location of the seagrasses. Surf grass existing in the middle intertidal and shallow subtidal may experience a reduction due to loss of suitable habitat, via burial or increased depth, and/or increased competition with macroalgae or other sessile species for space on the substrate. Increased submersion may also permit more extensive grazing by marine phyla. The indirect impacts of SLR on deeper offshore eel grasses are less impactful. More likely alteration of sediment amount, transport and burial are a concern for grasses in this habitat. Shallow eel grasses resulting from restoration in coastal wetlands may face stressors associated with; submersion, transgression, altered sedimentation and attenuation of light. The effects of OA on seagrasses are largely unknown, though the acidity has the potential to impact the associated biotic communities.

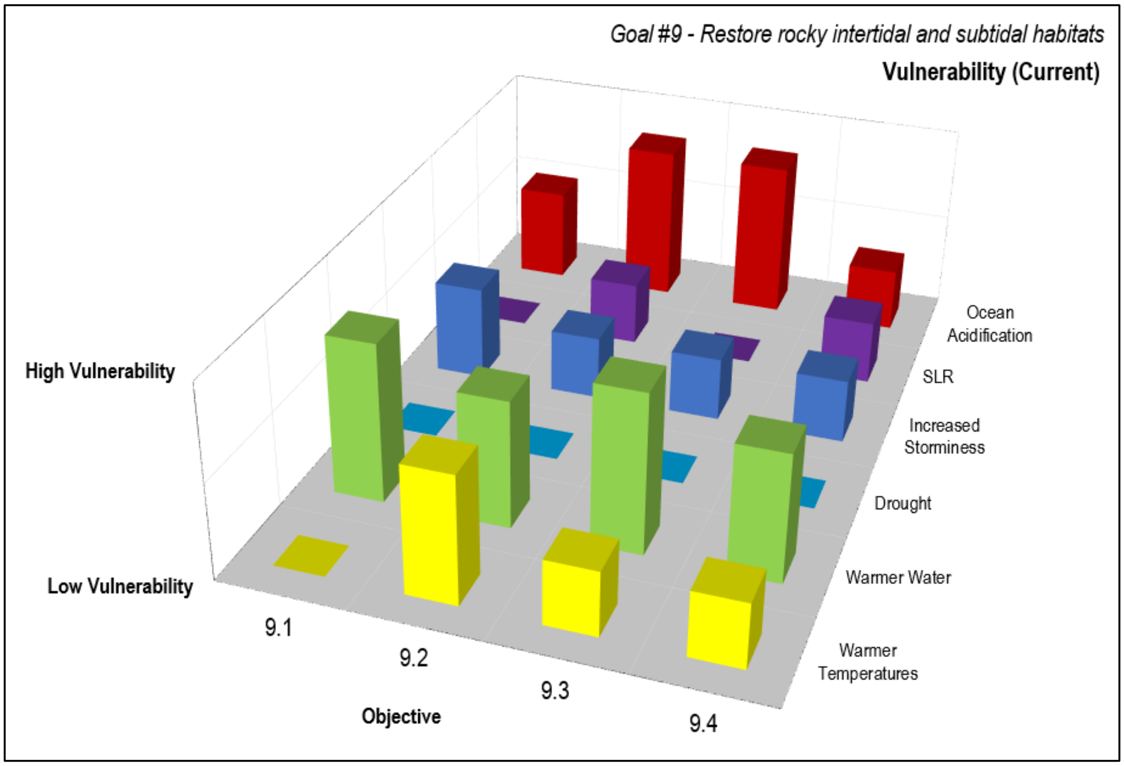


Figure 51. Goal 9– Current Vulnerability.

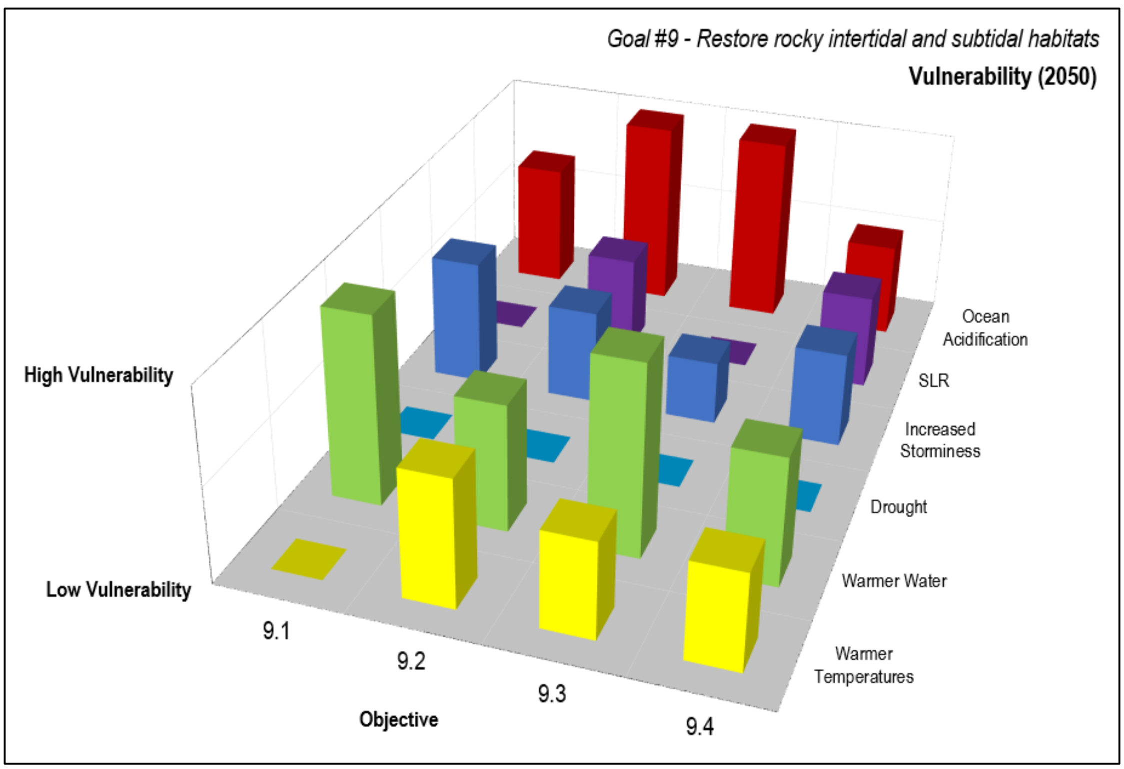


Figure 52. Goal 9 – 2050 Vulnerability.

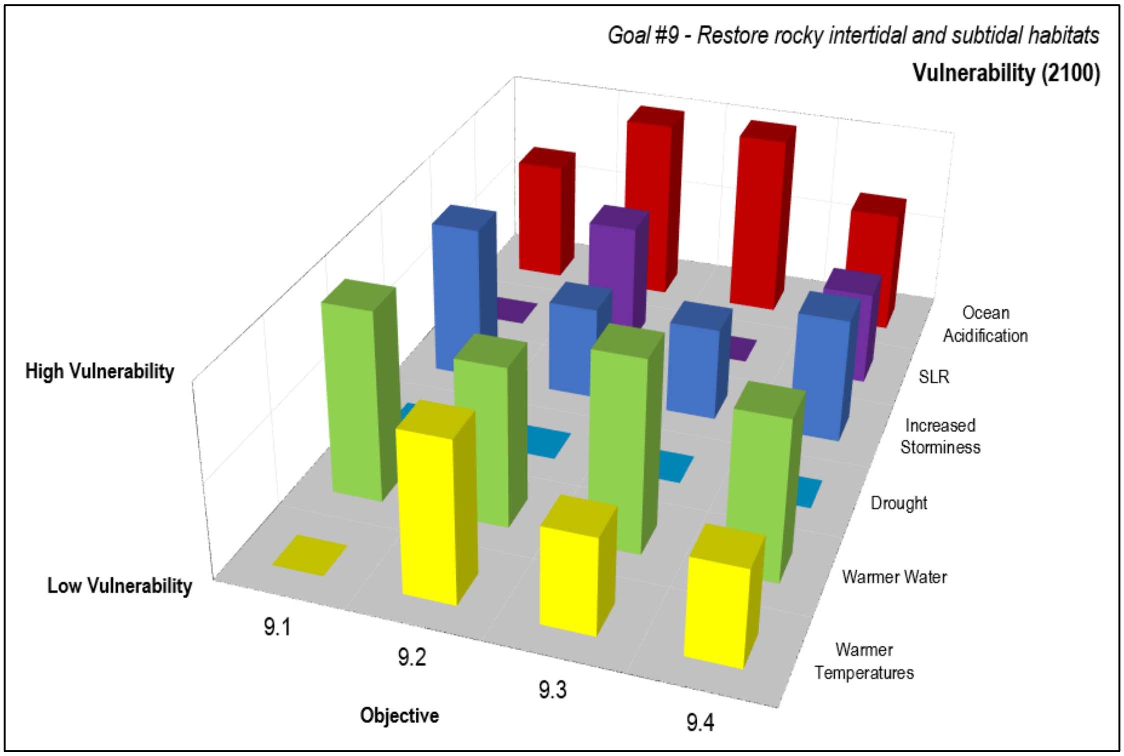


Figure 53. Goal 9 – 2100 Vulnerability.

Goal 10 – Protect and restore open ocean and deep water HABs

While Goal 10 only has two objectives, they are very different, with Objective 10.1 as an expansion of knowledge and understanding for unique habitats, and Objective 10.2 as an evaluation of open ocean harmful algal blooms, or HABs, and their associated impacts. As the goal is focused on open ocean habitats, it is likely that several of the stressors tied to oceanic waters will increase the vulnerability of both objectives, primarily warmer water, increased storminess, and OA. Overall, the vulnerability for these aforementioned stressors are higher for Objective 10.2 because the extent harmful algal bloom are known to be more directly tied to warmer water, increased nutrient loading from larger storms, and OA. While both objectives are tied to evaluations and monitoring which can be restructured adaptively, both objectives are identified as data gaps for our region and need significantly more information to derive good conclusions.

Objective 10.1 – Update and expand knowledge of unique habitats in SM Bay

The adaptive capacity of updating and expanding knowledge of these habitats for many of the climate change stressors for Objective 10.1 was identified as medium or high (e.g. warmer temperatures, drought, SLR). Adaptive monitoring plans and data evaluations can always be updated or structured to identify trends, or to collect new and different forms of data. The sensitivity for several of the stressors was also identified as low, e.g. warmer temperatures, drought and SLR, which are not currently understood to have a direct effect on open ocean or deep water habitats. An exception to this lack of direct causation my present itself in the reduction of discharge from POTWs in response to drought.

Warmer water, OA, and increases in storminess may have a direct impact on many of the habitats that are included in this evaluation. The ability of the organization and objective to adapt may be impacted. One example is survey days (e.g. boat days) may be reduced due to increases in storminess. Another example is that various types of water quality sensors may be sensitive to changes in water acidity resulting in inaccurate readings or requiring more frequent maintenance or replacement. Light attenuation due to increased turbidity may also have widespread impacts on communities within the water column and in neighboring nearshore systems such as Torrance Beach.

Objective 10.2 – Assess HABs, causes, impacts, on Bay's ecosystems

Objective 10.2 is currently vulnerable to several climate change stressors, but primarily warmer water. Warmer waters could cause increases in phytoplankton and may impact the extent and frequency of HAB occurrences. Warmer waters may also cause temporal shifts in presence, concentration or proportional representation of particular phytoplankton in the near shore and near shore pelagic environments of Santa Monica Bay. Increases in microbial communities may also drive the depletion of dissolved oxygen from the water column. Global studies suggest that increasing temperatures, enhanced stratification, alteration of ocean currents, intensification or weakening of local nutrient upwelling, reduced calcification through OA, and heavy precipitation and storm events causing changes in land runoff and micronutrient availability may all interact in a complex manner, making results very difficult to predict (Hallegraeff 2010). The impacts of OA, storminess, and warmer waters predicted to increase over time suggest that the vulnerability of Objective 10.2 will similarly increase over time. Adaptive capacity of the organization to assess HABs is generally high as protocols and methods may be modified as needed.

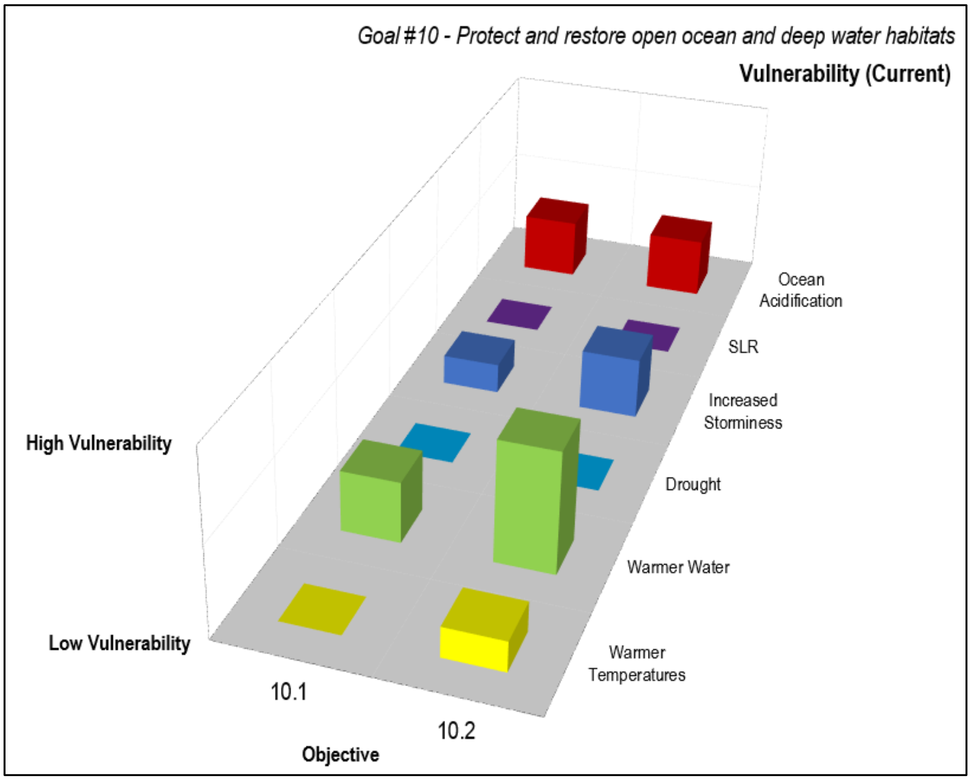


Figure 54. Goal 10 – Current Vulnerability.

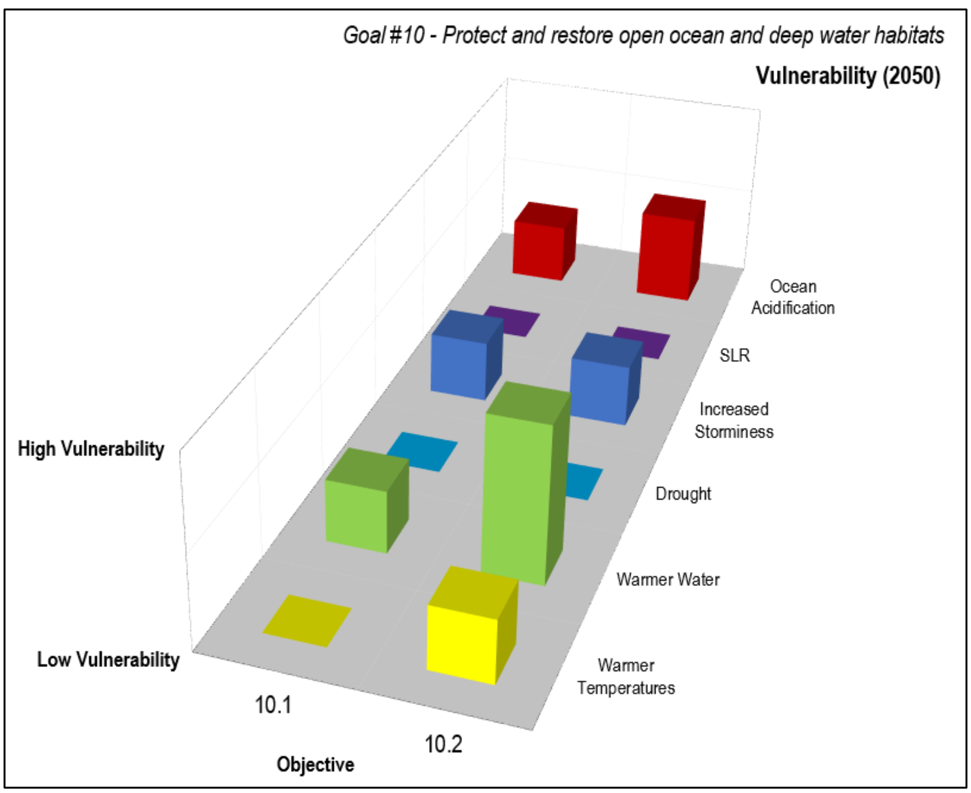


Figure 55. Goal 10 – 2050 Vulnerability.

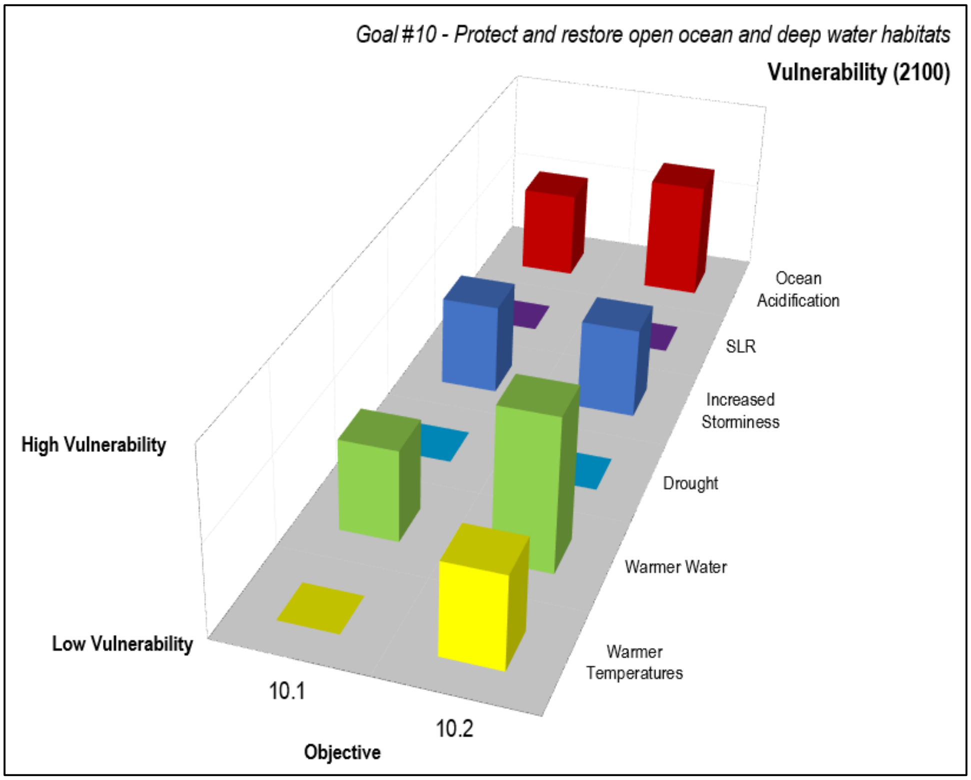


Figure 56. Goal 10 – 2100 Vulnerability.

Goal 11 – Protect public health

This goal and affiliated objectives address the health risks associated with swimming in the Bay's surf zone and with eating contaminated seafood. Among the six climate stressors, warmer water and increased storminess have relatively high level of impacts across all five objectives, though the underpinning mechanisms in essence differ between objectives addressing swimming and seafood-related issues. The main cause of swimming risks is pathogen-contaminated urban runoff and storm water discharge. Warmer water may foster growth of pathogenic bacteria and viruses, and increased storminess may result in larger volume of storm water discharge. Locally, the main cause of seafood risk stems from several species of fish contaminated with DDT and PCBs which were historically deposited in the sediment on Palos Verdes shelf. Warmer waters may result in shift in pattern of fish movement and distribution, and increased storminess may cause new or more resuspension of the contaminated sediment.

Overall for both issues and in the long run, warmer water appears to have the most significant impacts. Potential impacts of increased storminess should also be taken into account in developing storm water capture capital projects and contaminated sediment remediation plans. The impacts of SLR should also be taken into account in storm water project design if the project locations are adjacent to beaches and surf zone.

Objective 11.1 – Achieve minimum beach closures and postings at Santa Monica Bay beaches

This objective is aimed at reducing and even eliminating beach closure through runoff diversions for dry-weather in the short term, and through watershed-based storm water capture, infiltration, and reuse for the wet-weather in the long-term. These measures can be affected by warmer water because it can foster growth of pathogens. The predicted level of this impact in the near term should not require major upgrades or new structural control measures, but may need to take these factors into account in the longer term as the exposure to this problem is projected to worsen. Increased storminess is both an imminent and long-term concern as it will likely to require changes in project setting and sizing, which can make the projects more costly. Conversely, increased drought conditions could reduce bacterial loading associated with runoff therefore reducing the need for more dry-weather diversions. SLR is also a concern, particularly for impairing operation of dry-weather diversion and treatment facilities as they are all located on or close to the beach front.

Objective 11.2 – Develop and adopt new pathogen indicators and source identification tools

Overall, because this objective deals with research and regulatory activity, they are only moderately sensitive to a couple of the climate stressors. New research and new indicator criteria should take into account of various levels of effects by several stressors on bacterial sources, loading, and dispersion in receiving waters, which include primarily increase in bacteria growth rate due to warmer water, less or more loading, and smaller or larger dispersion zones due to drought or increased storminess. Addressing these impacts through is considered relatively easy as it involves revisions of existing research or new research plan, and revisions of indictor criteria verses implementation of new capital projects.

Objective 11.3 – Update seafood consumption and advisories and risk communication messages

This objective deals with the communication messaging, which is essential for carrying out institutional control measures laid out in the subsequent objective (11.4). Therefore, the types and levels of influences by climate stressors are approximately the same as Objective 11.4. Warmer water may result in shift of fish population and distribution even drastically as many fish species are highly sensitive to temperature change. Increasing storminess may increase sediment resuspension and cause more fish contamination, therefore the need to revise fish consumption advisories. In all these cases, the adaptive capacity for addressing these impacts is considered high as agencies should be able to revise the advisories and communication messages if necessary.

Objective 11.4 – Maintain and enhance institutional control measures (enforcement, monitoring, and education) through coordination with partner agencies to reduce the risk of consumption of contaminated fish in high risk ethnic communities

This objective deals with institutional control measures and by and large the types and levels of influences by climate stressors are approximately the same as Objective 11.3. In fact, it should probably be categorized as a milestone as it is just a more specific version of Objective 11.3. However, for the purposes of this analyses, it was evaluated as its own objective.

Warmer water may result in shift of fish population and distribution even drastically as many fish species are highly sensitive to temperature change. Increasing storminess may increase sediment resuspension and cause more fish contamination, therefore the need to revise fish consumption advisories. In all these cases, the adaptive capacity for addressing these impacts is considered high as enforcement, monitoring, and education programs should be relatively easy to adjust.

Objective 11.5 – Remediate contaminated sediments

Similar to Objectives 11.4 and 11.5, implementation of this objective will be mainly impacted by two climate stressors, warmer water and increased storminess, but the impacts here will likely be substantial, and may lead to the reevaluation of the feasibility of various remediation alternatives. Warmer water may change the distribution of contaminated fish, and increased storminess may affect the possibility of sediment resuspension. The realization of both risks may lead to changes in risk assessments and feasibility reevaluations associated with remediation plans.

OA may also have an impact on this objective by affecting the rate of contaminant degradation. However, there is no supporting evidence, especially for possibility of any noticeable effect within the timeframe of the remediation goal (in 50 years).

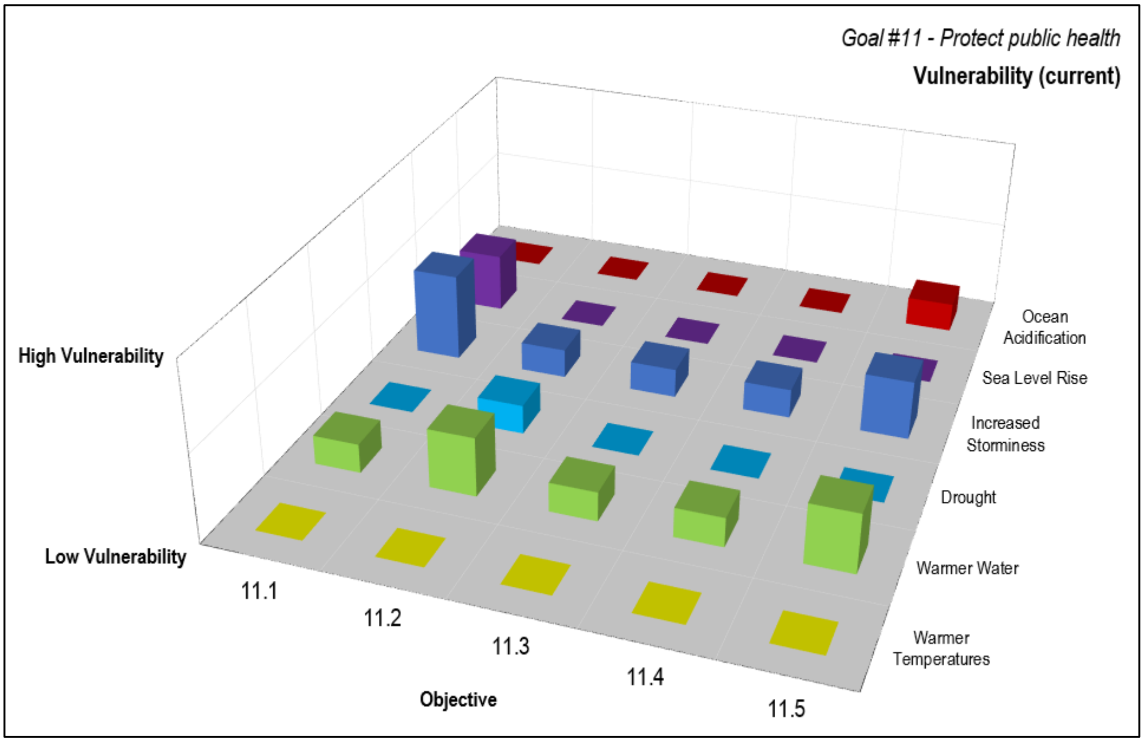


Figure 57. Goal 11 – Current Vulnerability.

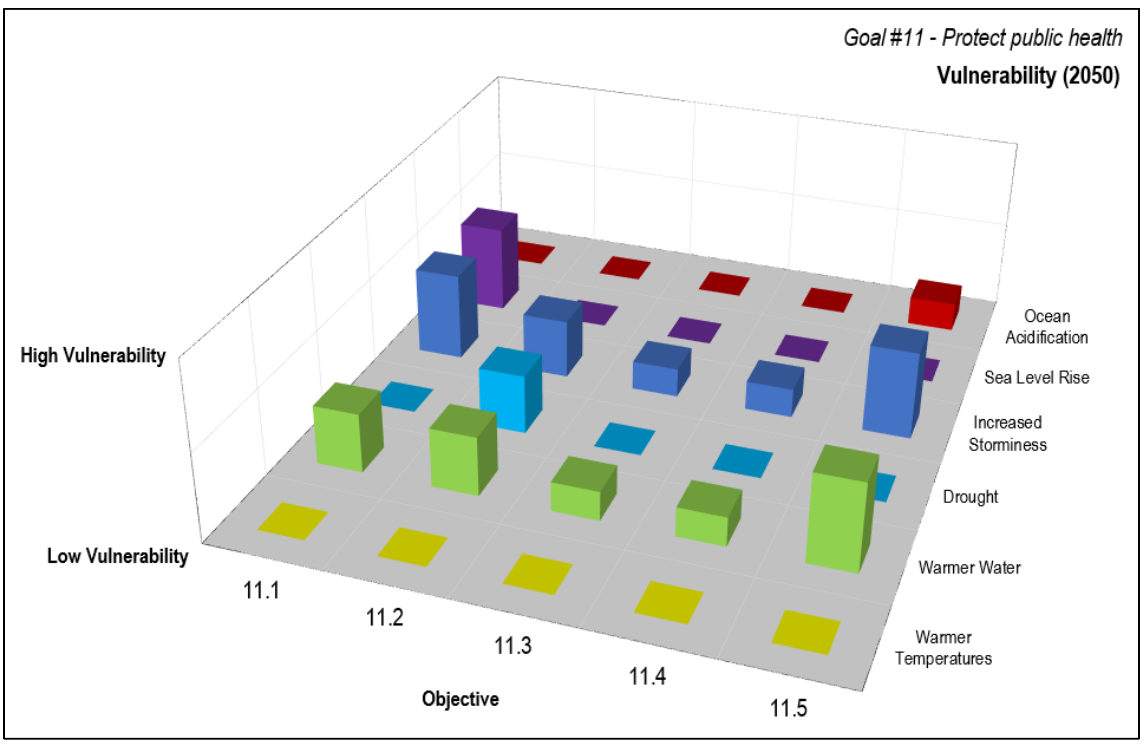


Figure 58. Goal 11 – 2050 Vulnerability.

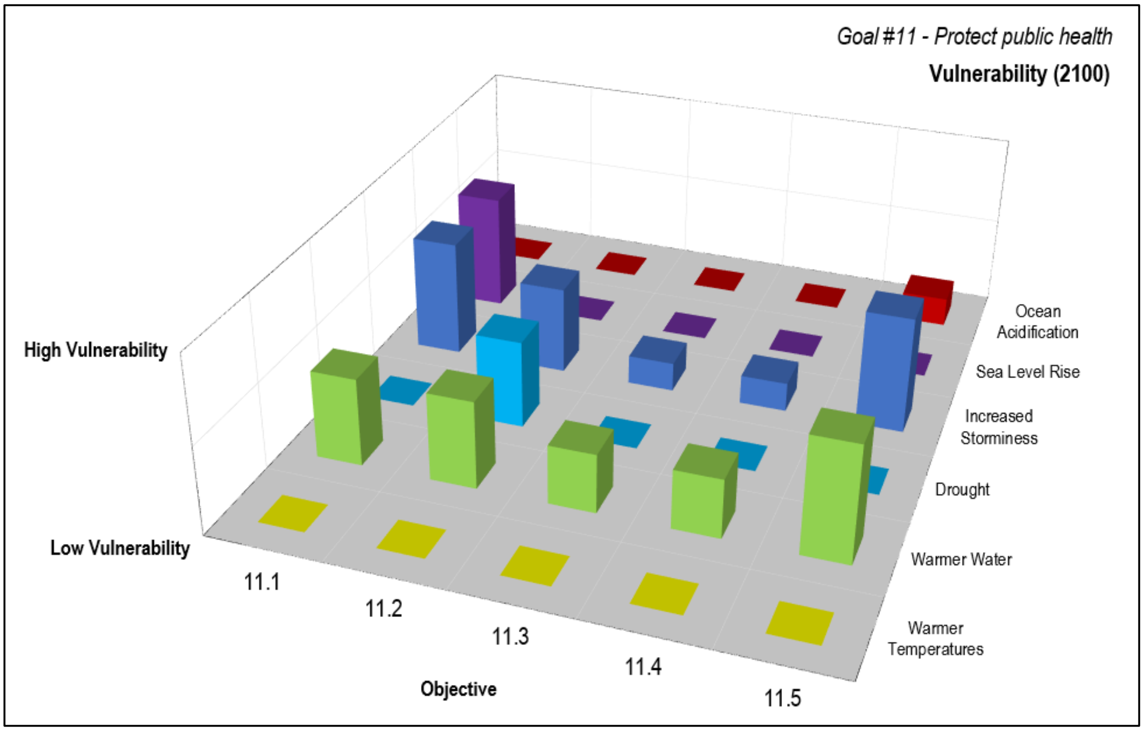


Figure 59. Goal 11 – 2100 Vulnerability.

Goal 12 – Maintain / increase natural flood protection through ecologically functioning floodplains and wetlands

Goal 12 is primarily tied to acquiring and restoring ecologically functioning floodplains, wetlands, and river systems. As hydrology is a key component to both objectives, they are both vulnerable to some extent to increased storminess, drought, SLR, and warmer waters. Similarly to previous goals, much of the vulnerability comes from stressors tied to impacts to flooding and erosion. However, there is some adaptive capacity associated with both objectives due to the potential to acquire properties that will expand the floodplain through restoration.

Objective 12.1 – Acquire and restore priority parcels to increase acreage of ecologically functioning floodplains and wetlands

SLR will have a significant impact on Objective 12.1 if the wetlands are not able to transgress inland and upslope with increasing sea level. An increase in the area and depth of inundated coastal areas may shift habitats from intertidal to subtidal over time. Similarly, more floodplain is needed as a buffer from flooding and associated erosion with increases in storminess. While this objective is sensitive to several stressors (e.g. storminess, SLR), it is also somewhat adaptable, with targeted purchase of properties in key areas to allow for adaptive management. Additionally, restoration planning should incorporate key climate change stressors from the beginning. Objective 12.1 is not highly vulnerable to warmer temperatures, though restoration areas may be affected by drought. The restoration component of this objective increases its vulnerability because it has to take vegetation recruitment an irrigation into account. Warmer temperatures may also have a slight effect on the vulnerability of this objective, similar to other restoration projects throughout other goals.

Objective 12.2 – Develop and implement a comprehensive regional sediment management plan for restoring natural hydrological functions of river systems

Similar to Objective 12.1, Objective 12.2 is related to planning efforts to restore hydrology and natural functions of river systems through regional sediment management planning. Thus, the main stressors affecting this objective are those that affect sediment budget (erosion, transport, and deposition) in river and beach systems (i.e. storminess and drought). Planning has a high level of adaptive capacity, but many of the systems and habitats that this objective contains are vulnerable to multiple climate change stressors. For example, sediment management on beaches or in coastal areas may be more challenging due to increased inundation from SLR and increased storminess. It may also potentially be vulnerable to SLR due to salinity intrusion into coastal watershed areas and upstream in rivers. As storminess leads to changes in runoff patterns over time, there is increased risk for erosion, and flooding events. Warmer temperatures have the potential to lead to an increased risk of wildfire and subsequent problems with erosion. Adaptive strategies should be incorporated into all planning and restoration efforts. Objective 12.2 is not particularly vulnerable to OA because it is specific to habitats further up in the watershed.

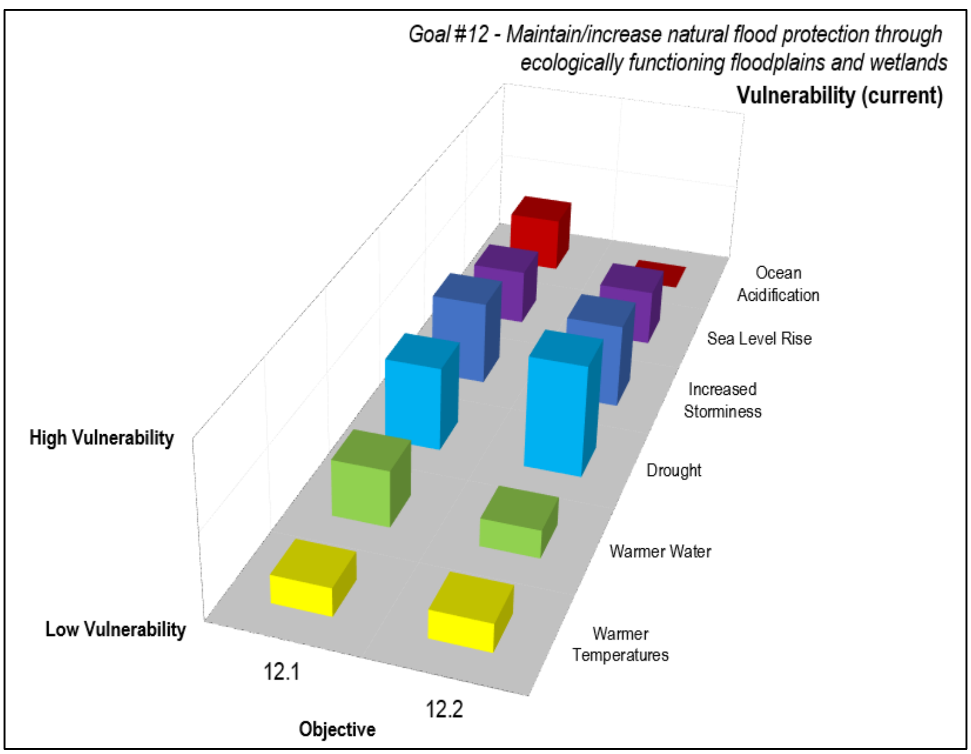


Figure 60. Goal 12 – Current Vulnerability.

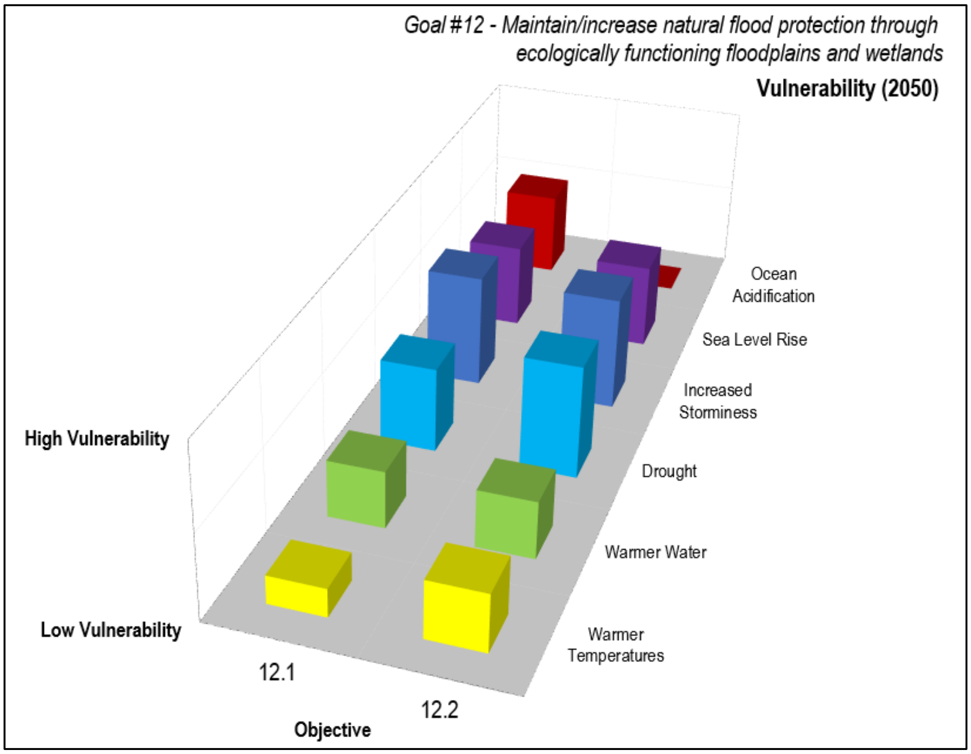


Figure 61. Goal 12 – 2050 Vulnerability.

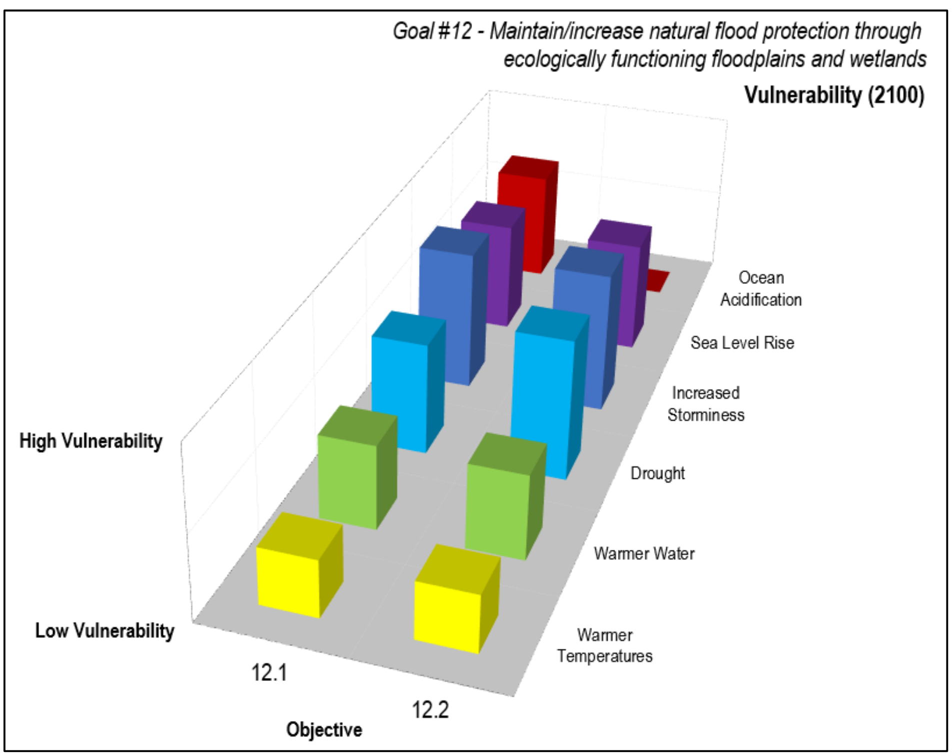


Figure 62. Goal 12 – 2100 Vulnerability.

Goal 13 – Increase public access to beaches and open space

Goal 13 is directly related to public access for beaches and open spaces throughout the Santa Monica Bay Watershed. Overall, this goal exhibited low vulnerability to most of the climate change stressors. In fact, out of all of the goals, it was one of the least vulnerable. Objectives 13.1, 13.2, and 13.3 all displayed similar trends to each climate stressor and similar trends over time. Objective 13.4 was more vulnerable because of the increased vulnerability of its focal habitat: sandy beaches. Objectives 13.1, 13.2, and 13.3 all displayed some low level vulnerability to drought or increased storminess, which increased slightly over time. Drought and storminess combined have the potential to cause erosion or to affect trail closures.

For all the objectives except 13.4, there was low vulnerability displayed for warmer temperatures, warmer waters, SLR, and OA. Most of the objectives also displayed a high level of adaptive capacity for most of the climate change stressors, due to the fact that public access points can be modified and updated over time, while factoring in climate change stressors.

Objective 13.1 – Increase public access to the Santa Monica Mountains through purchase and enhancement of open space

The purchase and enhancement of open space in the Santa Monica Mountains (Objective 13.1) had very low vulnerability overall, as property purchases and the enhancement of public access points and trails are highly adaptable. The combination of drought and increased storminess could increase the vulnerability of this objective due to the increased potential for erosion, and the increased potential of drought-driven wildfires. The low vulnerability to the two stressors is likely to increase slightly over time, due to increased exposure (intensity and extent) over time. Coastal habitats are slightly more vulnerable to climate change stressors.

Objective 13.2 – Increase acreage and access to parks and open space in urbanized areas through acquisition and conservation of private parcels

The vulnerability of Objective 13.2 was very similar to Objective 13.1, with an added potential of flooding in urban areas through increased storminess. Similarly to 13.1, Objective 13.2 has very low vulnerability, increasing only slightly for drought and storminess over time.

Objective 13.3 – Increase public access points to Ballona Creek and Wetlands

The vulnerability of Objective 13.3 is very similar to Objectives 13.1 and 13.2. This objective is still in the planning stages for the Ballona Wetlands Ecological Reserve, therefore, the planning is highly adaptable around climate change stressors. Drought and storms may still impact access, especially for this objective, as safety adjacent to the Creek and Wetlands in storm events may factor into planning and open public access.

Objective 13.4 – Increase public access to Santa Monica Bay beaches

Objective 13.4, increasing public access to beaches in the Santa Monica Bay, is likely only sensitive to SLR and wave-driven erosion from increased storminess. These two factors combined have the potential to significantly reduce the availability of public access, and in fact, this is already happening along beaches in Malibu. Similarly to Objectives 13.1, 13.2, and 13.3, warmer temperatures, warmer waters, and OA are not likely to affect its vulnerability. Drought is also unlikely to significantly affect this objective.

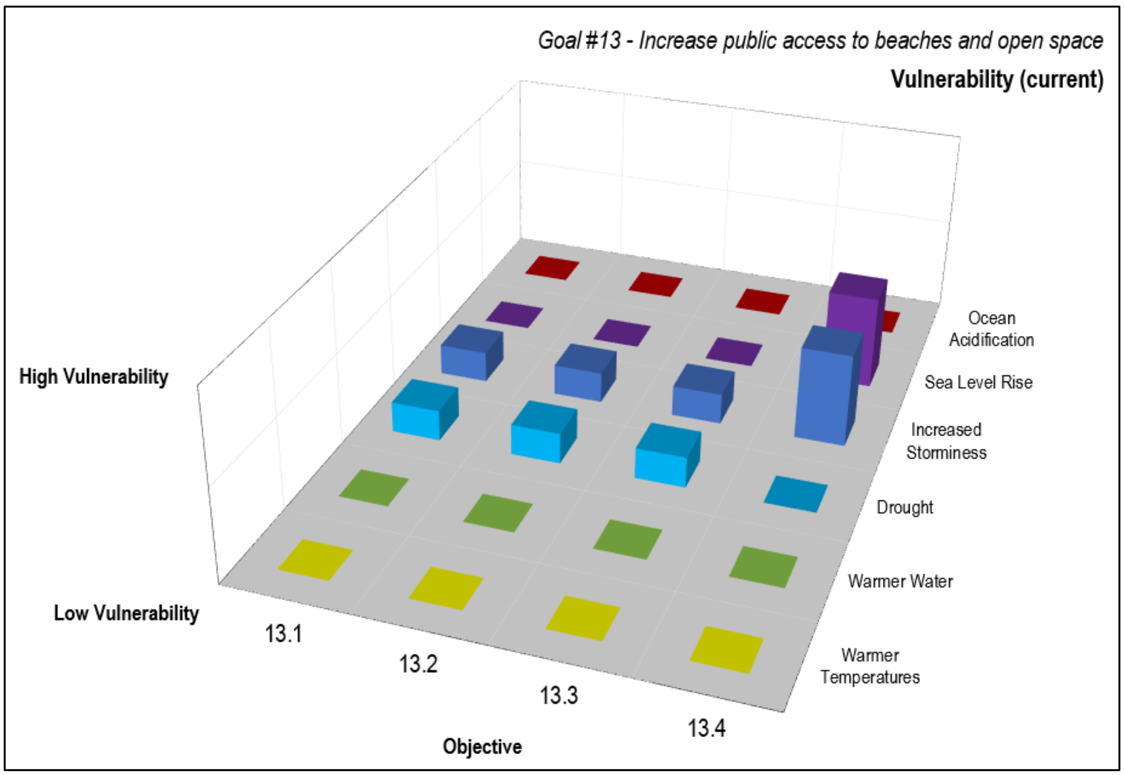


Figure 63. Goal 13 – Current Vulnerability.

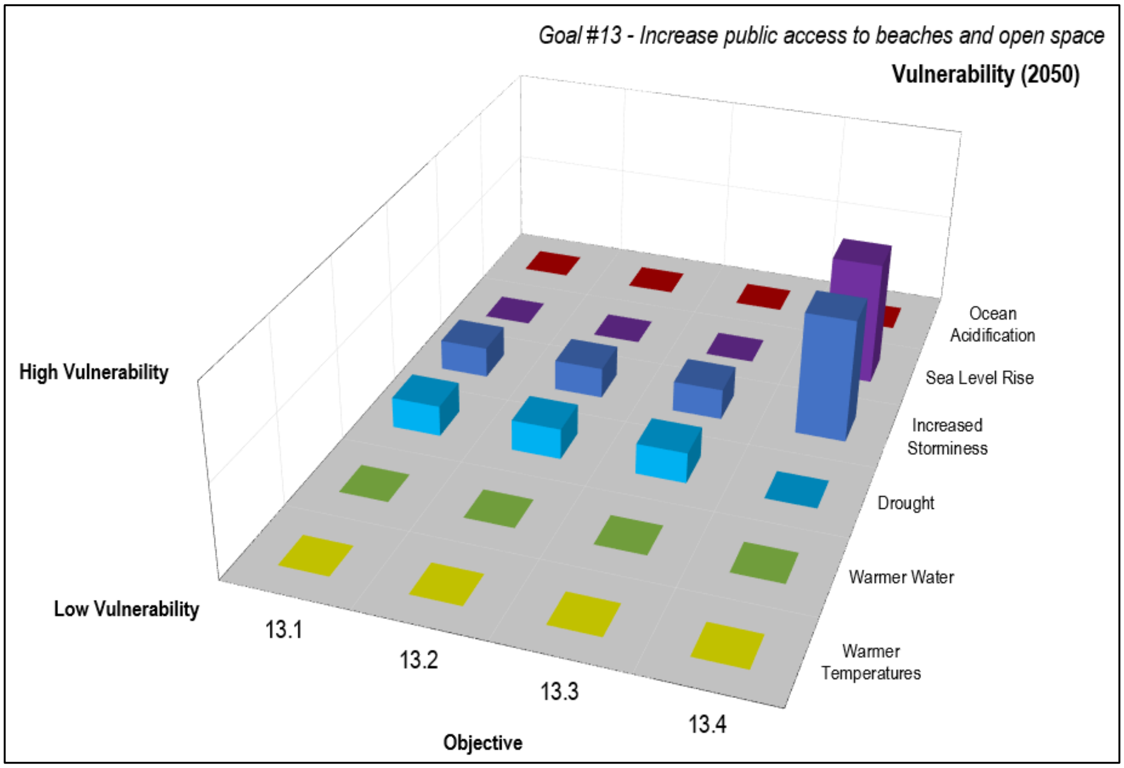


Figure 64. Goal 13 – 2050 Vulnerability.

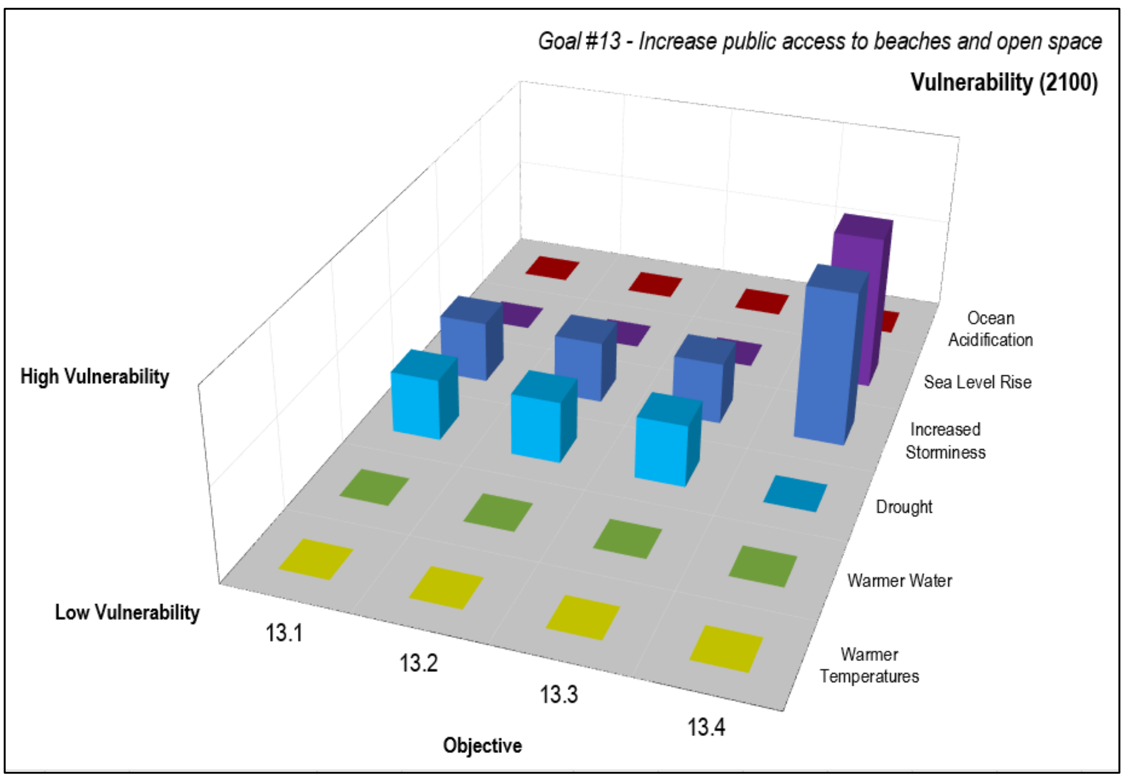


Figure 65. Goal 13 – 2100 Vulnerability.

Goal 14 – Conserve water and increase local water supply

Because the focus of this goal and affiliated objectives is water resource and supply, drought is undoubtedly the dominant climate stressor, followed by increased storminess that affects their achievement. Drought may actually generate more support for water conservation and increase demand for recycled water, but the predominant effect is to make increase of local water supply more difficult to achieve. Existing drought already greatly impacts local water supply and may get worse in the future, primarily because there will be a lack of water for conserving, recycling, and reuse. Increased storminess may reduce the local water supply capability as local storage facilities are not able to retain the storm water from the more intense but fewer storm events.

Warmer temperatures may have impacts including increased evaporation rates as well as increased water consumption. SLR may affect local water supply if desalination facilities along the coastline experience infrastructure or operational issues. Despite significant effort and progress made in water conservation and recycling amid current drought, the achievements have taken most, if not all low-hanging fruit, which can make further progress difficult, especially if drought and impacts of other climate stressors get worse over time.

Objective 14.1 - Increase local water supplies

This objective focuses on capturing, treating, and reusing storm water runoff as well as treating and reusing contaminated groundwater. These measures will primarily be affected by drought and increased storminess. Existing drought conditions have already greatly reduced the capacity of local water supply and the shortage will get worse with increased future drought conditions. There have been, and will continue to be if drought condition persists, a lack of water for replenishing local reservoirs and replenishment basins. Increased storminess in the form of less frequent but intense precipitation events may result in less overage capture and storage if local facilities are not able to retain water. Warmer temperatures may add more stress to the system because of the increased evaporation rate for water stored in local reservoirs and replenishment basins. Finally, there may be limited effects of SLR if construction of desalination facilities along the coastline is added to the equation; similarly, water tables may be impacted by salinity intrusion from SLR.

Objective 14.2 - Enhance water conservation

This objective focuses on efforts to reduce water demand through enhanced conservation measures, including both potable and landscaping uses. Increased drought and warmer temperatures may provide an opportunity to generate more support for water conservation; however, conservation becomes increasingly difficult when the most readily achievable conservation measures have already been implemented. Warmer temperatures combined with increased storminess (in the form of more intense but fewer precipitation events) may increase water consumption.

Objective 14.3 - Further increase wastewater recycling and reuse

This objective focuses on recycling sufficient amount of wastewater to replace current imported water supplies. Increased drought will have conflicting effects on wastewater recycling –it will increase demand for recycled water but at the same time reduce the total amount of wastewater available for treatment and recycling. This is already becoming a major challenge for POTWs in the region and will be more so in the future. Increased storminess may affect the amount of wastewater handled by POTWs, but the effects on the amount of recycled water may be limited.

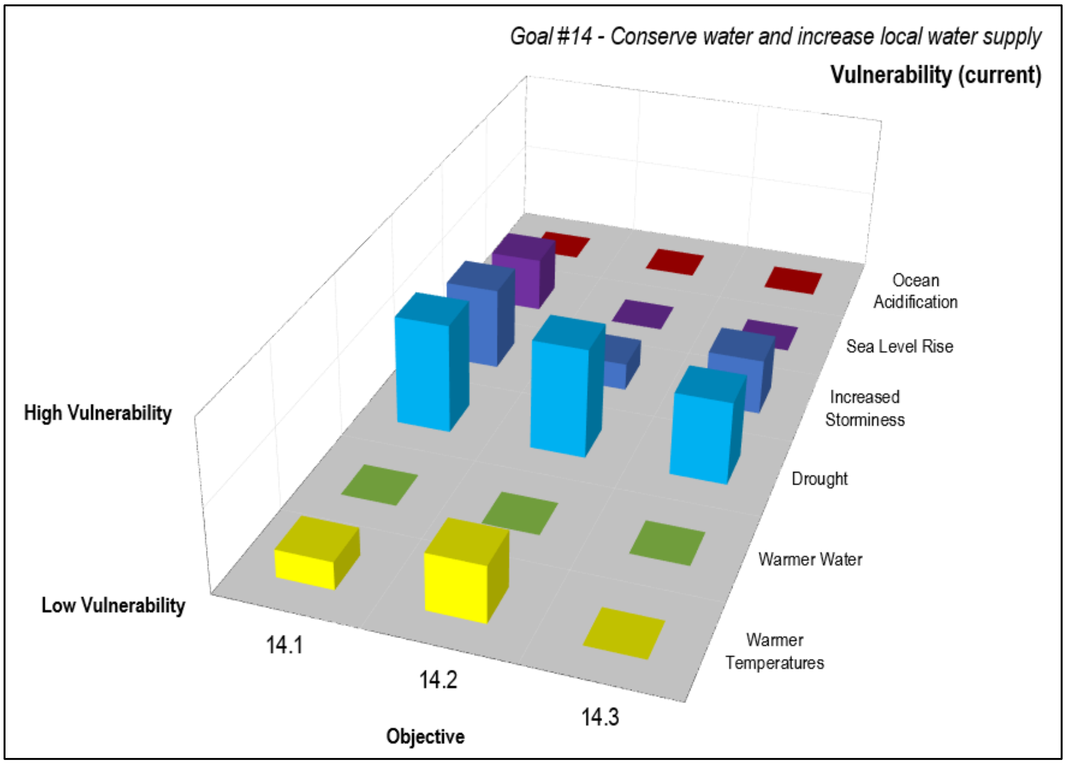


Figure 66. Goal 14 – Current Vulnerability.

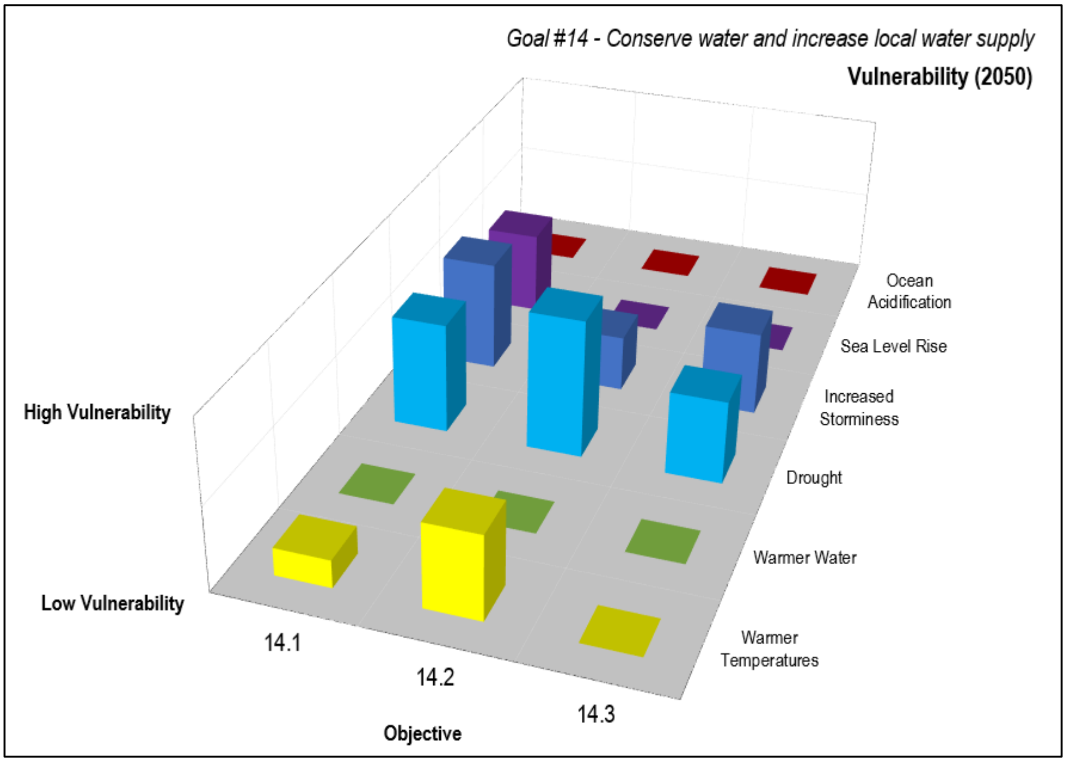


Figure 67. Goal 13 – 2050 Vulnerability.

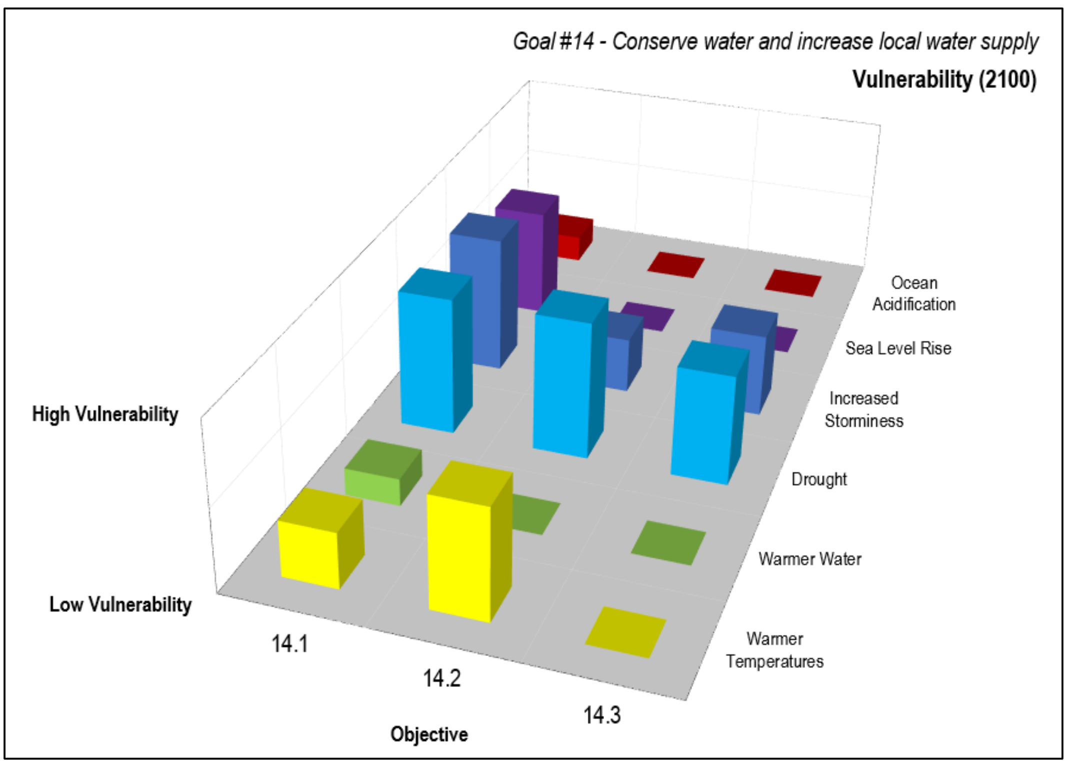


Figure 68. Goal 14 – 2100 Vulnerability.

Goal Level Analysis by Stressor

Methods

In addition to the objective-level vulnerability analysis (above), a goal-level vulnerability analysis was conducted at the request of the expert climate scientist panel. It is based on the percentage of the number of objectives within a goal with a particular ranking and is broken down by individual climate change stressor for ease of interpretation. For example, if seven out of seven objectives for Goal 4 all had a ranking of high adaptive capacity for warmer temperatures, then that bar would be shown as full green. Similarly, if four out of eight objectives had a low adaptive capacity for sea level rise and the other four had a medium ranking for adaptive capacity, then that bar would be indicated as half yellow and half red. This broad, categorical analysis allows for an evaluation across all goals together.

Each of the six climate change stressors are evaluated with a chart for adaptive capacity and a chart for sensitivity for all goals. Adaptive capacity and sensitivity were chosen to be represented at the goal-level because out of the whole vulnerability framework, they exhibited the most variability across goals and could be effectively compared. The rankings for exposure (current), exposure (2050), and exposure (2100) all exhibited similar trends at the goal-level, and generally increased over time. Note that adaptive capacity and sensitivity have opposite categorizations, e.g. red indicates a low level of adaptive capacity and a high level of sensitivity, as indicated in the figure legends in each chart.

The number of objectives for each goal included in the analyses is noted at top of each chart. An understanding of the total number of objectives assists in the interpretation of the trends. For example, a goal with only two objectives (i.e. Goal 3, 5, 8, 10, and 12) that showed a 50-50% split of medium and high adaptive capacity would indicate one objective with each ranking.

Results

In very general terms, the climate change stressor warmer temperatures exhibited a pattern of high adaptive capacity and low-to-medium sensitivity. Warmer water and OA are both ocean-influenced climate change stressors, and overarching patterns displayed by both were variable depending on whether the goal was associated with oceanic waters or not. For those goals coupled with the ocean (e.g. Goal 9), the adaptive capacity was shown as relatively low and the sensitivity was relatively high. Drought was one of the stressors with relatively high adaptive capacity throughout many of the goals, and storminess was highly variable. SLR, interestingly, had fairly high adaptive capacity for many of the goals, and a variable range of rankings for sensitivity. No consistent pattern is present across all goals for any individual climate change stressor for either adaptive capacity or sensitivity.

Warmer temperatures

Warmer temperatures showed a high adaptive capacity for many goals. Goals 6, 7, and 9, relating to slightly more sensitive habitat types, displayed a medium ranking for adaptive capacity. Only one objective in Goal 2 had a low adaptive capacity, due to its link to air quality and pollution; no other goals displayed that categorization. Most goals displayed a low or medium sensitivity to warmer temperatures. Goal 9 displayed a higher sensitivity, likely due to the intertidal-based objectives.

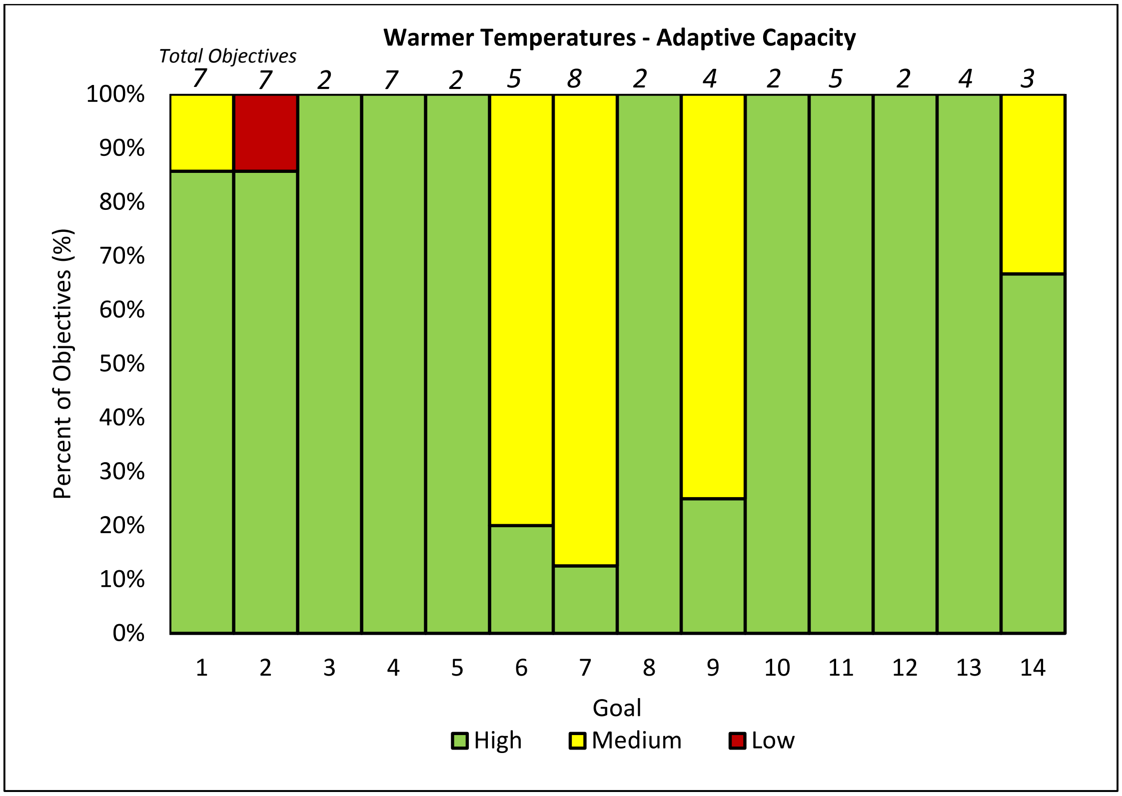


Figure 69. Adaptive capacity graph for all goals representing the percentage of number of objectives with ‘high’, ‘medium’, and ‘low’ rankings for warmer temperatures.

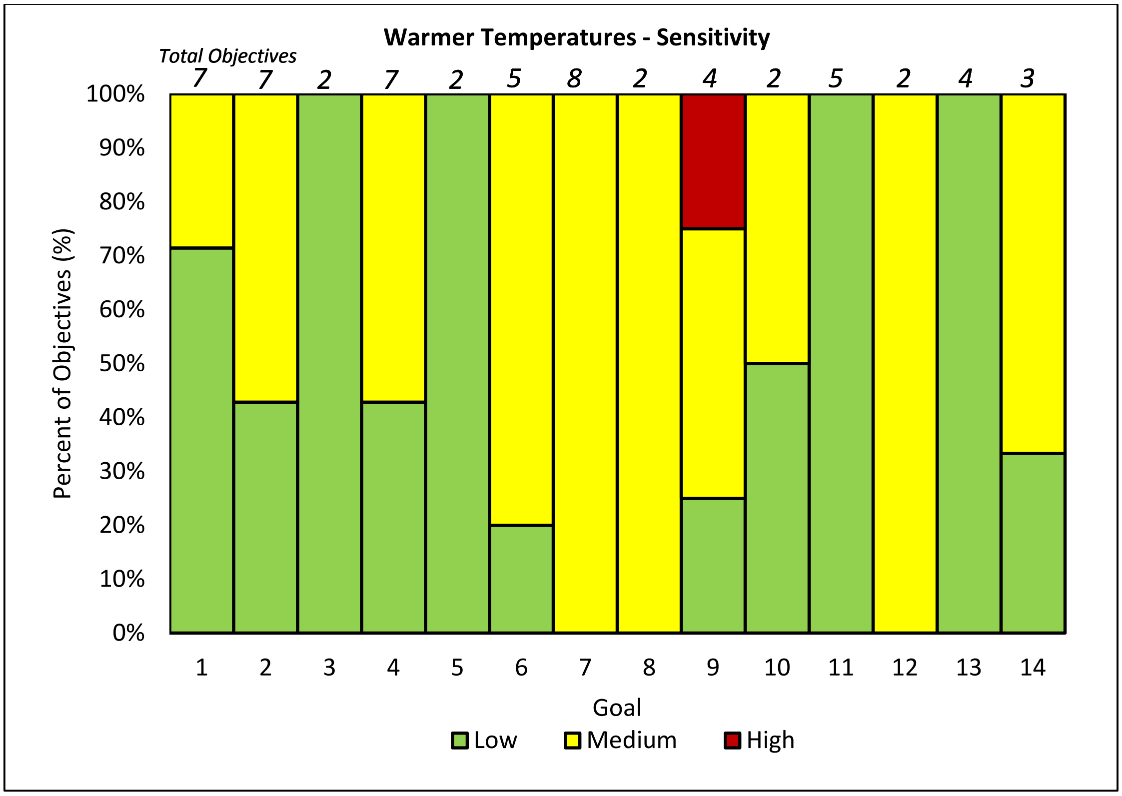
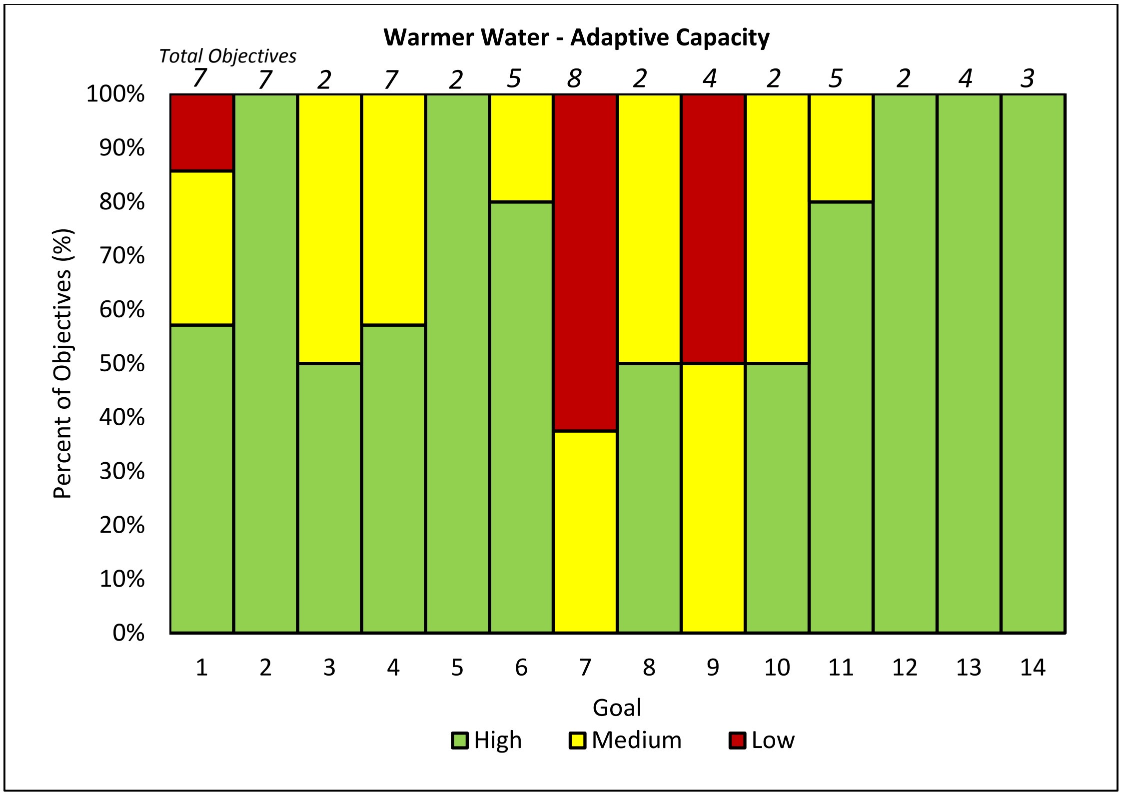


Figure 70. Sensitivity graph for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for warmer temperatures.

Warmer Water

Warmer water was variable based on goal for both adaptive capacity and sensitivity. This stressor displayed a low adaptive capacity for Goals 7 and 9 (wetlands and subtidal/intertidal restorations). These habitat types are more vulnerable to this climate change stressor. A high adaptive capacity was displayed across all objectives for Goals 2, 5, 12, 13, and 14. These goals are primarily tied to public access or land acquisition and are therefore more adaptable. Similarly, Goals 6 and 11 only had one objective each ranked as medium for adaptive capacity, the rest were high. Goals 7, 9, and to a lesser extent 4, 6, and 10 displayed a high sensitivity to warmer water, with Goals 2, 13, 14 displaying low sensitivity across all objectives.



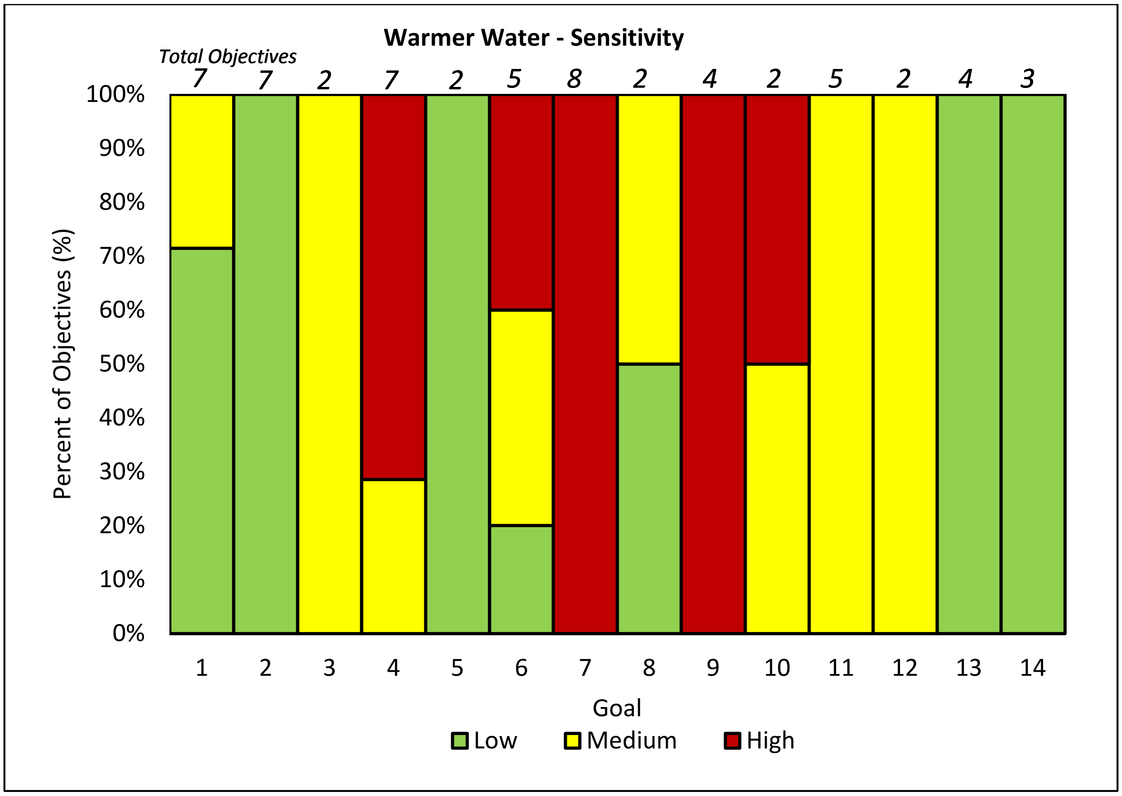


Figure 71. Adaptive capacity (top) and sensitivity (bottom) graphs for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for warmer water.

Increasing Drought

The patterns displayed by increasing drought indicated relatively high or medium adaptive capacity for many goals; conversely, many goals displayed high or medium rankings for sensitivity. Goal 3, 5, 7, 8, 12, and 14 all had at least 50% of their objectives ranked as high for sensitivity. These goals are primarily associated with restoration projects, water quality (Goal 3), or water conservation (Goal 14).

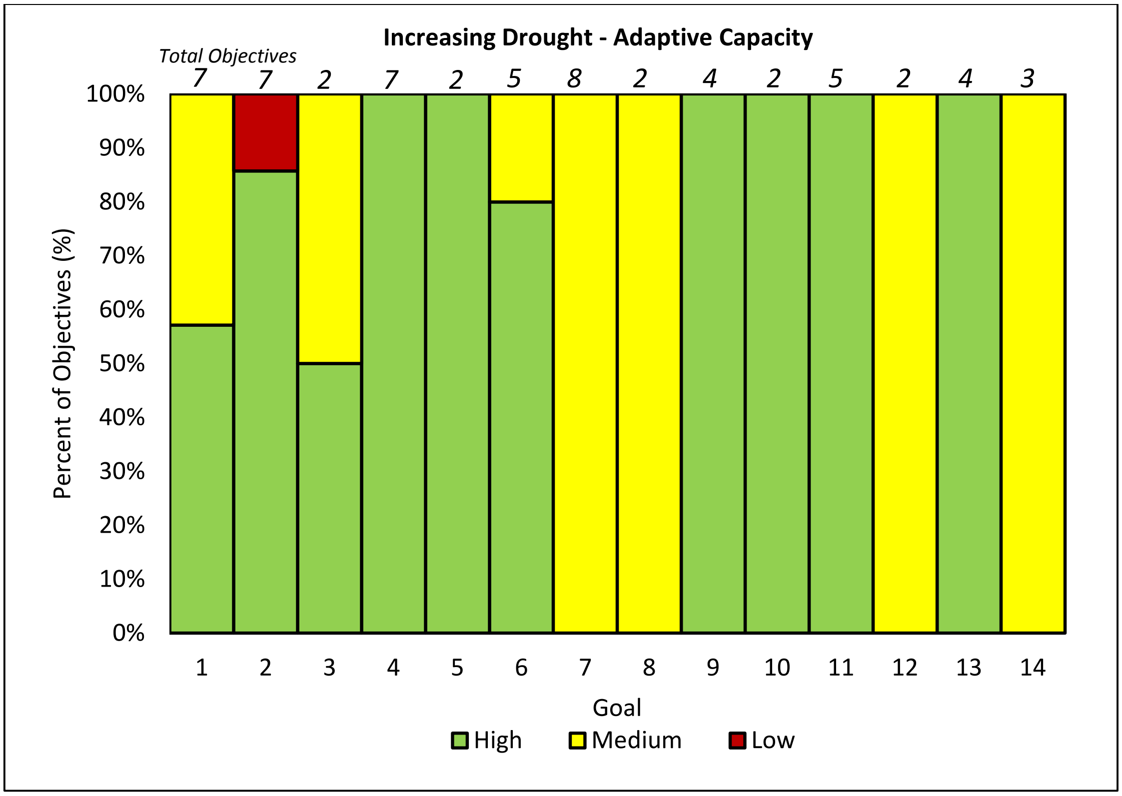


Figure 72. Adaptive capacity graph for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for increasing drought.

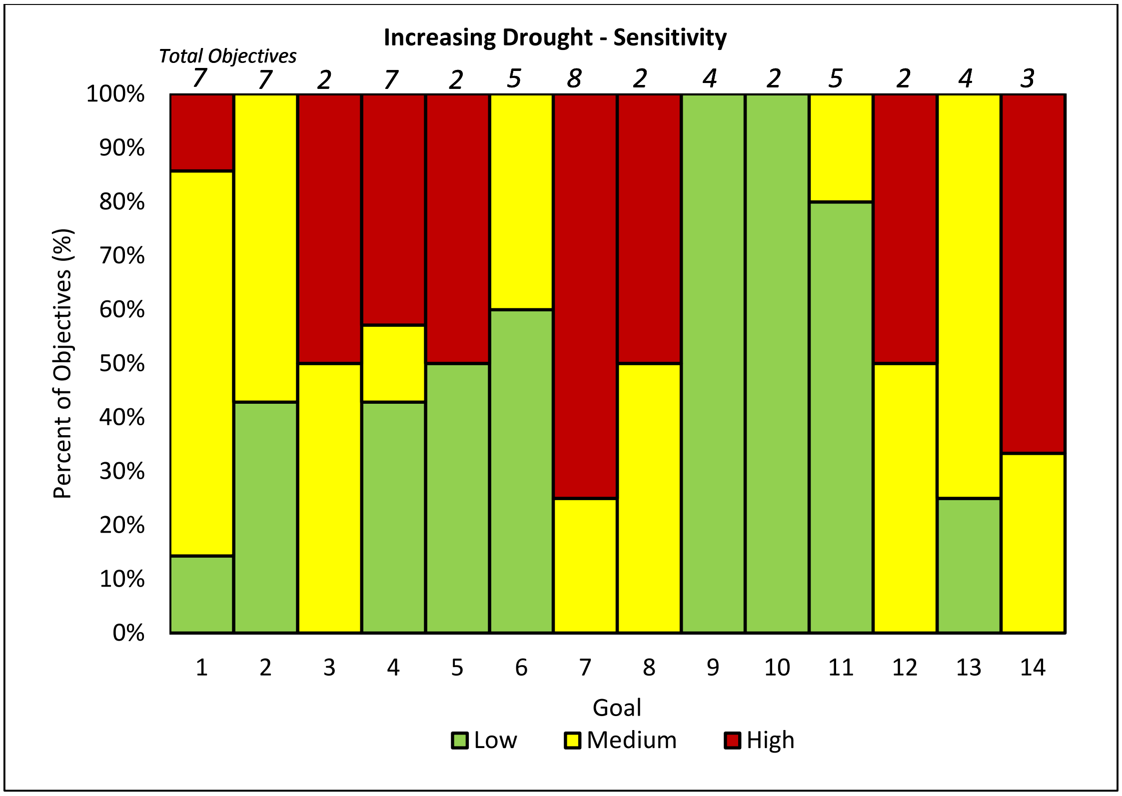


Figure 73. Sensitivity graphs for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for increasing drought.

Increasing Storminess

Goal-level trends for increasing storminess for adaptive capacity were split approximately in half between high and medium adaptive capacity. Conversely, but displaying a similar trends as increasing drought, many goals displayed high or medium rankings for sensitivity. Goals 8 and 12 both indicated a high sensitivity to increasing storminess for all objectives. Only a few goals displayed even a proportion of low sensitivity rankings (e.g. Goal 1, 2, 6).

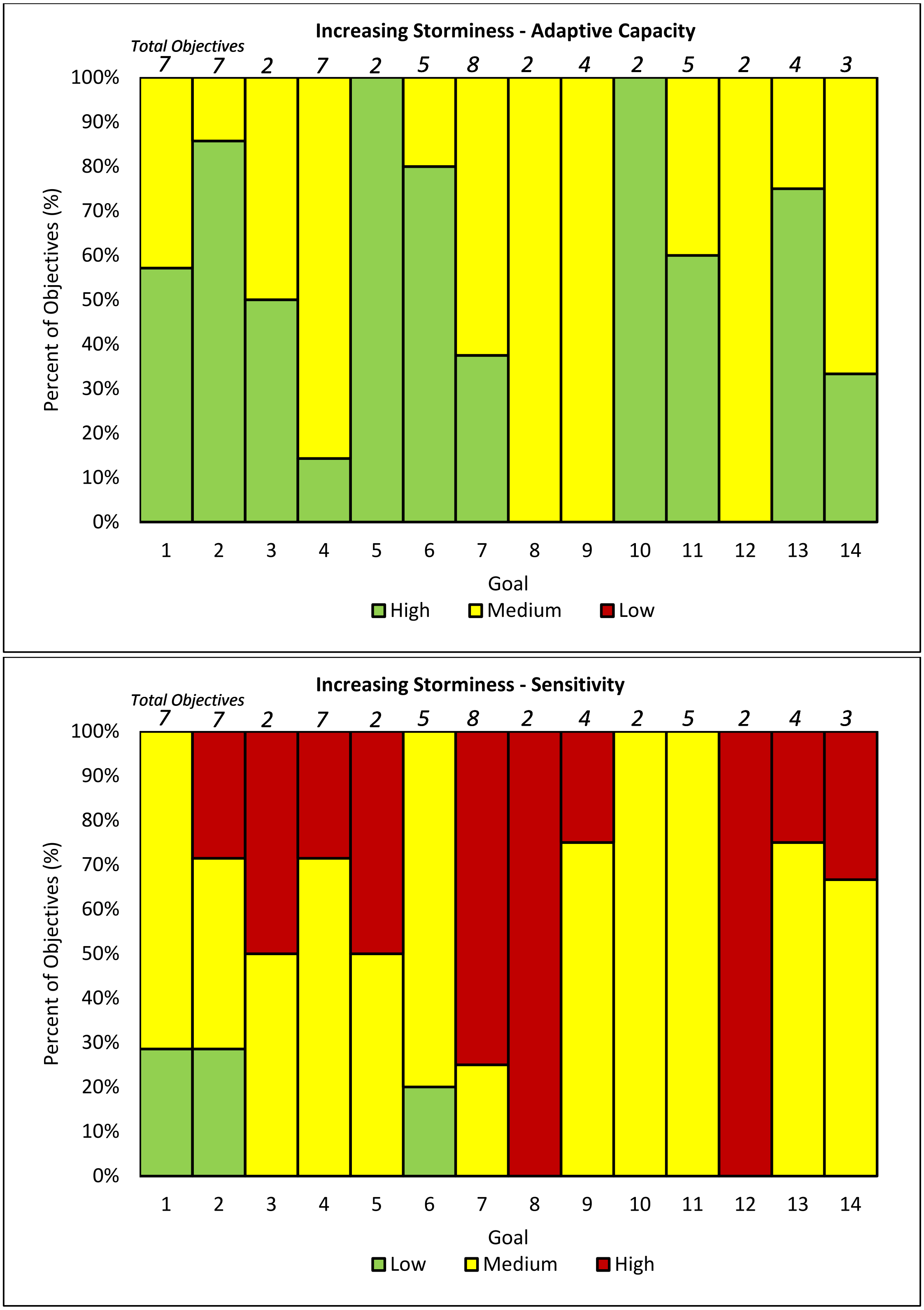


Figure 74. Adaptive capacity (top) and sensitivity (bottom) graphs for all goals representing the percentage of number of objectives with ‘high’, ‘medium’, and ‘low’ rankings for increasing storminess.

Sea Level Rise

Interestingly, only one goal (one objective) had a low adaptive capacity for SLR, Goal 7 (wetland restoration). Five goals displayed high adaptive capacity for all objectives (100%), including Goals 2, 3, 5, 6, and 10. Several goals had 50% or greater number of objectives with medium adaptive capacity, i.e. Goals 7, 8, 9, and 12. Five goals had high sensitivity for more than 25% of the number of objectives evaluated, i.e. Goals 4, 7, 8, 12, and 13. Goal 9 had half of the objectives display low sensitivity (subtidal habitats) and half display medium sensitivity (intertidal habitats).

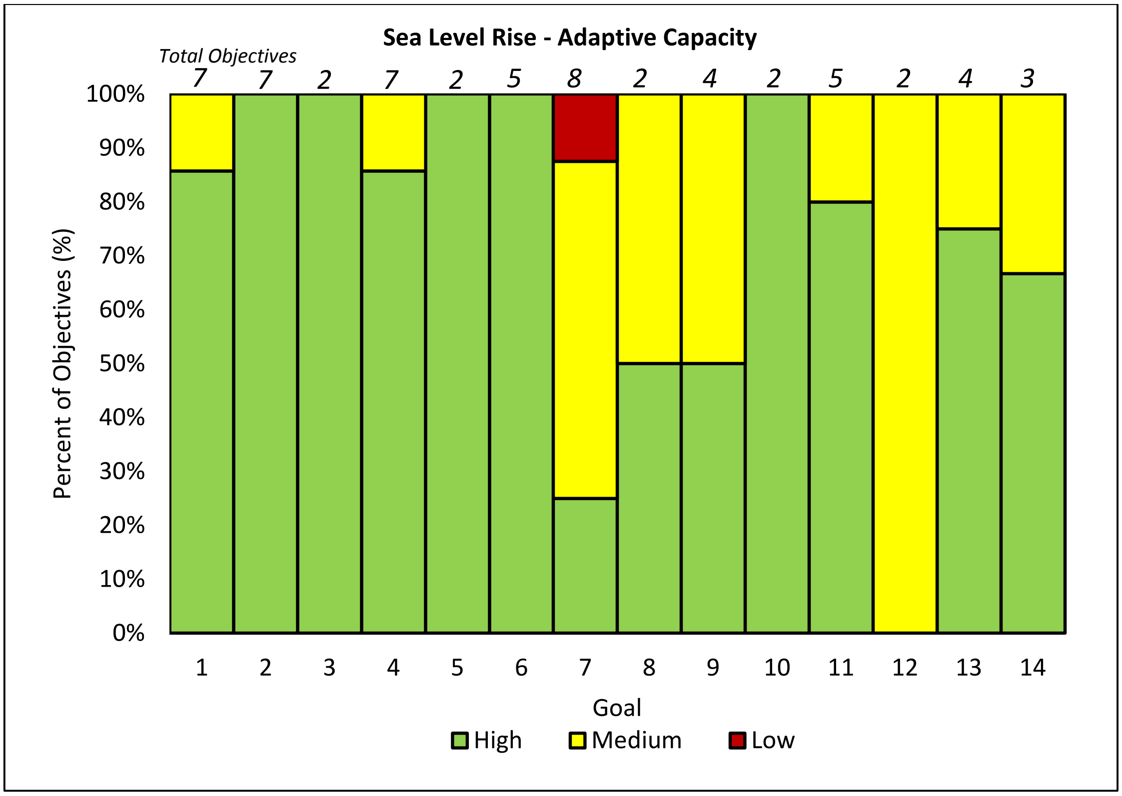


Figure 75. Adaptive capacity graph for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for sea level rise.

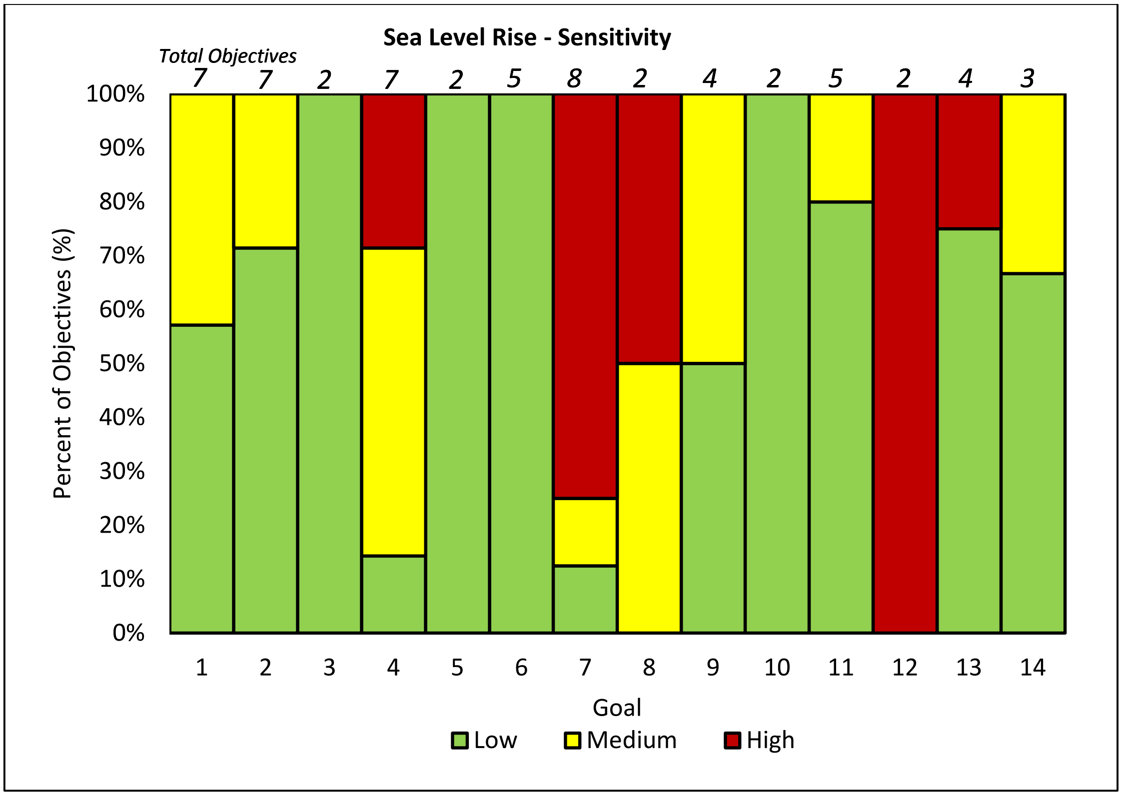


Figure 76. Sensitivity graph for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for sea level rise.

Ocean Acidification

Many of the goals that displayed high adaptive capacity and low sensitivity to OA were not related to the ocean or subtidal habitats, e.g. Goals 2, 5, 13, and 14. Several goals displayed at least 50% of the number of objectives with a low adaptive capacity, i.e. Goals 7, 8, and 9, and approximately the same percentage of objectives with high sensitivity. Many goals that had high sensitivity were also not able to adapt. These goals include restoration and protection efforts in intertidal, subtidal, or coastal habitats that may be affected by OA. As OA is a significant data gap for our regional climate change models, many of these assessments represent best professional estimates.

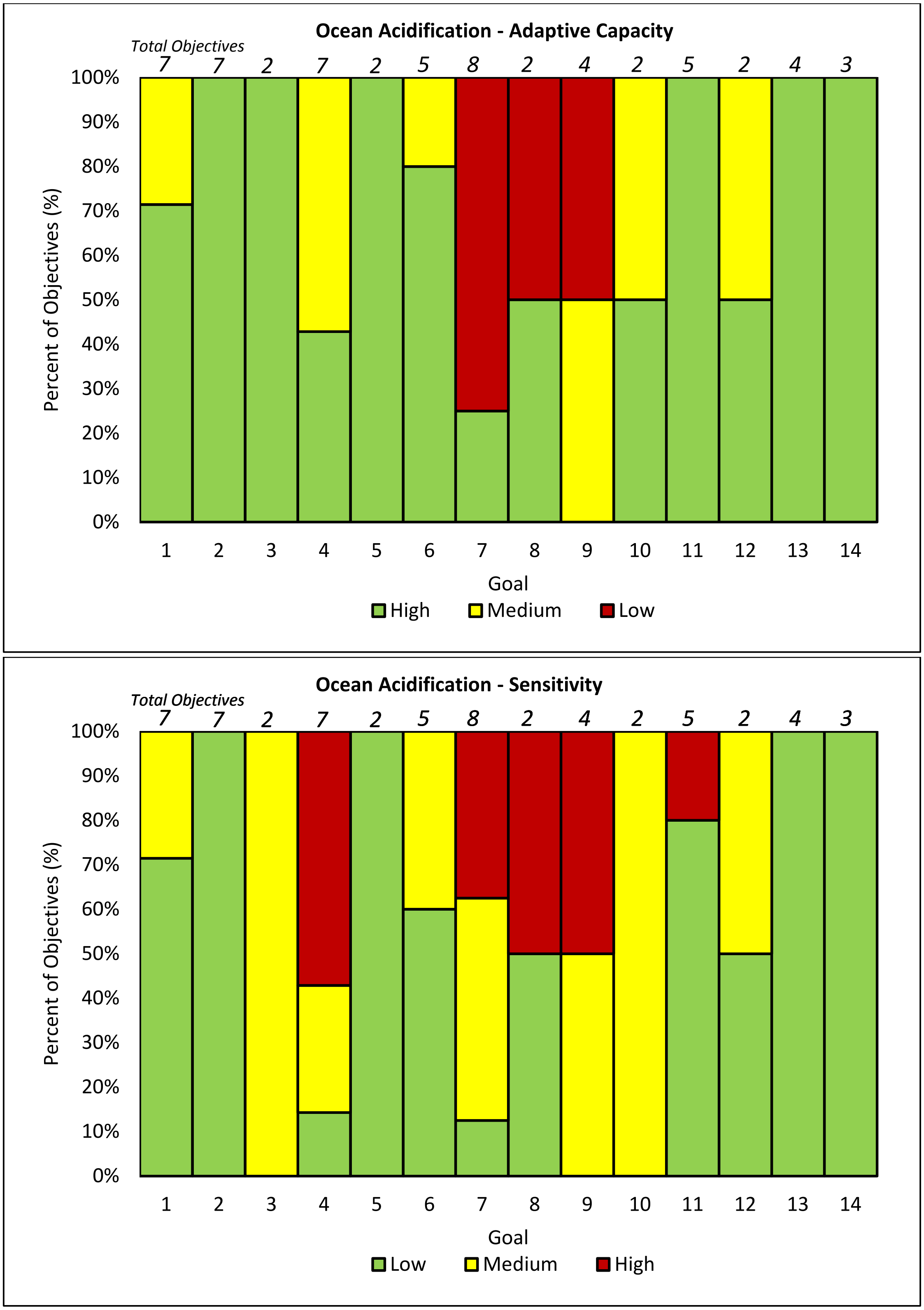


Figure 77. Adaptive capacity (top) and sensitivity (bottom) graphs for all goals representing the percentage of number of objectives with 'high', 'medium', and 'low' rankings for warmer temperatures.

Conclusions and Next Steps

BRP 2019 Update

Santa Monica Bay National Estuary Program was established in 1988 pursuant to Section 320 of the federal Clean Water Act (CWA), with the mission to develop and implement a Comprehensive Conservation and Management Plan (CCMP) to protect the water quality and natural resources of Santa Monica Bay. The CCMP for Santa Monica Bay, known as the Bay Restoration Plan (BRP) was approved by Governor Pete Wilson in December 1994 and by US EPA Administrator Carol Browner in 1995. The 1995 BRP identified almost 250 actions, including 74 priority actions, that address critical problems such as storm water and urban runoff pollution, habitat loss and degradation, and public health risks associated with seafood consumption and swimming near storm drain outlets. The BRP outlined specific programs to address the environmental problems facing the Bay and identified implementers, timelines, and funding needs.

Federal guidance for funding SMBNEP requires a periodic revision and/or update to the BRP to reevaluate priority issues and program priorities, and develop new approaches and actions deemed necessary to address emerging issues and challenges. The BRP was most recently updated in 2013 through an extensive public process and also included a check-up of progress made in the five years since the last revision in 2008. The 2013 BRP update incorporated new approaches and milestones to address remaining and emerging challenges, especially those related to a set of priorities identified by the stakeholders including the attainment of state and federal water quality goals, promotion of green infrastructure, wetland, stream, and marine habitat protection and restoration, fishery management and beneficial use of natural sediment. The update, for the first time, included several milestones specifically for addressing impacts of climate change, including calls for more vulnerability assessments and regional collaboration for developing adaptation plans to make the Bay "climate ready."

The next major revision of the BRP is scheduled to be completed by 2019. While no specific process has been laid out, it is anticipated that this will be a major revision similar to the one conducted in 2008, involving a comprehensive assessment of the progress up-to-date and future necessity and feasibility of all goals, objectives, and milestones in the current BRP. The content and results of this project, the Climate Change Vulnerability Assessment (CCVA) will play a central role in BRP revision. The report itself only represents the first phase of the CCVA. The subsequent step is to apply the findings from this project to conduct risk-based action planning and develop specific BRP revision recommendations.

CCVA Conclusions

Completion of the CCVA is not an end point for SMBNEP. In addition to results from this project directly informing and assisting in the revision of SMBNEP's BRP, the CCVA process also drew on staff within different teams to inform the assessment. Resultantly, staff were able to work in teams differently configured than normal. This led to more inclusion, and considerable ‘outside-the-box’ thinking. SMBNEP staff now share a more contextual perspective of the BRP goals and objectives generating interconnectivity in concept and in the near future in action. Additionally, the project helped staff become more aware of climate action planning in the Los Angeles region and local stressor models.

Experts from outside the organization were asked to apply their acumen to this assessment. The collaboration bore many benefits to the approach and content of the assessment. There was a great amount of enthusiasm for this project from those who volunteered their time. SMBNEP is optimistic that these individuals and their colleagues will actively engage in the second phase of this project.

In summary, the total number of risks identified as part of the BRP evaluation was 474 across 59 objectives. Objectives relating to land acquisition or education and outreach tended to have more opportunities identified and fewer overall risks, while those relating to coastal habitats that are vulnerable to many climate change stressors had significantly more. However, it is important to understand that these risk counts should not be evaluated quantitatively, which is why the expert climate scientist panel decided not to include the number of risks in the CCVA framework. The number of risks identified is not necessarily correlated to its overall vulnerability, as some identified risks may contribute disproportionately more to an objective’s vulnerability score. Some risks may eventually end up making some objectives infeasible or requiring immediate management action. The list of risks for each objective contained in Appendix B contributed to the overall vulnerability analysis, and some are discussed in more detail in the individual narratives found in the CCVA.

The overarching results from the vulnerability analysis and the interpretation of the visualizations was highly variable, and often individual and objective-dependent. Interpretations of the vulnerability of objectives that were broader often had more potential associated risks, and therefore a higher susceptibility to vulnerability from one or more climate change stressors. Objectives that were more specific may have had targeted associated risks identified as well as specific stressors. In general, outreach, education, and policy objectives were not very vulnerable and had a high associated adaptive capacity. Objectives or goals that were linked to a vulnerable habitat were often susceptible to multiple climate change stressors that increased the potential vulnerability of that habitat, e.g. objectives related to intertidal habitats and coastal wetlands. Additionally, objectives or goals that were related to a habitat with a low adaptive capacity to a particular stressor were often more vulnerable, e.g. kelp forests and their associated biological communities will have trouble adapting to OA and warmer waters, and the effects of both stressors may interact over time. OA was also identified in many cases as being a data gap, and more research is needed into this stressor to increase the confidence of the vulnerability evaluations for that stressor.

Next Steps – Climate Change Risk-Based Action Planning

EPA’s Being Prepared for Climate Change Workbook recommends NEPs and other organizations to go through a ten-step process for developing risk-based action plans. The ten-step process is divided into two phases – Step one through five in Phase 1 are associated with vulnerability analysis and step six through ten in Phase 2 are associated with action development. This project adapted the approach laid out in the Workbook and completed Phase 1, the vulnerability assessment of the BRP. The results of the vulnerability assessment presented in this report will be used to inform the next phase, risk-based action planning, which will be carried out prior to, and in conjunction with the planned BRP revision. The ultimate goal and final product of this process will be the newly revised BRP goals, objectives, and action items that either directly address climate change impacts, or are adaptive or sustainable under the stress of predicted climate change impacts.

Specifically during the next phase, BRP objectives identified to be moderately or highly vulnerable will be prioritized and further evaluated to determine whether their achievement are still realistic, and if they still are, whether the climate change impacts can be accepted, avoided, transferred, or mitigated. Alternative strategies and mechanisms for risk avoidance, transfer, and mitigation will be explored including, but are not limited to: revising implementation scale and timeline, revising and adopting new numerical targets and policies, revising existing or designing new project or monitoring plans, moving project locations, and/or scaling existing management practices. New, especially innovative actions specifically for both monitoring and mitigating climate change impacts may also be identified and evaluated as part of this process and new projects or programs may also be initiated.

Finally, adaptation strategies and mechanisms identified in the above steps will be used to inform the BRP revision. Those strategies and mechanisms will be further screened for their feasibility and those deemed most feasible and cost-effective will be incorporated into the newly revised BRP. Similar to approach taken during the vulnerability assessment phase, the evaluation and ultimate BRP revision will involve technical review provided by a panel of experts. The final stage of action selection and incorporation into the BRP will be done through broader engagement of NEP stakeholders. In addition to revisions of existing objectives and goals to incorporate climate change planning or actions, *new* objectives or milestones to specifically address individual problems or challenges from climate change stressors will also be considered in the BRP revision.

In addition to revising the BRP, it is anticipated that the results of the vulnerability assessment presented in this report and adaptation strategy developed during the planed next phase will have broader, regional implications. These products will help not only to inform similar planning process conducted by other agencies and organizations, but also to promote and facilitate more research and monitoring to provide essential data needed for climate change adaptation planning.

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Climate Change Tool Inventory							
Climate Change Tool	Type	Geographic Scale	Agencies Involved	Topic	Topics of Interest	Website	Time Scale
CropScape	Online	National	National Aeronautics and Space Administration, U.S. Department of Agriculture| National Agricultural Statistics Service	Agriculture/cropland/estimate major commodities and produce digital, crop-specific, categorized geo-referenced output products	Agriculture	http://nassgeodata.gmu.edu/CropScape/	pa: 1997-2015
Soil Climate Analysis	Online	National	U.S. Department of Agriculture - Natural Resources Conservation Service - National Water and Climate Center	Agriculture/soil/precipitation, air temperature, relative humidity, wind speed and direction, barometric pressure, snowwater content, snow depth, soil moisture, soil temperature	Agriculture	http://www.wcc.nrcs.usda.gov/scan/	pa: 2012-2016
VegScape—Vegetation Condition Explorer	Online	National	U.S. Department of Agriculture - National Agricultural Statistics Service - George Mason University - Center for Spatial Information and Science Systems	Agriculture/cropland/vegetation condition/NDVI, VCI, RVCI, RMVCI, MVCI index	Agriculture	http://nassgeodata.gmu.edu/VegScape/	pa: 2000-2016
CalWeedMapper	Online	California	California Invasive Plant Council (Cal-IPC)	Biodiversity/Invasive species/invasive plant distribution	Biodiversity	http://calweedmapper.cal-ipc.org	pa: 2010-2016, f: 2050
Modeling Bird Distribution Responses to Climate Change	Online	California	Point Blue Conservation Science	Biodiversity/bird and vegetation distribution responses to climate change/temperature, precipitation, Vegetation, Soil permeability, Soil PH, Soil available water capacity (AWC)	Biodiversity	http://data.prbo.org/apps/bssc/index.php?page=bird-distribution-map	pa: 1971-2000, f: 2038-2070
Bioidiversity Information Serving Our Nation (Inventory)	Online	National	U.S. Geological Survey (USGS)	Biodiversity/species occurrence data, records of an organism at a particular time in a particular place	Biodiversity	http://bison.usgs.ornl.gov/#home	Multiple time scale
Data Basin (Inventory)	Online	National	Conservation Biology Institute	Biodiversity/precipitation, invasive species distribution, biodiversity Conservation	Biodiversity	http://databasin.org/	Multiple time scale
Evironmental Sensitivity Index	Online	National	National Oceanic and Atmospheric Administration	BIodiversity/species distribution/Birds, fish, habitats, invertebrates, marine mammals	Biodiversity	http://egisws02.nos.noaa.gov/esi/esi.html	pa: 1981-2016
California Climate and Hydrology Change Graphs	Online	California	Climate Commons	Climate change/historical trend on recharge, runoff, max/min month temperature, actual/potential evapotranspiration, soil storage, climatic water deficit	Climate Change I	http://climate.calcommons.org//aux/BCM_WS_graph/	pa: 1931-2010, f: 2099

Climate Change Tool Inventory							
Climate Change Tool	Type	Geographic Scale	Agencies Involved	Topic	Topics of Interest	Website	Time Scale
Climate Inspector	Online	Global	National Center for Atmospheric Research	Climate change/Air Temperature change, Precipitation level	Climate Change I	https://gisclimatechange.ucar.edu/inspector	pa: 2010-2016, f: 2050
Climate Outlooks	Online	National	NOAA- National Oceanic and Atmospheric AdministrationClimate Prediction Center	Climate Change/air temperature change and forecast, precipitation level, heat, drought, wind chill outlook	Climate Change I	http://www.cpc.ncep.noaa.gov/	Real time, f: 7 days
ClimateData.us	Online	National	HabitatSeven	Climate Change/air temperature change and forecast, precipitation level	Climate Change I	http://www.climatedata.us/	pa: 1950-2005, f: 2100
Climate Wizard	Online	National	The Nature Conservancy	Climate Change/Average air temperature change and forecast, precipitation level	Climate Change I	http://climatewizard.org/	pa: 1960-2016, f: 2080
CMIP Climate Data Processing Tool	Excel	National	U.S. Department of Transportation	Climate Change/min&max air temperature change and forecast, precipitation level	Climate Change I	http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/	pa: 1961-2000, f: 2046-2065, 2081-2100
CMIP5 Global Climate Change Viewer (GCCV)	Online	Global	U.S. Geological Survey|Regional and Global Climate	future temperature and precipitation changes	Climate Change I	http://regclim.coas.oregonstate.edu/gccv/	1998-2004
Economics: National Ocean Watch (ENOW) Explorer	Online	National	National Oceanic and Atmospheric Administration (NOAA)	Coastal living resources & Offshore mineral construction	Climate Change I	http://coast.noaa.gov/enowexplorer/	2005-2013
National Climate Change Viewer	Online	National	USGS	future temperature and precipitation changes; change in climate and water balance	Climate Change I	http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp	pa:1950-2005 f:2099
State Temperature Trends	Online	California	National Oceanic and Atmospheric Administration- National Centers for Environmental Information	annual and seasonal temperature change and trend	Climate Change I	http://www.ncdc.noaa.gov/temp-and-precip/state-temps/	1895-2015
Climatology Data	Online	National	UC Davis Bodega Marine Laboratory	Seawater Temperature	Climate Change I	http://bml.ucdavis.edu/boon/data_clim_46013.html	Multiple models with multiple time scale
California's Coast in an El Nino Year	Online	Califronia	NOAA	Seawater Temperature, El Nino	Climate Change I	http://www.cencoos.org/learn/elnino	Multiple models with multiple time scale
Climate Explorer	Online	National	U.S. Climate Resilience Toolkit	Temperature, Precipitation, Sea Level Rise, People and Assets Impacted.	Climate Change I & II	http://toolkit.climate.gov/climate-explorer/?tp=g_a&center=-10500000.0,4500000.0&zoom=4&p=L	pa:1940-now
Advanced Hydrologic Prediction Service	Online	National	National Weather Service	Temperature, Precipitation, River Flood Risk	Climate Change I & II	http://water.weather.gov/ahps/forecasts.php	real time, f: 4.5 days

Climate Change Tool Inventory							
Climate Change Tool	Type	Geographic Scale	Agencies Involved	Topic	Topics of Interest	Website	Time Scale
Cal-Adapt Climate Tools	Online	California	Cal-Adapt	Temperature, Snowpack, Precipitation, Sea Level Rise, Wildfire	Climate Change I & II	http://cal-adapt.org/tools/	Multiple models with multiple time scale
Climate at a Glance	Online	National	National Centers for Environmental Information	Temperature, Precipitation, Drought	Climate Change I & II	http://www.ncdc.noaa.gov/cag/	pa:1895-2016
Climate Adaptation Knowledge Exchange (CAKE)	Online	Global	EcoADapt	Climate adaptation	Climate Change II	http://cakex.org	Multiple models with multiple time scale
Ocean Acidification Hotspots	Online	National	Natural Resources Defense Council	Coastal Acidification	Climate Change II	http://www.nrdc.org/oceans/acidification-hotspots/default.asp	f:2099
Coastal Resilience	Online	National	The Nature Conservancy, The Natural Capital Project, NOAA, U.S. Geological Survey	Sea Level Rise, Coastal Erosion, Biodiversity Conservation, Energy Facilities, Land-Based Transportation	Climate Change II	http://maps.coastalresilience.org/network/	
Historical Hurrican Tracks	Online	National	Digital Coast	Hurricane Tracks	Climate Change II	https://coast.noaa.gov/hurricanes/	pa:1840-now
Inundation Analysis Tool	Online	Global	National Oceanic and Atmospheric Administration (NOAA)	Sea-level rise	Climate Change II	http://tidesandcurrents.noaa.gov/inundation/	Santa Monica Bay Station: 1975.9.20-1975.11.1
MATCH	Online	Global	United States Global Change Research Program	Human Health	Climate Change II	http://www.match.globalchange.gov/geoportal/catalog/main/home.page	
National Assessment of Coastal Vulnerability to Sea Level Rise	Online	National	USGS	tidal range, wave height, coastal slope, shoreline change, geomorphology, and historical rate of relative sea level rise	Climate Change II	http://woodshole.er.usgs.gov/project-pages/cvi/	
NOAA Tides & Currents	Online	National	United States Department of Commerce - National Oceanic and Atmospheric Adiministration	Coastal Flood Risk	Climate Change II	http://tidesandcurrents.noaa.gov	pa:1920- now
Nonpoint-Source Pollution and Erosion Comparison Tool	Software	National	National Oceanic and Atmospheric Administration	Coastal Flood Risk - Coastal Erosion	Climate Change II	https://coast.noaa.gov/digitalcoast/tools/opennspect	
Sea Level Change Curve Calculator	Online	National	U.S. Army Corps of Engineers - Responses to Climate Change Team	Coastal Flood Risk - Sea Level Rise	Climate Change II	http://www.corpsclimate.us/ccaceslcurves.cfm	pa:1986-2015 f:2100
Sea Level Rise and Coastal Flood Web Tools Comparison Matrix	Online	Regional	National Oceanic and Atmospheric Administration	Coastal Flood Risk - Sea Level Rise & Storm Surge	Climate Change II	http://sealevel.climatecentral.org/matrix/	
Sea Level Trends	Online	Global	National Oceanic and Atmospheric Administration-Center for Operational Oceanographic Products and Services (CO-OPS)	Sea Level	Climate Change II	http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml	pa:1854-2006
Surging Seas—Sea Level Rise Analysis	Online	Global	Climate Central	Sea Level Prediction & Risk Zones	Climate Change II	http://sealevel.climatecentral.org/	

Climate Change Tool Inventory							
Climate Change Tool	Type	Geographic Scale	Agencies Involved	Topic	Topics of Interest	Website	Time Scale
Water Evaluation And Planning (WEAP)	Online	National	Stockholm Environment Institute (SEI)	Integrated Freshwater resources planning	Freshwater Resources	http://www.weap21.org/index.asp?action=200	
National Water Information System: Mapper	Online	National	United States Geological Survey	Ecosystem Vulnerability - Water Resources	Freshwater Resources	http://maps.waterdata.usgs.gov/mapper/index.html	multiple sites with multiple time scales
U.S. Drought Portal	Online	National	U.S. Department of Agriculture - U.S. Department of Energy - U.S. Department of Health and Human Services	The U.S. Drought Monitor and Data	Freshwater Resources	http://droughtmonitor.unl.edu/Home.aspx	pa:2000 - now
TreeFlow: Streamflow Reconstructions from Tree Rings	Online	Regional	Climate Assessment for the Southwest (CLIMAS)-Western Water Assessment	Historical Streamflow	Freshwater Resources	http://treeflow.info/data	multiple water flows with multiple starting years - 2012
Snow Telemetry (SNOTEL) Data	Software	Global	U.S. Department of Agriculture | Natural Resources Conservation Service-National Water and Climate Center	Estimate of the Amount of Water Contained in Snowpack	Freshwater Resources	http://www.wcc.nrcs.usda.gov/snotel/earth/index.html	1981-2010
Future San Francisco Bay Tidal Marshes	Online	San Francisco Bay and Estuary	Point Blue Conservation Science	Marsh Elevation, Bird Density, Zonation Results	Marine Habitat & Wildlife	http://data.prbo.org/maps/sfbmap_html.php	2010/2030/2050/2070/2090/2110
Simple Population Model Tool for Four Marsh Bird Species	Online	San Francisco Bay and Estuary	Point Blue Conservation Science, CA LCC	Birds, Tidal marshes	Marine Habitat & Wildlife	http://data.prbo.org/apps/sfbslr/index.php?page=lcc-page	
Essential Fish Habitat Mapper	Online	Global	National Oceanic and Atmospheric Administration	Fish Habitat	Marine Habitats & Wildlife	http://www.habitat.noaa.gov/protection/efh/efhmapper/index.html	
California Communities Environmental Health Screening Tool-CalEnviroScreen 2.0	Online	California	Office of Environmental Health Hazard Assessment	Pollution	Pollution	http://www.oehha.ca.gov/ej/ces2.html	
ForWarn Forest Change Assessment Viewer	Online	National	United States Department of Agriculture	Forest	Terrestial Habitat Loss	http://forwarn.forestthreats.org/fcav2/	multiple layers with multiple time scales
Web Soil Survey (WSS)	Online	National	USDA	soil survey information	Terrestial Habitat Loss	http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx	
Climate Change and Carbon Tools	Online	National	United States Department of Agriculture	Forest Planning	Terrestrial Habitat Loss	http://www.fs.usda.gov/ccrc/tools	multiple tools with multiple time scales
Template for Addressing Climate Change Impacts and Management Options (TACCIMO)	Online	National	United States Department of Agriculture	Forest Planning	Terrestrial Habitat Loss	http://www.forestthreats.org/research/tools/taccimo	
Actions Likely to Increase Plant and Animal Resilience to Climate Change	Online	California	The Nature Conservancy	Actions likely to increase plant and animal resilience to climate change	Terrestrial Habitat Loss	http://tnc.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=f93d63623bf6441390d418de5f9444ab	
Data Basin	Online	Global	Conservation Biology Institute	Conservation Planning	Terrestrial Habitat Loss	http://databasin.org/maps/11e0a90b800a41819461bd48702df2db/active	2000-2007

Climate Change Tool Inventory							
Climate Change Tool	Type	Geographic Scale	Agencies Involved	Topic	Topics of Interest	Website	Time Scale
Desert LCC Conservation Planning Atlas	Online	Southwest United States	Desert LCC	Desert ecosystems	Terrestrial Habitat Loss	http://dlcc.databasin.org/	multiple datasets
Coastal Change Analysis Program(C-CAP) Land Cover Atlas	Online	National	National Oceanic and Atmospheric Administration	Land Cover	Terrestrial Habitat Loss	https://coast.noaa.gov/ccapatlas/	1996-2011
National Gap Analysis	Online	National	USGS	status, range, and distribution of plant communities and/or animal species' habitats	Terrestrial Habitat Loss	http://gapanalysis.usgs.gov/viewers/	
Alien Forest Pest Explorer	Online	National	U.S. Forest Service-Northern Research Station-University of Vermont-Spatial Analysis Lab	Pest Range, Forest Damaging	Terrestrial Habitat Loss	http://foresthealth.fs.usda.gov/portal/Flex/APE	
Climate Change and Extreme Weather Vulnerability Assessment Framework	Journal	National	The Federal Highway Administration	Transportation	Urbanization	http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications/vulnerability_assessment_framework/index.cfm	
U.S. Energy Mapping System	Online	National	U.S. Energy Information Administration	Electricity Usage by Cities	Urbanization	http://www.eia.gov/state/maps.cfm?src=home-f3	1960-2014
ScienceBase	Online	National	U.S. Geological Survey (USGS)	Spatial data		https://www.sciencebase.gov/	
EnviroAtlas	Online	National	United States Environmental Protection Agency (EPA)	Biodiversity conservation, climate stabilization, air, water resources		http://enviroatlas.epa.gov/enviroatlas/InteractiveMapEntrance/InteractiveMap/index.html	
California Swell Model Archive	Online	California	UC Davis Bodega Marine Laboratory	Wave	Marine Habitats & Wildlife	http://cdip.ucsd.edu/?nav=recent&sub=nowcast&units=metric&tz=UTC&pub=public&map_stati=1%2C2%2C3&xitem=get_model	
Pacific Rocky Intertidal Monitoring: Trends and Synthesis	Online	California	UC Santa Cruz Ecology and Evolutioanry Biology Department	Invasive Species	Marine Habitats & Wildlife	http://gordon.science.oregonstate.edu/marineinvasive/map.html	1990-2016

Goal #1

Bay Restoration Plan Climate Change Risks

Water Quality

Goal #1 - Improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state regulatory framework

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
1.1 Attain water quality goals in TMDLs adopted for 303(d) listed waterbodies in the Santa Monica Bay watershed.	x	x					May lead to lower eutrophication threshold and tightening of TMDL loading limits under current TMDL	R
	x	x					May lead to change in pathogen survival rate and change in TMDL loading limits	R
			x				May lead to more concentrated pollutant discharges and nutrient, metal, and toxic TMDLs may require revisions to load allocations	R
		x		x			May lead to more exceedance of bacteria load allocation (# of days) under current TMDLs	R
						x	Nutrient loading may exasperate acidification of coastal water and lead to tightening of allocations under current TMDLs	R
					x		May increase vulnerability of beach front water diversion and treatment facilities	
			x	x			May increase stream erosion and sedimentation and impact benthic inverts	R
			x				May lead to fewer bacterial load exceedance days due to fewer storm events	O
1.2 Eliminate and prevent water and sediment quality impairments from both point and nonpoint sources for waterbodies in the Malibu Creek watershed	x	x	x	x		x	Impacts and changes to benthic community	R
	x	x		x			May increase bacteria loading	R
	x	x	x				Increased eutrophication potential	R
	x	x	x				May impact dissolved oxygen levels in water	R
			x	x			Increased erosion and or sediment deposition	R
	x	x	x	x			Species may have different tolerance regimes	R
			x				May increase risk of wildfires and subsequent vegetation loss and increase in erosion and sedimentation potential	R
				x			Increase in turbidity / resuspended sediment / stratification / decrease in water clarity	R
					x		Greater coastal wetland loss may occur or increase in salinity intrusion up-creek	R
	x	x	x	x	x		Watershed impacts and change in dry and wet weather input to Malibu Creek may have subsequent impacts to lagoon flora and fauna composition	R
	x	x	x			x	Invasion of non-native species and/or changes in species composition	R
		x					May decrease bacteria loading	O

Goal #1

Bay Restoration Plan Climate Change Risks

Water Quality

Goal #1 - Improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state regulatory framework

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
1.3 Eliminate biological impacts of water intake and discharge from coastal power and desalination plants.		x					Phase out of once-through cooling will reduce discharge of warmer water, and the warming of ocean water, but likely in very limited local scale	R
						x	May affect brine discharge as a result in strength and type of chemical reactions	R
					x		May impact shoreline power generation and directly increase the vulnerability of coastal desalination facilities	R
			x				More severe drought may increase demand for desalination, increasing the potential water intake and impingement	R
1.4 Eliminate all harmful discharges to Areas of Special Biological Significance (ASBS)				x			May impact discharge to streams and increase impacts related to extreme events	R
			x				More severe drought may increase the need to relax the discharge prohibition in order to maintain minimum stream flow needed for the health of riparian habitats	R
			x				More severe drought may lead to more water conservation and reduction of non-storm water discharge	O
1.5 Institute a reliable regional funding mechanism for storm water quality improvement			x				More funding, thus larger assessment fee may be needed to treat, store, and infiltrate more storm water under increasing drought condition	R
				x	x		More funding, thus larger assessment fee may be needed to address the impacts of increasing storminess on the flood control infrastructure	R
1.6 Reduce and prevent non-storm water runoff from urban land uses			x				More severe drought may increase the need to relax the discharge prohibition in order to maintain minimum stream flow needed for the health of riparian habitats	R
			x				More severe drought may lead to more water conservation and reduction of non-storm water discharge	O
1.7 Eliminate nonpoint pollution from on-site wastewater disposal systems (OWDSs)				x	x		Increased inflow to the treatment facility due to rain water seepage into the sewer system	R
				x	x		OWTS failures due to flooding / sea level rise	R
			x				Increased drought may reduce water use and the needed capacity of the treatment facility	O
			x				Increased drought may reduce water use and the need for OWTS maintenance	O

Bay Restoration Plan Climate Change Risks

Goal #2

Water Quality

Goal #2 - Improve water quality through pollution prevention and source control

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
2.1. Increase pervious surfaces and storm water infiltration where feasible by supporting green infrastructure	x		x	x			Impacts to vegetation / flowering season	R
				x			Need more and accelerated implementation of LID / green infrastructural projects to capture more storm water	R
			x	x			Increased non-native vegetation invasion in rain gardens	R
			x				Impacts to wetland-tolerant (e.g. bioswale) natives	R
			x	x			Change in precipitation may increase / decrease effectiveness of rain gardens	R
			x				More analysis may be needed to incorporate the effects of drought to the cumulative benefits of LID implementation	R
				x			Increase in storm frequency or intensity may affect project design and flooding will have to be considered	R
				x			Increased storm frequency may increase effectiveness of rain barrels and subsequent desire for installation	O
2.2 Reduce generation of trash through restricting and reducing the use of disposable plastics and polystyrene products				x			More frequent and larger storm events may wash more trash into the streams and the ocean	R
			x				Increased drought may reduce amount of trash washing into streams and the ocean	O
2.3. Reduce aerial deposition of storm water pollutants to the Bay and the Bay watershed	x		x				Warmer air temperature and more sunny days may exasperate air pollution and result in more aerial deposition	R
				x			Possible secondary effect of increased aerial deposition leading to increased pollutants in runoff and associated Bay waterbodies	R
2.4. Reduce pollution from commercial and recreational boating activities	x	x					Recreational boating may increase	R
		x					Discharges of sewage may have a greater effect on water quality, more bacteria consuming more oxygen in a higher water temperature may lead to more cases of hypoxic or anoxic water	R
				x			Increase in the frequency of storms may delay infrastructure repairs	R
				x	x		May impact the infrastructure (stationary pumpout facilities and mobile pumpout boats) placement and management needed for proper sewage management	R
	x	x		x			Increase frequency of maintenance / emptying of collection units	R

Goal #2

Bay Restoration Plan Climate Change Risks

Water Quality

Goal #2 - Improve water quality through pollution prevention and source control

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
2.4 Reduce pollution from commercial and recreational boating activities		x			x	x	Popular fishing locations may change and additional collections units will need to be strategically placed	R
			x				May impact specific lakes and pollutants where a lower water level due to drought would increase the concentration and adverse effects of pollutants	R
	x	x		x	x		New maintenance strategies may be needed i.e. always empty collection units before a storm to prevent accidental pollution	R
			x	x	x		Locations/opportunities for recycling boat related HHW may need to be relocated	R
						x	May increase the rate at which zinc anodes on a boat will degrade and copper leaches from bottom hull paints, both of which have severely adverse impacts on aquatic life	R
				x			Boating activities may be reduced	O
2.5. Reduce discharge of trash, oil and grease, and other pollutants from commercial and other high density areas				x	x		Additional maintenance / cleaning may be needed for catch basin screens to prevent flooding and operate properly and to prevent the accumulation of trash	R
			x	x			Pollutants may increase as runoff input / frequencies change and as pollutants build up and are transferred into waterways on the "first flush"	R
			x				May increase vulnerability to fire (e.g. cigarette butts) and require relocation of cigarette disposal areas / receptacles	R
	x						May increase frequency / duration of visitation and recreation in coastal areas, increasing related impacts	R
			x				Screens and infiltration devices may not be utilized as frequently due to drought, in this case funding may be better spent on other pollution prevention tools	O
2.6. Sustain and expand annual Coastal Cleanup	x						May require additional equipment (shade, water) to keep volunteers cool, could limit hours or participation due to heat	R
	x	x	x	x			Vegetative growth patterns of natives and invasives may change	R
				x	x		Events may be cancelled due to bad weather/surf	R
				x	x		More trash may accumulate as result of storm events	R
					x		Coastal sites may become inundated	R

Goal #2

Bay Restoration Plan Climate Change Risks

Water Quality

Goal #2 - Improve water quality through pollution prevention and source control

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
2.7. Increase public awareness through Public Involvement and Education (PIE) mini-grant program	x	x	x	x	x	x	As this program could fund a large variety of projects, the individual projects may be vulnerable to any number of stressors, but the program itself will likely not be impacted	R
	x	x	x	x	x	x	More grant funding for education and restoration may be needed due to climate change impacts	R
	x	x	x	x	x	x	More grant funding for education and restoration may be available	O

Goal #3

Bay Restoration Plan Climate Change Risks

Water Quality

Goal #3 - Address potential impacts of emerging contaminants

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
3.1. Institutionalize monitoring of emerging contaminants		x				x	May change strength and type of chemical reactions, requiring monitoring methodologies and protocols to be adjusted accordingly	R
				x			Increased runoff may impair the ability to accurately measure contaminant loads and may change concentration, loading, and extent of storm water dispersal zone	R
			x				Reduction in water use and increased water recycling may result in more concentrated discharge with more concentrated contaminants of concern resulting in higher detection limits	O
3.2. Reduce loading of emerging contaminants in waterways		x				x	May change strength and type of chemical reactions, requiring monitoring methodologies and protocols to be adjusted accordingly	R
		x	x	x		x	May influence loading and associated adverse ecological impacts of emerging contaminants	R
				x			Increased runoff may change concentration, loading, and extent of storm water dispersal zone	R
			x				Reduction in water use and increased water recycling may result in more concentrated discharge with more concentrated contaminants of concern	R

Bay Restoration Plan Climate Change Risks

Goal #4

Natural Resources

Goal #4 - Create/support policies and programs to protect natural resources

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
4.1 Facilitate development and adoption of natural stream protection ordinances and/or policies	x	x	x	x			Policy development may change	R
	x	x	x	x			Water quality may be impacted including through eutrophication and impacts to dissolved oxygen	R
	x		x	x			May require more volunteer work to remove invasive vegetation	R
	x	x	x	x			Change in water levels may affect education of natural annual process of a stream	R
	x	x	x	x			Changes in runoff and infiltration may alter stream hydrology	R
	x	x	x	x			Changes in runoff and infiltration may impact biotic community	R
					x		Salt water intrusion on coastal streams may change ecosystem	R
	x	x	x				Increased number of year round visits may disturb the ecosystem	R
	x	x	x	x			New invasive species may appear and alter education methods and policies	R
				x			Increased number of storm events may limit volunteer work	R
			x				More demand and willingness to adopt hydrology modification policy aimed at protecting streams as water supply	O
				x			Decreased number of visits / visitors due to more / altered storm events and impacts	O
	x		x	x			More demand and willingness to protect natural streams due to its cooling effect and buffer for flooding	O
4.2 Enhance assessment and effective management of Marine Protected Areas in the Bay	x	x					Recreational and commercial vessel activity may increase	R
				x			Recreational and commercial vessel activity may decrease	R
				x			May limit aerial vessel survey flights to conduct MPA monitoring	R
		x					Warmer water may affect fish distributions, marine fauna, kelp forests, etc	R
		x				x	New invasive species may appear and have altered policy implications	R
						x	Acidification will affect shellfish and marine invertebrate populations	R

Bay Restoration Plan Climate Change Risks

Goal #4

Natural Resources

Goal #4 - Create/support policies and programs to protect natural resources

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
4.2 Enhance assessment and effective management of Marine Protected Areas in the Bay		x			x	x	Altered management policies may be required or MPAs may need expansion for equivalent levels of protection	R
			x				May increase potential aerial vessel survey flight days	O
4.3 Evaluate and establish additional management measures to improve protection of fishery resources		x					Warmer water may affect fish species distribution and population size	R
		x				x	New invasive species may impact existing management strategies and protections	R
		x		x		x	Impacts to shellfish species' distributions and population sizes	R
		x				x	Impacts to the distribution and population size of spiny lobster	R
	x	x	x	x	x	x	Opportunity may arise to educate on changing fishery management and climate change through articles and opinion pieces	O
4.4 Promote and create programs to increase the supply of healthy local sustainable seafood		x		x		x	Impacts to the distribution and population size of these species, which may result in change of supply of these species in local seafood markets	R
		x				x	Feasibility and sustainability of aquaculture may be affected	R
	x	x	x	x	x	x	Consumers may gain an increased understanding of the climate change effects on the seafood product market	O
	x	x	x	x	x	x	Educational opportunities may arise via social media and opinion editorials	O
	x	x	x	x	x	x	May have opportunities to build organizational partnerships	O
4.5 Evaluate and address potential impacts of climate change on Santa Monica Bay		x	x	x	x	x	Change in the accuracy or effectiveness of hydrological models	R
		x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
	x	x					Species that will not tolerate temperature changes may die / migrate	R
	x	x					Species may be weakened by heat and become out-competed	R
	x	x	x				Species may need to consume more water as temperature rises	R

Goal #4

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #4 - Create/support policies and programs to protect natural resources

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
4.5 Evaluate and address potential impacts of climate change on Santa Monica Bay	x	x	x	x			Species invasions/changes in species ranges, habitats, or reproductive patterns	R
			x				Species may not tolerate new drought regime	R
			x				Increased irrigation may be needed to establish vegetation at restoration sites	R
	x		x				Wildfire risk may increase	R
			x	x	x		Increased coastal erosion risks	R
			x	x	x		Disturbance may be too great for sensitive or newly installed native plants to establish	R
			x	x			Increased runoff; increased / altered precipitation may change infiltration potential	R
	x	x	x	x			Increased eutrophication risks and associated lowered dissolved oxygen levels	R
					x		Saline water intrusion may increase	R
		x		x		x	Impacts to shellfish species' distributions and population sizes	R
		x		x		x	May adversely impact fish reproductive cycles	R
		x				x	May impact planktonic community and food web	R
				x	x		Increased support for "hard-scape" solutions	R
	x	x	x	x	x	x	Opportunity for more assessment and pilot projects	O
	x	x	x	x	x	x	Increased support and collaboration	O
				x	x		Increased support for "soft" solutions	O
4.6 Facilitate and coordinate water quality improvement and habitat restoration programs in key watersheds	x			x			Potential increase/decrease in volunteer days	R
		x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
	x	x					Species that will not tolerate temperature changes may die / migrate	R
	x	x					Species may be weakened by heat and become out-competed	R
	x		x				Wildfire risk may increase	R
			x	x	x		Increased coastal erosion risks	R
			x	x	x		Disturbance may be too great for sensitive or newly installed native plants to establish	R
			x	x			Increased runoff; increased / altered precipitation may change infiltration potential	R
	x	x	x	x			Increased eutrophication risks and associated lowered dissolved oxygen levels	R
	x	x	x	x	x	x	Permit requirements may need to be modified	R

Goal #4

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #4 - Create/support policies and programs to protect natural resources

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
4.6 Facilitate and coordinate water quality improvement and habitat restoration programs in key watersheds				x	x		Over-wash of coastal areas / habitats may occur	R
	x	x	x	x	x	x	Adverse water quality impacts	R
	x	x	x	x			Species invasions / changes in species ranges, habitats, or reproductive patterns	R
	x	x	x	x	x	x	Increased motivation to coordinate and participate in IRWMP	O
			x	x	x		Increased need to demonstrate benefits of water quality improvement and natural habitats in addressing climate change stressors	O
4.7 Implement a Comprehensive Bay Monitoring Program	x	x	x	x	x	x	Existing monitoring protocols or plans may need to be rewritten to address potential alteration from climate change stressors	R
	x	x	x	x	x	x	Some existing funding sources may be impacted or altered	R
	x	x	x	x	x	x	Adaptive management strategies may be necessary	R
	x	x	x	x	x	x	Habitat distributions may change	R
	x	x	x	x	x	x	Species invasions / changes in species ranges, habitats, or reproductive patterns may alter monitoring methods or target species	R
	x	x	x	x	x	x	Impacts to water quality and subsequent alterations of chemical detection limits	R
	x	x	x	x	x	x	Current indices may not be appropriate	R
	x	x	x	x	x	x	More opportunity for interdisciplinary studies / research	O
	x	x	x	x	x	x	Increase in participation in regional monitoring programs	O
	x	x	x	x	x	x	Fundraising ability may increase as people are more concerned about climate change effects on the Bay; possible collaborative opportunities	O
	x	x	x	x	x	x	Increased incorporation of comprehensive monitoring into permit requirements	O

Goal #5

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #5 - Acquire land for preservation of habitat and ecological services

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
5.1 Acquire 2000 acres of priority open space in the Santa Monica Mountains	x	x	x	x	x		Information / prioritization may require revisions	R
			x	x			Landslide / erosion risk may increase and riparian or stream areas may be affected	R
	x		x				Wildfire risk may increase	R
			x		x		Groundwater table may change in salinity or decline	R
					x		Mountain parcel value may increase as coastal parcel value decreases	R
	x		x	x			More support for open space acquisition and cooling effect of vegetation cover, water storage / preservation effect, and storm water infiltration effects	O
5.2 Acquire priority parcels in urbanized areas of the watershed			x	x			Landslide / erosion risk may increase and riparian or stream areas may be affected	R
	x		x				Wildfire risk may increase	R
				x	x		Coastal parcels may be at increased risk for storm surge / flooding	R
					x		Greater coastal wetland losses may occur	R
			x		x		Groundwater table may change in salinity or decline	R
					x		Law of erosion / rolling easements may allow more direct purchases of lands that will allow wetlands or beaches to shift naturally	O
	x	x	x	x	x	x	Information / prioritization may require revisions	O
	x		x	x			More support for open space acquisition and cooling effect of vegetation cover, water storage/preservation effect, and storm water infiltration effects	O
					x		Mountain parcel value may increase as coastal parcel value decreases	O
				x	x		Land use may be converted from residential / business to open space	O

Goal #6

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #6 - Manage Invasive Species

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
6.1 Achieve 303d listing for aquatic invasive species	x	x	x	x	x	x	New or expanded protocols may have to be developed	R
	x	x	x				Invasive species may migrate	R
	x	x	x				New invasive species may appear	R
	x	x	x	x			Impacts to native species may increase	R
				x			Storminess may increase transport of aquatic invasive species	R
					x		Sea level may push saltier water farther upstream	R
	x	x					303d listing requirements may change	R
	x	x					Invasive species may survive heat better	R
		x					Dissolved oxygen capacity of water may drop	R
			x				Drought may decrease aquatic invasive species	O
6.2 Coordinate and fund public education and outreach on invasive species	x	x					Invasive species may survive heat better	R
			x	x			Changes in water input to systems may impact native species or enhance the ability for invasive species to compete with natives	R
	x	x	x	x	x	x	Invasive species may migrate	R
	x	x	x	x	x	x	New invasive species may appear and/or transport to new areas	R
	x	x	x	x	x	x	Education / outreach materials may need to be revised	R
	x			x			Longer growing season may lead to an extra reproductive cycle for invasive species	R
	x	x	x	x	x	x	More opportunity for interdisciplinary studies/ research	O
	x	x	x	x	x	x	Increased media interest in mudsnail and other invasive species' effects on ecosystem	O
6.3 Develop and adopt plans and policies for invasive species control and prevention	x	x	x	x	x	x	Current adopted plans may require revision	R
				x			Potential misperception by public that more storminess means less drought and could lead to more use of non-natives in landscaping	R
	x	x	x	x	x	x	New invasive species may appear and/or transport to new areas	R
	x	x	x	x	x	x	Probability of expanded / altered distributions of invasive species	R
			x				Native gardens and xeriscaping may become more prevalent	O

Bay Restoration Plan Climate Change Risks

Goal #6

Natural Resources

Goal #6 - Manage Invasive Species

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
6.4 Prevent importation and sale of known invasive species	x	x	x	x			Alteration of temperature and hydrology regimes may promote / encourage sale of invasive species	R
6.5 Fund and conduct invasive species removal programs and projects	x						Species that will not tolerate warmer summers may die/migrate	R
	x						Species may be weakened by heat and become out-competed	R
	x						Species may need to consume more water as temperature rises	R
	x	x	x	x	x	x	Species invasions/ changes in species ranges, habitats, or reproductive patterns	R
	x						Invasive species may move into places that used to be too cold	R
	x						Plants that need a "setting" cold temperature may be affected	R
	x						A longer growing season may lead to an extra reproductive cycle	R
	x	x	x	x	x	x	New invasive species may appear and/or transport to new areas	R
	x	x	x				Possibility of expanded distributions of non-native species	R
			x				Species may not tolerate a new drought regime	R
			x	x			Changes in water input to systems may impact native species or enhance the ability for invasive species to compete with natives	R
			x				Increased irrigation may be needed to establish vegetation at restoration sites	R
	x		x				Wildfire risk may increase	R
				x			Newly installed natives may be disturbed by increased surface water flow and disturbance	R

Goal #6

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #6 - Manage Invasive Species

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
6.5 Fund and conduct invasive species removal programs and projects				x			Disturbance may be too great for sensitive or newly installed native plants to establish	R
			x	x	x		Increased potential for erosion	R
				x	x		Coastal overwash	R
					x		Saline water intrusion	R
	x	x	x	x			Increase / decline in crayfish	R
	x	x	x				Changes in stream conditions	R
					x		Large storm events may temporarily suppress populations of some aquatic invasive species	R
	x			x			Changes to volunteer events	R
				x			Less irrigation may be needed to establish vegetation at restoration sites	O

Goal #7

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #7 - Restore wetlands, streams, and riparian zones

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
7.1 Restore Ballona Wetlands	x	x	x	x	x	x	Species invasions/changes in species ranges, habitats, or reproductive patterns	R
	x	x	x	x	x	x	Food webs impacted	R
		x	x				Change in capacity of dissolved oxygen in water could lead to increased impacts of eutrophication/stratification	R
		x	x				Salinity distribution may be altered and have impacts to benthic and fish community	R
		x					Enhanced potential for parasites and/or disease	R
			x	x			Alteration of freshwater input could change hydrology system	R
				x			Increased stormwater runoff could affect water quality	R
				x			Changes in water quality	R
				x			Increased turbidity may have impacts on fish community and reproduction	R
					x		Loss of wetland and adjacent habitats	R
						x	Impacts to shellfish	R
	x	x	x	x	x	x	Change in effectiveness of models and more data analysis may be needed	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	O
7.2 Restore Malibu Lagoon	x	x	x	x	x	x	Change in effectiveness of models and more data analysis	R
	x	x	x	x	x	x	Species invasions/changes in species ranges, habitats, or reproductive patterns	R
			x				Alteration of hydrology regime	R
				x			Hydrological and biological process of the lagoon may be altered	R
				x	x		Berm geomorphology may be affected / impacts to bar built estuary mouth dynamics	R
				x			Increased soil erosion and potential for sediment deposition	R
				x			Impacts to benthic invert community	R
				x			Increased turbidity may have impacts on fish community and reproduction	R
					x		Sea level rise may affect the hydrology of the lagoon	R
					x		Loss of wetland and adjacent habitats	R
				x		x	Changes to water chemistry may affect fish reproductive cycles	R
						x	Impacts to planktonic community and food web	R
						x	Impacts to shellfish	R

Bay Restoration Plan Climate Change Risks

Goal #7

Natural Resources

Goal #7 - Restore wetlands, streams, and riparian zones

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
7.3 Remove fish barriers and open 20 miles of stream habitat to migrating steelhead trout	x	x	x	x			Changes in stream hydrology	R
	x	x					Warmer stream temperatures	R
	x	x	x	x	x	x	Changes to prioritization of projects	R
		x					Low dissolved oxygen concentration impacts on native cold water species	R
			x				Loss of access to upstream, deep pools	R
			x				Loss of access to spawning and rearing areas	R
			x				Loss of access to perennial tributaries as areas of refugia	R
				x			Less infiltration	R
				x			Increased erosion	R
				x			Increased turbidity	R
				x			Impacts to benthic community	R
					x		Salinity changes to groundwater in coastal areas	R
						x	Changes in coastal phytoplankton community and food web	R
				x			Potential for failure of stream band at Topanga Canyon Road	R
7.4 Restore urban streams, including daylighting culverted streams and removing cement channels	x	x	x	x	x	x	Change in effectiveness of models and more data analysis	R
	x	x	x	x	x		Species invasions/changes in species ranges, habitats, or reproductive patterns	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
			x				Less support if the greenway projects result in more need for irrigation	R
			x				Stream flow may be reduced or diminished	R
	x						Less support if the project results in more evaporation	R
							More support if project contributes to CO2 sequestration and cooling in urban area	O
							More support if the projects introduce more drought-tolerant vegetation	O
			x	x			More support if the projects provide more storm water infiltration and buffer to flooding	O

Goal #7

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #7 - Restore wetlands, streams, and riparian zones

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
7.5 Restore Topanga Lagoon	x	x	x	x	x	x	Change in effectiveness of models and more data analysis	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
		x	x	x	x		Hydrological and biological process of the lagoon may be altered	R
					x		Sea level rise may need to be incorporated into the restoration design	R
	x	x	x	x	x	x	Species invasions/changes in species ranges, habitats, or reproductive patterns	R
	x	x					Change in capacity of dissolved oxygen in water could lead to increased impacts of eutrophication/stratification	R
		x					Bacteria and algal growth may increase	R
		x					Increase potential for disease (fish)	R
			x				Changes in freshwater input to the system effecting water quality and impacts to brackish species	R
				x	x		Berm geomorphology may be affected	R
				x	x		Tide gate function may be affected	R
				x			Increased soil erosion and potential for sediment deposition	R
				x			Impacts to benthic community	R
				x			Increased turbidity may have impacts on fish community and reproduction	R
					x		Los of wetland margin habitat	R
						x	Changes to water chemistry may affect fish reproductive cycles	R
						x	Changes in coastal phytoplankton community and food web	R
						x	Impacts to shellfish	R

Goal #7

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #7 - Restore wetlands, streams, and riparian zones

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
7.6 Restore Oxford Lagoon to provide native species habitat, improved water quality, improved flood storage, and greater public access	x	x	x	x	x	x	Species invasions/changes in species ranges, habitats, or reproductive patterns	R
	x	x					Change in capacity of dissolved oxygen in water could lead to increased impacts of eutrophication/stratification	R
			x				Changes in freshwater input to the system effecting water quality and impacts to brackish species	R
				x	x		Berm geomorphology may be affected	R
				x	x		Tide gate function may be affected	R
				x			Increased soil erosion and potential for sediment deposition	R
				x			Impacts to benthic community	R
				x			Increased turbidity may have impacts on fish community and reproduction	R
					x		Los of wetland and adjacent habitat	R
						x	Changes to water chemistry may affect fish reproductive cycles	R
						x	Changes in coastal phytoplankton community and food web	R
						x	Impacts to shellfish	R
7.7 Restore Del Rey Lagoon to improve water quality and increase wetlands habitat and public access	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
				x	x		Circulation and flushing of the lagoon may be impacted	R
	x	x	x	x	x	x	Change in effectiveness of models and more data analysis	R

Goal #7

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #7 - Restore wetlands, streams, and riparian zones

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
7.8 Restore Trancas Lagoon	x	x	x	x	x	x	Change in effectiveness of models and data analysis	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
	x	x	x	x	x	x	Species invasions/changes in species ranges, habitats, or reproductive patterns	R
	x	x					Change in capacity of dissolved oxygen in water could lead to increased impacts of eutrophication/stratification	R
			x	x	x		Changes to bar built estuary/mouth dynamics	R
		x					Warmer water may affect the composition of the lagoon's biological community	R
			x				Less upstream flow may alter the hydrological and biological process of the lagoon	R
			x				Water quality impacts	R
				x			Increasing storminess may alter the hydrological and biological process of the lagoon	R
				x			Increased soil erosion and potential for sediment deposition	R
					x		Sea level rise may affect the hydrology of the lagoon and sea level rise scenarios need to be incorporated in restoration design	R
				x			Changes in water clarity	R
				x			Increased soil erosion and potential for sediment deposition	R
				x			Impacts to benthic community	R
				x			Increased turbidity may have impacts on fish community and reproduction	R
					x		Los of wetland and adjacent habitat	R
						x	Changes to water chemistry may affect fish reproductive cycles	R
						x	Changes in coastal phytoplankton community and food web	R
						x	Impacts to shellfish	R

Goal #8

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #8 - Restore bluffs, dunes, and sandy beaches

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
8.1 Restore native coastal bluff and upland scrub habitat	X	X					Temperature driven species redistribution(s)	R
	X		X				Species may be weakened by heat or drought and become out-competed	R
	X		X				Species may need to consume more water as temperature rises	R
	X	X	X	X	X		Species invasions / changes in species ranges, habitats, or reproductive patterns	R
	X						Bird migration may be mistimed and may halt field restoration	R
	X						Invasive species may move into places that used to be too cold	R
	X		X	X			New invasive species may appear	R
			X	X	X		May see increases in geomorphology impacts over time and altered sediment movement	R
			X				Increased irrigation requirement for installed native vegetation establishment	R
			X	X			Species may not tolerate a new water regime	R
	X		X				Wildfire risk may increase	R
			X	X			Increase in runoff and flooding risks	R
			X	X			Landslide / erosion risk	R
			X	X			Disturbance may be too great for sensitive plants to establish	R
			X	X			Increased / altered precipitation may change infiltration potential	R
				X			Newly installed natives may be disturbed by increase surface water flow	R
				X	X		Increased erosion to foredunes / coastal bluffs	R
				X	X		Coastal overwash	R
				X	X		Increased potential for hard-scape alternatives	R
					X		Saline water intrusion	R

Goal #8

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #8 - Restore bluffs, dunes, and sandy beaches

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
8.2 Protect and manage sandy beach habitats	x	x	x		x		Temperature driven species redistributions	R
	x	x	x				Increase in number of beach visitors	R
	x	x		x	x	x	Patterns of grunion runs may be affected; impacts to fish reproduction	R
				x	x		Increased beach erosion and need for beach replenishment; reduction in beach width	R
				x	x		Increased potential for hard-scape alternatives	R
						x	Decrease in pH will affect all calcifying organism	R
				x	x		Shoreline and coastal foredune erosion; impacts to beach morphology and wrack accrual	R
	x	x	x				Impacts to bird migrations	R
	x		x				Irrigation may be required for newly established restoration areas	R
				x	x		Beach habitat area(s) may shift	R
	x	x	x	x	x	x	Species invasions / changes in species ranges, habitats, or reproductive patterns	R
				x	x		Coastal overwash	R
				x			Disturbance of newly planted / seeded natives; disturbance of sensitive plant species	R
	x	x	x	x	x	x	Changes to beach management strategies and policies may be required	R
	x	x	x	x	x	x	Changes to existing monitoring strategies may be required	R
			x		x		Changes to groundwater table	R
				x			Decrease in number of beach visitors	O
					x		More opportunity for natural sea level rise protection projects	O
	x	x	x	x	x	x	Potential opportunities for project-specific private, local funders	O
	x	x	x	x	x	x	Potential increase in media and educational interest of beach projects and coastal protection	O

Bay Restoration Plan Climate Change Risks

Goal #9

Natural Resources

Goal #9 - Restore rocky intertidal and subtidal habitats

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
9.1 Restore and monitor sixty acres of kelp forest		x					Kelp becomes stressed due to warmer water reducing reproduction and slowing restoration response	R
				x			Large storm events may rip out kelp, slowing restoration response	R
				x			Increased urban runoff from storms may increase contaminants, slowing kelp growth	R
				x			Increased sediment flow from storms may prevent kelp from seeding onto the reef	R
					x		Sea level rise may shift distribution of kelp dependent on depth	R
						x	Ocean acidification will affect urchins, a calcifying species, which may change the abundance of urchins in kelp forests	R
				x			Increased wave action may impact reefs	R
	x	x					New invasive species may occur	R
		x		x		x	Impacts to fish reproduction	R
		x		x	x	x	Changes in coastal phytoplankton community and food web	R
	x	x	x	x	x	x	Impacts to or alterations of monitoring priorities and planning efforts	R
	x	x					Increase in disease	R
	x	x	x	x	x	x	Incorporate climate change planning into dam removal and positioning of material	O
9.2 Protect and manage rocky intertidal habitat	x	x					Animals engaged in partnerships with obligate algal symbionts at risk if temperatures alter relationship between partners	R
	x	x					Temperature driven species redistribution	R
	x	x					Changing phenology may have large implications for fish and wildlife production because trophic coupling of important species in the food chain may be interrupted	R
	x	x				x	Parasite population growth rates may increase	R
	x	x					Species ranges may shift poleward	R
				x	x		Waves may dislodge organisms, flip boulders, crush organisms, and/or alter back-shore sediment input to the system	R
	x	x				x	Altered species composition and abundance of marine fauna	R
					x		Increased potential impacts to fauna from predation or increased exposure to predators	R

Goal #9

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #9 - Restore rocky intertidal and subtidal habitats

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
9.2 Protect and manage rocky intertidal habitat					x		Loss of suitable habitat if no landward migration is possible	R
					x		Intertidal habitats that do not accrete or migrate landward proportionally to relative sea level rise are susceptible to inundation	R
						x	Decrease in pH will affect all calcifying organisms	R
	x	x	x	x	x	x	Site specific adaptive management may be needed	R
	x	x	x	x	x	x	Potential opportunities for project-specific private, local funders	O
	x	x	x	x	x	x	Increased media attention on effect of climate change stressors on habitat	O
9.3 Re-introduce and restore abalone population		x					Warmer water could shift abalone spawning seasons, making it difficult to study and predict spawning	R
		x					Abalone are more vulnerable to Withering Foot Syndrome in warm water conditions, increasing disease in already reduced wild populations	R
		x					Warmer water causes kelp to die off, reducing a primary food source for abalone	R
		x					Newly invasive species may appear, outcompeting abalone for food or space	R
				x			Increased storms make it difficult for SCUBA divers to access outplanting sites for monitoring and outplanting abalone	R
				x			Increased storms may stir up sand and sediment on rocky reefs, making it more difficult for abalone to settle on the reef	R
					x		Sea level rise may affect black abalone habitat through inundation, because they live mostly in the intertidal zone	R
						x	Decrease in pH will affect all calcifying organisms	R

Goal #9

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #9 - Restore rocky intertidal and subtidal habitats

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
9.4 Assess and protect seagrass habitats	x	x	x	x	x	x	May affect assessment methods and indicators	R
		x					May cause geographic shifts in species range	R
	x	x	x				Warmer water may affect seagrass distribution	R
				x			Storm damage may change the extent and availability of substrate suitable for seagrass habitat	R
					x		Sea level rise may change the extent and availability of substrate suitable for seagrass habitat	R
				x			Increased runoff may enhance loading of nutrients to coastal waters and alter primary producer communities to those species with faster growth-nutrient uptake rates (i.e. shift towards phytoplankton which will reduce light availability to seagrasses)	R

Goal #10

Bay Restoration Plan Climate Change Risks

Natural Resources

Goal #10 - Protect and restore open ocean and deep water habitats

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
10.1 Update and expand knowledge of unique habitats within Santa Monica Bay	x	x	x	x	x	x	May change assessment methods and indicators	R
		x					Warmer water may affect the flora and fauna of these habitats requiring additional or new research and monitoring methods	R
				x			Bacteria loads, wave action, and beach erosion and increased sediments may need to be added to assessments	R
					x		Sea level rise may affect nearshore habitats through inundation	R
						x	Decrease in pH will affect all calcifying organisms but the extent is largely unknown	R
						x	Shellfish predators may not survive the disappearance of shellfish, thus requiring more frequent monitoring or adaptive survey methods	R
10.2 Assess harmful algal bloom and its causes and impacts on the Bay's ecosystem		x					Metabolism by the water-column and benthic microbial communities may increase and may drive the depletion of dissolved oxygen	R
		x					Extent and frequency of HABs may increase	R
				x			Increased runoff may lead to increased supplies of organic matter and nutrients and lead to enhanced hypoxia	R
				x			Freshwater delivery may reduce water residence times and reduce potential for hypoxia	R
		x	x	x	x		May affect the coordination and actions of alert HAB alert network	R
		x	x	x	x		Opportunity for ongoing and increased media concern	O
			x				Drought may reduce runoff and wastewater discharge and nutrient loading as a result	O

Goal #11

Bay Restoration Plan Climate Change Risks

Benefits and Values to Humans

Goal #11 - Protect Public Health

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
11.1. Achieve minimum beach closures and postings at Santa Monica Bay beaches		x		x			Increased growth of harmful bacteria pathogens and/or increased urban runoff; thus, increased risk to swimmers	R
				x			Integrated approach needs to take into account of increased storm intensity and frequency in project setting and sizing	R
					x		Sea water inundation of existing diversions	R
			x				Increased drought will reduce dry-weather runoff due to increased water conservation and reuse and may reduce the need for more dry-weather diversions	O
11.2. Develop and adopt new pathogen indicators and source identification tools		x	x	x			New indicator criteria may need to be established	R
		x					Research needs to take into account the effects of warmer water temperature on behavioral change of bacteria and viruses	R
11.3. Update seafood consumption advisories and risk communication messages		x				x	May affect the areas and species surveyed or listed on advisories	R
	x	x				x	May result in fish distribution shifts and number of contaminated fish caught by fishermen	R
				x			Increase in suspension of contaminated sediments that may affect fish	R
	x		x				More people may fish year round, increasing the need for outreach	R
				x	x		May affect placement of fish advisory signage and material	R

Goal #11

Bay Restoration Plan Climate Change Risks

Benefits and Values to Humans

Goal #11 - Protect Public Health

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
11.4 Maintain and enhance institutional control measures (enforcement, monitoring, and education) through coordination with partner agencies to reduce the risk of consumption of contaminated fish in high risk ethnic communities	x	x				x	May result in fish distribution shift and number of contaminated fish caught by fishermen	R
11.5. Remediate contaminated sediments	x	x				x	May result in fish distribution shift and number of contaminated fish caught by fishermen	R
				x	x		Increase in suspension of contaminated sediments	R
		x		x	x		May lead to increased need for risk assessment or feasibility re-evaluation of remediation planning	R

Goal #12

Bay Restoration Plan Climate Change Risks

Benefits and Values to Humans

Goal #12 - Maintain/increase natural flood protection through ecologically functioning floodplains and wetlands

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
12.1. Acquire and restore priority parcels to increase acreage of ecologically functioning floodplains and wetlands				x	x		More floodplain and wetland restoration may be required to provide a buffer zone for increased flooding	R
			x	x	x		Increased potential for erosion	R
					x		New areas may become inundated	R
			x	x	x		Wetland habitat may shift	R
12.2. Develop and implement a comprehensive regional sediment management plan for restoring natural hydrological functions of river systems.	x	x	x	x	x		Need for management adaptation	
			x				May result in less stream flow and less sediment transport, more in-stream deposition or less sediment transported to the ocean.	R
				x	x		Sediment delivery may increase	R
				x	x		Sediment erosion may increase where flows are intensified	
					x		Beaches may become inundated which may require more sediment supply for beach replenishment	R
				x			Greater pulsing of rain runoff reaching rivers will lead to much higher frequency and extent of floods after intense storms	R
				x			Faster downstream flows may erode sediment and reduce the area of shallow habitats along the shores	R

Goal #13

Bay Restoration Plan Climate Change Risks

Benefits and Values to Humans

Goal #13 - Increase public access to beaches and open space

Organizational Objective	Climate stressor: 1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification	Risk	Risk (R) or Opportunity (O)
13.1. Increase public access to Santa Monica Mountains through purchase and enhancement of open space				x	x		Inundation may change the availability of coastal land available for purchase	R
			x				Potential increase in wildfire(s)	R
			x	x			Increased potential for erosion and landslides impacting public access and open space enhancement	R
13.2. Increase acreage and access to parks and open space in urbanized areas through acquisition and conversion of private parcels				x	x		Inundation may change the availability of coastal land available for purchase	R
				x			Increase in potential for urban areas to flood	R
				x	x		Change in inundation patterns or flooding may alter the connectivity of lagoons, wetlands, and creeks and associated areas for public access	R
13.3. Increase public access points to Ballona Creek and wetlands			x				Landscaping design of new greenway projects may increase need to consider more drought-tolerant vegetation	R
			x	x			Increased potential for erosion and landslides impacting public access and open space enhancement	R
				x	x		Change in inundation patterns or flooding may alter the connectivity of lagoons, wetlands, and creeks and associated areas for public access	R
				x			Design of new greenway projects needs to take into consideration increased flood levels	R
	x		x				More public demand for greenways in urban area	O
13.4. Increase public access to Santa Monica Bay beaches				x	x		Increase in shoreline erosion, flooding, and storm damage may lead to less access	R
				x	x		Loss of sandy beaches and less availability of easements	R
				x	x		Loss of access to beach trails at some locations	R
				x	x		Beach nourishment may become too expensive to sustain	R
	x	x	x				More public use and need for beach use and access	O

Goal #14

Bay Restoration Plan Climate Change Risks

Benefits and Values to Humans

Goal #14 - Conserve water and increase local water supply

Organizational Objective	Climate stressor						Risk	Risk (R) or Opportunity (O)
	1 – warmer temperatures	2 – warmer water	3 – increasing drought	4 – increasing storminess	5 – sea level rise	6 – ocean acidification		
14.1. Increase local water supplies	x		x				More water demand and consumption due, in part, to higher evaporation rate	R
			x				Less runoff available for capture	R
			x				Impacts to reservoirs and replenishment basins	R
				x			Less storm water captured because of the extreme, uneven storm patterns; thus, increase in need for storage / supply	R
					x		Increase in salt water intrusion into groundwater	R
					x		Impacts to coastal desalination facilities	R
			x				More expensive for imported water and, as a result, relatively less expensive and more cost-effective to recharge storm water, thus less need for additional financial incentive	O
			x				More willingness and less need to provide more incentive for storm water recharge projects	O
14.2. Enhance water conservation	x		x				Higher evaporation rate will result in more water consumption by landscaping	R
	x		x				New conservation measures may be more expensive or difficult to implement	R
			x				More demand for recycled water	R
				x			Potential increase in water use associated with less frequent (but more intense) storm events	R
			x				More willingness and less need for additional incentives for water conservation	O
	x		x				More willingness and more demand for heat and drought tolerant vegetation	O
14.3 Further increase wastewater recycling and reuse			x	x			Less water use and as a result less wastewater available for recycling; altered water available for reuse	R
			x				More demand for water	R
			x				More willingness to accept indirect and direct potable use of recycled wastewater	O

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #1
Water Quality										
Goal #1 - Improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state regulatory framework										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
1.1	Attain water quality goals in TMDLs adopted for 303(d) listed waterbodies in the Santa Monica Bay Watershed	Warmer Temperatures	1	2	1	1	1	1.33	1.33	1.33
		Warmer Water	2	3	1	2	3	2.00	2.33	2.67
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	2	2	1	2	3	1.67	2.00	2.33
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	2	2	1	2	3	1.67	2.00	2.33
1.2	Eliminate and prevent water and sediment quality impairments from both point and nonpoint sources for waterbodies in the Malibu Creek Watershed	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	3	3	2	2	3	2.67	2.67	3.00
		Increasing Drought	2	3	2	3	3	2.33	2.67	2.67
		Increasing Storminess	2	2	1	2	2	1.67	2.00	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
1.3	Eliminate biological impacts of water intake and discharge from coastal power and desalination plants	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	2	2	1	1	1	1.67	1.67	1.67
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	1	1	1	1	1	1.00	1.00	1.00
		Sea Level Rise	1	1	1	2	2	1.00	1.33	1.33
		Ocean Acidification	2	2	1	1	1	1.67	1.67	1.67
1.4	Eliminate all harmful discharges to Areas of Special Biological Significance (ASBS)	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	1	1	1.33	1.33	1.33
		Increasing Storminess	2	2	1	1	1	1.67	1.67	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #1
Water Quality										
Goal #1 - Improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state regulatory framework										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
1.5	Institute a reliable regional funding mechanism for storm water quality improvement	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	2	2	1.33	1.67	1.67
		Increasing Storminess	1	2	1	2	2	1.33	1.67	1.67
		Sea Level Rise	1	2	1	1	1	1.33	1.33	1.33
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
1.6	Reduce and prevent non-storm water runoff from urban land uses	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	1	1	1.33	1.33	1.33
		Increasing Storminess	1	1	1	1	1	1.00	1.00	1.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
1.7	Eliminate nonpoint pollution from on-site wastewater disposal systems (OWDSs)	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	2	2	1.33	1.67	1.67
		Sea Level Rise	1	2	1	2	2	1.33	1.67	1.67
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Appendix C

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #2
Water Quality										
Goal #2 - Improve water quality through pollution prevention and source control										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
2.1	Increase pervious surfaces and storm water infiltration where feasible by supporting green infrastructure	Warmer Temperatures	1	2	1	1	1	1.33	1.33	1.33
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	2	2	3	1.67	1.67	2.00
		Increasing Storminess	1	3	1	2	3	1.67	2.00	2.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
2.2	Reduce generation of trash through restricting and reducing the use of disposable plastics and polystyrene products	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	1	2	2	3	1.33	1.33	1.67
		Sea Level Rise	1	1	1	2	3	1.00	1.33	1.67
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
2.3	Reduce aerial deposition of storm water pollutants to the Bay and the Bay Watershed	Warmer Temperatures	3	2	2	2	3	2.33	2.33	2.67
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	3	2	2	2	3	2.33	2.33	2.67
		Increasing Storminess	1	2	1	1	1	1.33	1.33	1.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
2.4	Reduce pollution from commercial and recreational boating activities	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	2	3	1.00	1.33	1.67
		Increasing Drought	1	1	1	2	2	1.00	1.33	1.33
		Increasing Storminess	1	2	2	3	3	1.67	2.00	2.00
		Sea Level Rise	1	2	1	2	3	1.33	1.67	2.00
		Ocean Acidification	1	1	1	2	3	1.00	1.33	1.67

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #2
Water Quality										
Goal #2 - Improve water quality through pollution prevention and source control										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
2.5	Reduce discharge of trash, oil and grease, and other pollutants from commercial and other high density areas	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	2	2	1.33	1.67	1.67
		Increasing Storminess	2	3	2	3	3	2.33	2.67	2.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
2.6	Sustain and expand annual Coastal Cleanup	Warmer Temperatures	1	2	1	1	1	1.33	1.33	1.33
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	2	3	1.33	1.67	2.00
		Increasing Storminess	1	2	1	1	1	1.33	1.33	1.33
		Sea Level Rise	1	2	1	1	1	1.33	1.33	1.33
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
2.7	Increase public awareness through Public Involvement and Education (PIE) mini-grant program	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	1	1	1	1	1.00	1.00	1.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #3
Water Quality										
Goal #3 - Address potential impacts of emerging contaminants										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
3.1	Institutionalize monitoring of emerging contaminants	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	1	1	1	1.33	1.33	1.33
		Increasing Drought	1	2	1	1	2	1.33	1.33	1.67
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	2	1	1	1	1.33	1.33	1.33
3.2	Reduce loading of emerging contaminants in waterways	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	2	2	1	1	2	1.67	1.67	2.00
		Increasing Drought	2	3	1	2	2	2.00	2.33	2.33
		Increasing Storminess	2	3	1	2	2	2.00	2.33	2.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	2	1	1	1	1.33	1.33	1.33

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #4
Natural Resources										
Goal #4 - Create/support policies and programs to protect natural resources										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
4.1	Facilitate development and adoption of natural stream protection ordinances and/or policies	Warmer Temperatures	1	2	1	2	3	1.33	1.67	2.00
		Warmer Water	1	3	2	2	3	2.00	2.00	2.33
		Increasing Drought	1	3	2	3	3	2.00	2.33	2.33
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
4.2	Enhance assessment and effective management of Marine Protected Areas in the Bay	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	2	3	2	3	3	2.33	2.67	2.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	2	1	2	3	1.33	1.67	2.00
		Ocean Acidification	2	3	2	3	3	2.33	2.67	2.67
4.3	Evaluate and establish additional management measures to improve protection of fishery resources	Warmer Temperatures	1	2	1	1	1	1.33	1.33	1.33
		Warmer Water	2	3	2	3	3	2.33	2.67	2.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	2	1	2	3	1.33	1.67	2.00
		Ocean Acidification	2	3	2	3	3	2.33	2.67	2.67
4.4	Promote and create programs to increase the supply of healthy local sustainable seafood	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	2	2	2	3	3	2.00	2.33	2.33
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	2	2	1.33	1.67	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	2	3	2	3	3	2.33	2.67	2.67

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #4
Natural Resources										
Goal #4 - Create/support policies and programs to protect natural resources										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
4.5	Evaluate and address potential impacts of climate change on Santa Monica Bay	Warmer Temperatures	1	2	2	2	3	1.67	1.67	2.00
		Warmer Water	1	3	2	2	3	2.00	2.00	2.33
		Increasing Drought	1	3	2	3	3	2.00	2.33	2.33
		Increasing Storminess	2	3	2	2	3	2.33	2.33	2.67
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	2	3	2	3	3	2.33	2.67	2.67
4.6	Facilitate and coordinate water quality improvement and habitat restoration programs in key subwatersheds	Warmer Temperatures	1	1	2	2	3	1.33	1.33	1.67
		Warmer Water	1	3	2	2	3	2.00	2.00	2.33
		Increasing Drought	1	3	2	3	3	2.00	2.33	2.33
		Increasing Storminess	1	3	1	2	3	1.67	2.00	2.33
		Sea Level Rise	1	3	1	2	3	1.67	2.00	2.33
		Ocean Acidification	1	2	1	2	3	1.33	1.67	2.00
4.7	Implement a Comprehensive Bay Monitoring Program	Warmer Temperatures	1	1	1	1	2	1.00	1.00	1.33
		Warmer Water	1	2	1	2	3	1.33	1.67	2.00
		Increasing Drought	1	2	1	1	2	1.33	1.33	1.67
		Increasing Storminess	1	2	2	2	3	1.67	1.67	2.00
		Sea Level Rise	1	2	1	2	3	1.33	1.67	2.00
		Ocean Acidification	1	2	2	2	3	1.67	1.67	2.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #5
Natural Resources										
Goal #5 - Acquire land for preservation of habitat and ecological services										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
5.1	Acquire 2000 acres of priority open space in the Santa Monica Mountains	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	3	2	3	3	2.00	2.33	2.33
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
5.2	Acquire priority parcels in urbanized areas of the watershed	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	3	2	3	3	2.00	2.33	2.33
		Increasing Storminess	1	3	2	2	3	2.00	2.00	2.33
		Sea Level Rise	1	1	1	1	2	1.00	1.00	1.33
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #6
Natural Resources										
Goal #6 - Manage Invasive Species										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
6.1	Achieve 303d listing for aquatic invasive species	Warmer Temperatures	1	2	1	2	2	1.33	1.67	1.67
		Warmer Water	1	3	2	2	3	2.00	2.00	2.33
		Increasing Drought	1	2	2	2	3	1.67	1.67	2.00
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	2	1	2	2	1.33	1.67	1.67
6.2	Coordinate and fund public education and outreach on invasive species	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	2	1	1	2	1.33	1.33	1.67
		Increasing Drought	1	1	1	1	2	1.00	1.00	1.33
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
6.3	Develop and adopt a plan and policies for invasive species control and prevention	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	2	2	2	3	1.67	1.67	2.00
		Increasing Drought	1	2	2	2	3	1.67	1.67	2.00
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	2	1.00	1.00	1.33
6.4	Prevent importation and sale of known invasive species	Warmer Temperatures	1	1	1	2	2	1.00	1.33	1.33
		Warmer Water	1	1	1	2	2	1.00	1.33	1.33
		Increasing Drought	1	1	2	2	3	1.33	1.33	1.67
		Increasing Storminess	1	1	1	1	1	1.00	1.00	1.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #6
Natural Resources										
Goal #6 - Manage Invasive Species										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
6.5	Fund and conduct invasive species removal programs and projects	Warmer Temperatures	2	2	1	2	2	1.67	2.00	2.00
		Warmer Water	2	3	2	2	3	2.33	2.33	2.67
		Increasing Drought	2	1	2	2	3	1.67	1.67	2.00
		Increasing Storminess	2	2	1	2	3	1.67	2.00	2.33
		Sea Level Rise	1	1	1	2	2	1.00	1.33	1.33
		Ocean Acidification	2	2	1	2	3	1.67	2.00	2.33

Bay Restoration Plan Climate Change Vulnerability Assessment											Goal #7
Natural Resources											
Goal #7 - Restore wetlands, streams, and riparian zones											
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)	
7.1	Restore Ballona Wetlands	Warmer Temperatures	1	2	1	2	2	1.33	1.67	1.67	
		Warmer Water	2	3	2	3	3	2.33	2.67	2.67	
		Increasing Drought	2	3	2	3	3	2.33	2.67	2.67	
		Increasing Storminess	1	3	1	2	3	1.67	2.00	2.33	
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67	
		Ocean Acidification	3	2	1	2	3	2.00	2.33	2.67	
7.2	Restore Malibu Lagoon	Warmer Temperatures	2	2	1	2	2	1.67	2.00	2.00	
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00	
		Increasing Drought	2	3	2	3	3	2.33	2.67	2.67	
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67	
		Sea Level Rise	3	3	1	2	3	2.33	2.67	3.00	
		Ocean Acidification	3	3	1	2	3	2.33	2.67	3.00	
7.3	Remove fish barriers and open 20 miles of stream habitat to migrating steelhead trout	Warmer Temperatures	2	2	2	2	3	2.00	2.00	2.33	
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00	
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67	
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67	
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00	
		Ocean Acidification	1	2	1	2	3	1.33	1.67	2.00	
7.4	Restore urban streams, including daylighting culverted streams and removing cement channels	Warmer Temperatures	2	2	2	2	3	2.00	2.00	2.33	
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00	
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67	
		Increasing Storminess	1	3	1	2	3	1.67	2.00	2.33	
		Sea Level Rise	1	2	1	1	1	1.33	1.33	1.33	
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00	

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #7
Natural Resources										
Goal #7 - Restore wetlands, streams, and riparian zones										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
7.5	Restore Topanga Lagoon	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	3	2	1	2	3	2.00	2.33	2.67
7.6	Restore Oxford Lagoon to provide native species habitat, improved water quality, improved flood storage, and greater public access	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	2	3	2	2	3	2.33	2.33	2.67
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	3	3	1	2	3	2.33	2.67	3.00
7.7	Restore Del Rey Lagoon to improve water quality and increase wetlands habitat and public access	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	2	3	2	2	3	2.33	2.33	2.67
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	2	2	1	2	3	1.67	2.00	2.33
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	3	3	1	2	3	2.33	2.67	3.00
7.8	Restore Trancas Lagoon	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	3	2	1	2	3	2.00	2.33	2.67

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #8
Natural Resources										
Goal #8 - Restore coastal bluffs, dunes, and sandy beaches										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
8.1	Restore native coastal bluff and upland scrub habitat	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67
		Increasing Storminess	2	3	2	2	3	2.33	2.33	2.67
		Sea Level Rise	1	2	1	1	2	1.33	1.33	1.67
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
8.2	Protect and manage sandy beach habitats	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	2	2	1	2	2	1.67	2.00	2.00
		Increasing Drought	2	2	2	3	3	2.00	2.33	2.33
		Increasing Storminess	2	3	2	3	3	2.33	2.67	2.67
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	3	3	2	3	3	2.67	3.00	3.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #9
Natural Resources										
Goal #9 - Restore rocky intertidal and subtidal habitats										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
9.1	Restore and monitor sixty acres of kelp forest	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	2	2	2	3	3	2.00	2.33	2.33
9.2	Protect and manage rocky intertidal habitat	Warmer Temperatures	2	3	2	2	3	2.33	2.33	2.67
		Warmer Water	2	3	2	2	3	2.33	2.33	2.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	2	1	2	2	1.67	2.00	2.00
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	3	3	2	3	3	2.67	3.00	3.00
9.3	Re-introduce and restore abalone population	Warmer Temperatures	2	2	1	2	2	1.67	2.00	2.00
		Warmer Water	3	3	2	3	3	2.67	3.00	3.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	2	1	1	1	1.67	1.67	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	3	3	2	3	3	2.67	3.00	3.00
9.4	Assess and protect seagrass habitats	Warmer Temperatures	2	2	1	2	2	1.67	2.00	2.00
		Warmer Water	2	3	2	2	3	2.33	2.33	2.67
		Increasing Drought	1	1	1	1	2	1.00	1.00	1.00
		Increasing Storminess	2	2	1	2	3	1.67	2.00	2.33
		Sea Level Rise	2	2	1	2	2	1.67	2.00	2.00
		Ocean Acidification	2	2	1	2	3	1.67	2.00	2.33

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #10
Natural Resources										
Goal #10 - Protect and restore open ocean and deep water habitats										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
10.1	Update and expand knowledge of unique habitats within Santa Monica Bay	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	2	2	3	1.67	1.67	2.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	2	2	2	3	1.67	1.67	2.00
10.2	Assess harmful algal bloom and its causes and impacts on the Bay's Ecosystem	Warmer Temperatures	1	2	1	2	3	1.33	1.67	2.00
		Warmer Water	2	3	2	3	3	2.33	2.67	2.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	2	2	3	1.67	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	2	2	1	2	3	1.67	2.00	2.33

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #11
Benefits and Values to Humans										
Goal #11 - Protect public health										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
11.1	Achieve minimum beach closures and postings at Santa Monica Bay beaches	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	1	2	3	1.33	1.67	2.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	2	2	2	3	2.00	2.00	2.33
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
11.2	Develop and adopt new pathogen indicators and source identification tools	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	2	2	3	1.67	1.67	2.00
		Increasing Drought	1	2	1	2	3	1.33	1.67	2.00
		Increasing Storminess	1	2	1	2	3	1.33	1.67	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
11.3	Update seafood consumption and advisories and risk communication messages	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	1	1	2	1.33	1.33	1.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	1	1	1.33	1.33	1.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
11.4	Maintain and enhance institutional control measures (enforcement, monitoring, and education) through coordination with partner agencies to reduce the risk of consumption of contaminated fish in high risk ethnic communities	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	2	1	1	2	1.33	1.33	1.67
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	1	2	1	1	1	1.33	1.33	1.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #11
Benefits and Values to Humans										
Goal #11 - Protect public health										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
11.5	Remediate contaminated sediments	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	2	2	1	2	3	1.67	2.00	2.33
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	2	1	2	3	1.67	2.00	2.33
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	2	1	1	1	1.33	1.33	1.33

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #12
Benefits and Values to Humans										
Goal #12 - Maintain/increase natural flood protection through ecologically functioning floodplains and wetlands										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
12.1	Acquire and restore priority parcels to increase acreage of ecologically functioning floodplains and wetlands	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	2	2	2	3	1.67	1.67	2.00
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	2	2	1	2	3	1.67	2.00	2.33
12.2	Develop and implement a comprehensive regional sediment management plan for restoring natural hydrological functions of river systems	Warmer Temperatures	1	2	1	2	2	1.33	1.67	1.67
		Warmer Water	1	2	1	2	3	1.33	1.67	2.00
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #13
Benefits and Values to Humans										
Goal #13 - Increase public access to beaches and open space										
13.1	Increase public access to Santa Monica Mountains through purchase and enhancement of open space	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	1	2	1.33	1.33	1.67
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
13.2	Increase acreage and access to parks and open space in urbanized areas through acquisition and conversion of private parcels	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	1	2	1.33	1.33	1.67
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
13.3	Increase public access points to Ballona Creek and wetlands	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	2	1	1	2	1.33	1.33	1.67
		Increasing Storminess	1	2	1	1	2	1.33	1.33	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
13.4	Increase public access to Santa Monica Bay beaces	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	1	1	1	1	1	1.00	1.00	1.00
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	3	1	2	3	2.00	2.33	2.67
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00

Bay Restoration Plan Climate Change Vulnerability Assessment										Goal #14
Benefits and Values to Humans										
Goal #14 - Conserve water and increase local water supply										
Objective	Objective Description	Climate Stressor	(A) Adaptive Capacity 3-Low 2-Med 1-High	(S) Sensitivity 3-High 2-Med 1-Low	(E1) Exposure (current) 3-High 2-Med 1-Low	(E2) Exposure (2050) 3-High 2-Med 1-Low	(E3) Exposure (2100) 3-High 2-Med 1-Low	(V1) Vulnerability (current)	(V2) Vulnerability (2050)	(V3) Vulnerability (2100)
14.1	Increase local water supplies	Warmer Temperatures	1	2	1	1	2	1.33	1.33	1.67
		Warmer Water	1	1	1	1	2	1.00	1.00	1.33
		Increasing Drought	2	3	2	2	3	2.33	2.33	2.67
		Increasing Storminess	2	3	1	2	3	2.00	2.33	2.67
		Sea Level Rise	2	2	1	2	3	1.67	2.00	2.33
		Ocean Acidification	1	1	1	1	2	1.00	1.00	1.33
14.2	Enhance water conservation	Warmer Temperatures	2	2	1	2	3	1.67	2.00	2.33
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	2	3	2	3	3	2.33	2.67	2.67
		Increasing Storminess	1	2	1	2	2	1.33	1.67	1.67
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00
14.3	Further increase wastewater recycling and reuse	Warmer Temperatures	1	1	1	1	1	1.00	1.00	1.00
		Warmer Water	1	1	1	1	1	1.00	1.00	1.00
		Increasing Drought	2	2	2	2	3	2.00	2.00	2.33
		Increasing Storminess	2	2	1	2	2	1.67	2.00	2.00
		Sea Level Rise	1	1	1	1	1	1.00	1.00	1.00
		Ocean Acidification	1	1	1	1	1	1.00	1.00	1.00